MySQL 5.5 Reference Manual

Including MySQL NDB Cluster 7.2 Reference Guide
Abstract

This is the MySQL™ Reference Manual. It documents MySQL 5.5 through 5.5.62, as well as NDB Cluster releases based on version 7.2 of NDBCLUSTER through 5.5.65-ndb-7.2.39. It may include documentation of features of MySQL versions that have not yet been released. For information about which versions have been released, see the MySQL 5.5 Release Notes.

MySQL 5.5 features. This manual describes features that are not included in every edition of MySQL 5.5; such features may not be included in the edition of MySQL 5.5 licensed to you. If you have any questions about the features included in your edition of MySQL 5.5, refer to your MySQL 5.5 license agreement or contact your Oracle sales representative.

For notes detailing the changes in each release, see the MySQL 5.5 Release Notes.

For legal information, including licensing information, see the Preface and Legal Notices.

For help with using MySQL, please visit the MySQL Forums, where you can discuss your issues with other MySQL users.

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# Table of Contents

Preface and Legal Notices ........................................................................................................... xxiii  
1 General Information ................................................................................................................ 1
  1.1 About This Manual .............................................................................................................. 2
  1.2 Typographical and Syntax Conventions .............................................................................. 2
  1.3 Overview of the MySQL Database Management System .................................................. 4
      1.3.1 What is MySQL? ........................................................................................................ 4
      1.3.2 The Main Features of MySQL .................................................................................... 6
      1.3.3 History of MySQL ..................................................................................................... 8
  1.4 What Is New in MySQL 5.5 ................................................................................................. 9
  1.5 MySQL Information Sources ............................................................................................. 18
      1.5.1 MySQL Websites ....................................................................................................... 18
      1.5.2 MySQL Community Support at the MySQL Forums ............................................... 18
      1.5.3 MySQL Enterprise .................................................................................................... 18
  1.6 How to Report Bugs or Problems ...................................................................................... 19
  1.7 MySQL Standards Compliance .......................................................................................... 23
      1.7.1 MySQL Extensions to Standard SQL ......................................................................... 24
      1.7.2 MySQL Differences from Standard SQL ..................................................................... 27
      1.7.3 How MySQL Deals with Constraints ........................................................................ 29
  1.8 Credits ............................................................................................................................... 33
      1.8.1 Contributors to MySQL ............................................................................................. 33
      1.8.2 Documenters and translators .................................................................................... 37
      1.8.3 Packages that support MySQL .................................................................................. 39
      1.8.4 Tools that were used to create MySQL ..................................................................... 39
      1.8.5 Supporters of MySQL ............................................................................................... 40
  2 Installing and Upgrading MySQL ........................................................................................ 41
  2.1 General Installation Guidance .......................................................................................... 44
      2.1.1 Which MySQL Version and Distribution to Install .................................................... 44
      2.1.2 How to Get MySQL .................................................................................................. 45
      2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG ................................. 45
      2.1.4 Installation Layouts .................................................................................................... 59
      2.1.5 Compiler-Specific Build Characteristics .................................................................... 59
  2.2 Installing MySQL on Unix/Linux Using Generic Binaries ................................................. 59
  2.3 Installing MySQL on Microsoft Windows .......................................................................... 62
      2.3.1 MySQL Installation Layout on Microsoft Windows ..................................................... 65
      2.3.2 Choosing an Installation Package .............................................................................. 66
      2.3.3 MySQL Installer for Windows ................................................................................. 67
      2.3.4 Installing MySQL on Microsoft Windows Using an MSI Package ......................... 94
      2.3.5 MySQL Server Instance Configuration Wizard ........................................................ 101
      2.3.6 Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive .............. 118
      2.3.7 Troubleshooting a Microsoft Windows MySQL Server Installation ..................... 127
      2.3.8 Windows Postinstallation Procedures ...................................................................... 128
      2.3.9 Windows Platform Restrictions .............................................................................. 130
  2.4 Installing MySQL on OS X ............................................................................................... 132
      2.4.1 General Notes on Installing MySQL on OS X .......................................................... 132
      2.4.2 Installing MySQL on OS X Using Native Packages ............................................... 133
      2.4.3 Installing a MySQL Launch Daemon ....................................................................... 138
      2.4.4 Installing and Using the MySQL Preference Pane ................................................... 141
  2.5 Installing MySQL on Linux ............................................................................................... 146
      2.5.1 Installing MySQL on Linux Using RPM Packages .................................................... 147
      2.5.2 Installing MySQL on Linux Using Debian Packages ............................................. 152
      2.5.3 Deploying MySQL on Linux with Docker ................................................................ 153
3.6.3 Maximum of Column per Group ................................................................. 253
3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column ........ 253
3.6.5 Using User-Defined Variables ............................................................... 254
3.6.6 Using Foreign Keys ............................................................................... 254
3.6.7 Searching on Two Keys ........................................................................ 256
3.6.8 Calculating Visits Per Day ..................................................................... 256
3.6.9 Using AUTO_INCREMENT ....................................................................... 257
3.7 Using MySQL with Apache ....................................................................... 259
4 MySQL Programs ......................................................................................... 261
4.1 Overview of MySQL Programs .................................................................. 262
4.2 Using MySQL Programs .......................................................................... 266
  4.2.1 Invoking MySQL Programs ................................................................. 266
  4.2.2 Specifying Program Options ............................................................... 267
  4.2.3 Command Options for Connecting to the Server ............................... 280
  4.2.4 Connecting to the MySQL Server Using Command Options ............ 285
  4.2.5 Connection Compression Control ....................................................... 288
  4.2.6 Setting Environment Variables ........................................................... 288
4.3 Server and Server-Startup Programs ....................................................... 289
  4.3.1 mysql — The MySQL Server ............................................................... 289
  4.3.2 mysqld_safe — MySQL Server Startup Script .................................... 290
  4.3.3 mysql.server — MySQL Server Startup Script .................................. 295
  4.3.4 mysqld_multi — Manage Multiple MySQL Servers ............................ 297
4.4 Installation-Related Programs .................................................................. 301
  4.4.1 comp_err — Compile MySQL Error Message File ............................. 301
  4.4.2 mysqlbug — Generate Bug Report .................................................... 302
  4.4.3 mysql_install_db — Initialize MySQL Data Directory .................... 303
  4.4.4 mysql_plugin — Configure MySQL Server Plugins ......................... 305
  4.4.5 mysql_secure_installation — Improve MySQL Installation Security . 307
  4.4.6 mysql_tzinfo_to_sql — Load the Time Zone Tables ........................ 308
  4.4.7 mysql_upgrade — Check and Upgrade MySQL Tables .................... 308
4.5 Client Programs ....................................................................................... 314
  4.5.1 mysql — The MySQL Command-Line Client ....................................... 314
  4.5.2 mysqladmin — Client for Administering a MySQL Server ................ 337
  4.5.3 mysqlcheck — A Table Maintenance Program ................................... 345
  4.5.4 mysqldump — A Database Backup Program ...................................... 353
  4.5.5 mysqlimport — A Data Import Program .......................................... 372
  4.5.6 mysqlshow — Display Database, Table, and Column Information .... 378
  4.5.7 mysqlslap — Load Emulation Client .................................................. 383
4.6 Administrative and Utility Programs ......................................................... 391
  4.6.1 innodbchecksum — Offline InnoDB File Checksum Utility ................ 391
  4.6.2 myisam_ftdump — Display Full-Text Index information .................... 392
  4.6.3 myisamchk — MyISAM Table-Maintenance Utility ............................. 393
  4.6.4 myisamlog — Display MyISAM Log File Contents ............................. 410
  4.6.5 myisampack — Generate Compressed, Read-Only MyISAM Tables .... 411
  4.6.6 myisamaccess — Client for Checking Access Privileges .................... 417
  4.6.7 mysqlbinlog — Utility for Processing Binary Log Files .................... 420
  4.6.8 mysqldumpslow — Summarize Slow Query Log Files ......................... 434
  4.6.9 mysqlhotcopy — A Database Backup Program ................................... 436
  4.6.10 mysql_convert_table_format — Convert Tables to Use a Given Storage Engine ................................................................. 439
  4.6.11 mysql_find_rows — Extract SQL Statements from Files .................. 440
  4.6.12 mysql_fix_extensions — Normalize Table File Name Extensions ....... 441
  4.6.13 mysql_setpermission — Interactively Set Permissions in Grant Tables .................................................. 441
  4.6.14 mysql_waitpid — Kill Process and Wait for Its Termination ............ 442
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.11 Optimizing Locking Operations</td>
<td>989</td>
</tr>
<tr>
<td>8.11.1 Internal Locking Methods</td>
<td>990</td>
</tr>
<tr>
<td>8.11.2 Table Locking Issues</td>
<td>992</td>
</tr>
<tr>
<td>8.11.3 Concurrent Inserts</td>
<td>993</td>
</tr>
<tr>
<td>8.11.4 Metadata Locking</td>
<td>994</td>
</tr>
<tr>
<td>8.11.5 External Locking</td>
<td>997</td>
</tr>
<tr>
<td>8.12 Optimizing the MySQL Server</td>
<td>998</td>
</tr>
<tr>
<td>8.12.1 System Factors</td>
<td>998</td>
</tr>
<tr>
<td>8.12.2 Optimizing Disk I/O</td>
<td>999</td>
</tr>
<tr>
<td>8.12.3 Using Symbolic Links</td>
<td>1000</td>
</tr>
<tr>
<td>8.12.4 Optimizing Memory Use</td>
<td>1003</td>
</tr>
<tr>
<td>8.12.5 Optimizing Network Use</td>
<td>1007</td>
</tr>
<tr>
<td>8.13 Measuring Performance (Benchmarking)</td>
<td>1010</td>
</tr>
<tr>
<td>8.13.1 Measuring the Speed of Expressions and Functions</td>
<td>1011</td>
</tr>
<tr>
<td>8.13.2 The MySQL Benchmark Suite</td>
<td>1011</td>
</tr>
<tr>
<td>8.13.3 Using Your Own Benchmarks</td>
<td>1012</td>
</tr>
<tr>
<td>8.13.4 Measuring Performance with performance_schema</td>
<td>1012</td>
</tr>
<tr>
<td>8.14 Examining Thread Information</td>
<td>1012</td>
</tr>
<tr>
<td>8.14.1 Thread Command Values</td>
<td>1013</td>
</tr>
<tr>
<td>8.14.2 General Thread States</td>
<td>1015</td>
</tr>
<tr>
<td>8.14.3 Delayed-Insert Thread States</td>
<td>1021</td>
</tr>
<tr>
<td>8.14.4 Query Cache Thread States</td>
<td>1023</td>
</tr>
<tr>
<td>8.14.5 Replication Master Thread States</td>
<td>1023</td>
</tr>
<tr>
<td>8.14.6 Replication Slave I/O Thread States</td>
<td>1024</td>
</tr>
<tr>
<td>8.14.7 Replication Slave SQL Thread States</td>
<td>1025</td>
</tr>
<tr>
<td>8.14.8 Replication Slave Connection Thread States</td>
<td>1026</td>
</tr>
<tr>
<td>8.14.9 NDB Cluster Thread States</td>
<td>1026</td>
</tr>
<tr>
<td>8.14.10 Event Scheduler Thread States</td>
<td>1026</td>
</tr>
<tr>
<td>9 Language Structure</td>
<td>1029</td>
</tr>
<tr>
<td>9.1 Literal Values</td>
<td>1029</td>
</tr>
<tr>
<td>9.1.1 String Literals</td>
<td>1029</td>
</tr>
<tr>
<td>9.1.2 Numeric Literals</td>
<td>1032</td>
</tr>
<tr>
<td>9.1.3 Date and Time Literals</td>
<td>1032</td>
</tr>
<tr>
<td>9.1.4 Hexadecimal Literals</td>
<td>1034</td>
</tr>
<tr>
<td>9.1.5 Bit-Value Literals</td>
<td>1036</td>
</tr>
<tr>
<td>9.1.6 Boolean Literals</td>
<td>1038</td>
</tr>
<tr>
<td>9.1.7 NULL Values</td>
<td>1038</td>
</tr>
<tr>
<td>9.2 Schema Object Names</td>
<td>1038</td>
</tr>
<tr>
<td>9.2.1 Identifier Length Limits</td>
<td>1040</td>
</tr>
<tr>
<td>9.2.2 Identifier Qualifiers</td>
<td>1041</td>
</tr>
<tr>
<td>9.2.3 Identifier Case Sensitivity</td>
<td>1042</td>
</tr>
<tr>
<td>9.2.4 Mapping of Identifiers to File Names</td>
<td>1044</td>
</tr>
<tr>
<td>9.2.5 Function Name Parsing and Resolution</td>
<td>1046</td>
</tr>
<tr>
<td>9.3 Keywords and Reserved Words</td>
<td>1050</td>
</tr>
<tr>
<td>9.4 User-Defined Variables</td>
<td>1072</td>
</tr>
<tr>
<td>9.5 Expressions</td>
<td>1075</td>
</tr>
<tr>
<td>9.6 Comment Syntax</td>
<td>1080</td>
</tr>
<tr>
<td>10 Character Sets, Collations, Unicode</td>
<td>1083</td>
</tr>
<tr>
<td>10.1 Character Sets and Collations in General</td>
<td>1084</td>
</tr>
<tr>
<td>10.2 Character Sets and Collations in MySQL</td>
<td>1085</td>
</tr>
<tr>
<td>10.2.1 Character Set Repertoire</td>
<td>1086</td>
</tr>
<tr>
<td>10.2.2 UTF-8 for Metadata</td>
<td>1088</td>
</tr>
<tr>
<td>10.3 Specifying Character Sets and Collations</td>
<td>1089</td>
</tr>
<tr>
<td>10.3.1 Collation Naming Conventions</td>
<td>1090</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>13.1.16</td>
<td>CREATE SERVER Statement</td>
</tr>
<tr>
<td>13.1.17</td>
<td>CREATE TABLE Statement</td>
</tr>
<tr>
<td>13.1.18</td>
<td>CREATE TABLESPACE Statement</td>
</tr>
<tr>
<td>13.1.19</td>
<td>CREATE TRIGGER Statement</td>
</tr>
<tr>
<td>13.1.20</td>
<td>CREATE VIEW Statement</td>
</tr>
<tr>
<td>13.1.21</td>
<td>DROP DATABASE Statement</td>
</tr>
<tr>
<td>13.1.22</td>
<td>DROP EVENT Statement</td>
</tr>
<tr>
<td>13.1.23</td>
<td>DROP FUNCTION Statement</td>
</tr>
<tr>
<td>13.1.24</td>
<td>DROP INDEX Statement</td>
</tr>
<tr>
<td>13.1.25</td>
<td>DROP LOGFILE GROUP Statement</td>
</tr>
<tr>
<td>13.1.26</td>
<td>DROP PROCEDURE and DROP FUNCTION Statements</td>
</tr>
<tr>
<td>13.1.27</td>
<td>DROP SERVER Statement</td>
</tr>
<tr>
<td>13.1.28</td>
<td>DROP TABLE Statement</td>
</tr>
<tr>
<td>13.1.29</td>
<td>DROP TABLESPACE Statement</td>
</tr>
<tr>
<td>13.1.30</td>
<td>DROP TRIGGER Statement</td>
</tr>
<tr>
<td>13.1.31</td>
<td>DROP VIEW Statement</td>
</tr>
<tr>
<td>13.1.32</td>
<td>RENAME TABLE Statement</td>
</tr>
<tr>
<td>13.1.33</td>
<td>TRUNCATE TABLE Statement</td>
</tr>
<tr>
<td>13.2</td>
<td>Data Manipulation Statements</td>
</tr>
<tr>
<td>13.2.1</td>
<td>CALL Statement</td>
</tr>
<tr>
<td>13.2.2</td>
<td>DELETE Statement</td>
</tr>
<tr>
<td>13.2.3</td>
<td>DO Statement</td>
</tr>
<tr>
<td>13.2.4</td>
<td>HANDLER Statement</td>
</tr>
<tr>
<td>13.2.5</td>
<td>INSERT Statement</td>
</tr>
<tr>
<td>13.2.6</td>
<td>LOAD DATA Statement</td>
</tr>
<tr>
<td>13.2.7</td>
<td>LOAD XML Statement</td>
</tr>
<tr>
<td>13.2.8</td>
<td>REPLACE Statement</td>
</tr>
<tr>
<td>13.2.9</td>
<td>SELECT Statement</td>
</tr>
<tr>
<td>13.2.10</td>
<td>Subqueries</td>
</tr>
<tr>
<td>13.2.11</td>
<td>UPDATE Statement</td>
</tr>
<tr>
<td>13.3</td>
<td>Transactional and Locking Statements</td>
</tr>
<tr>
<td>13.3.1</td>
<td>START TRANSACTION, COMMIT, and ROLLBACK Statements</td>
</tr>
<tr>
<td>13.3.2</td>
<td>Statements That Cannot Be Rolled Back</td>
</tr>
<tr>
<td>13.3.3</td>
<td>Statements That Cause an Implicit Commit</td>
</tr>
<tr>
<td>13.3.4</td>
<td>SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements</td>
</tr>
<tr>
<td>13.3.5</td>
<td>LOCK TABLES and UNLOCK TABLES Statements</td>
</tr>
<tr>
<td>13.3.6</td>
<td>SET TRANSACTION Statement</td>
</tr>
<tr>
<td>13.3.7</td>
<td>XA Transactions</td>
</tr>
<tr>
<td>13.4</td>
<td>Replication Statements</td>
</tr>
<tr>
<td>13.4.1</td>
<td>SQL Statements for Controlling Master Servers</td>
</tr>
<tr>
<td>13.4.2</td>
<td>SQL Statements for Controlling Slave Servers</td>
</tr>
<tr>
<td>13.5</td>
<td>Prepared Statements</td>
</tr>
<tr>
<td>13.5.1</td>
<td>PREPARE Statement</td>
</tr>
<tr>
<td>13.5.2</td>
<td>EXECUTE Statement</td>
</tr>
<tr>
<td>13.5.3</td>
<td>DEALLOCATE PREPARE Statement</td>
</tr>
<tr>
<td>13.5.4</td>
<td>Automatic Prepared Statement Repreparation</td>
</tr>
<tr>
<td>13.6</td>
<td>Compound-Statements</td>
</tr>
<tr>
<td>13.6.1</td>
<td>BEGIN ... END Compound Statement</td>
</tr>
<tr>
<td>13.6.2</td>
<td>Statement Labels</td>
</tr>
<tr>
<td>13.6.3</td>
<td>DECLARE Statements</td>
</tr>
<tr>
<td>13.6.4</td>
<td>Variables in Stored Programs</td>
</tr>
<tr>
<td>13.6.5</td>
<td>Flow Control Statements</td>
</tr>
<tr>
<td>13.6.6</td>
<td>Cursors</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>14.11.7 Configuring InnoDB I/O Capacity</td>
<td>1772</td>
</tr>
<tr>
<td>14.11.8 Configuring Spin Lock Polling</td>
<td>1773</td>
</tr>
<tr>
<td>14.11.9 Purge Configuration</td>
<td>1774</td>
</tr>
<tr>
<td>14.11.10 Configuring Optimizer Statistics for InnoDB</td>
<td>1775</td>
</tr>
<tr>
<td>14.12 InnoDB Table Compression</td>
<td>1776</td>
</tr>
<tr>
<td>14.12.1 Overview of Table Compression</td>
<td>1777</td>
</tr>
<tr>
<td>14.12.2 Enabling Compression for a Table</td>
<td>1777</td>
</tr>
<tr>
<td>14.12.3 Tuning Compression for InnoDB Tables</td>
<td>1778</td>
</tr>
<tr>
<td>14.12.4 Monitoring InnoDB Table Compression at Runtime</td>
<td>1781</td>
</tr>
<tr>
<td>14.12.5 How Compression Works for InnoDB Tables</td>
<td>1782</td>
</tr>
<tr>
<td>14.12.6 SQL Compression Syntax Warnings and Errors</td>
<td>1785</td>
</tr>
<tr>
<td>14.13 InnoDB File-Format Management</td>
<td>1788</td>
</tr>
<tr>
<td>14.13.1 Enabling File Formats</td>
<td>1788</td>
</tr>
<tr>
<td>14.13.2 Verifying File Format Compatibility</td>
<td>1788</td>
</tr>
<tr>
<td>14.13.3 Identifying the File Format in Use</td>
<td>1791</td>
</tr>
<tr>
<td>14.13.4 Downgrading the File Format</td>
<td>1792</td>
</tr>
<tr>
<td>14.14 InnoDB Row Formats</td>
<td>1792</td>
</tr>
<tr>
<td>14.15 InnoDB Disk I/O and File Space Management</td>
<td>1797</td>
</tr>
<tr>
<td>14.15.1 InnoDB Disk I/O</td>
<td>1797</td>
</tr>
<tr>
<td>14.15.2 File Space Management</td>
<td>1798</td>
</tr>
<tr>
<td>14.15.3 InnoDB Checkpoints</td>
<td>1799</td>
</tr>
<tr>
<td>14.15.4 Defragmenting a Table</td>
<td>1800</td>
</tr>
<tr>
<td>14.15.5 Reclaiming Disk Space with TRUNCATE TABLE</td>
<td>1800</td>
</tr>
<tr>
<td>14.16 InnoDB Fast Index Creation</td>
<td>1801</td>
</tr>
<tr>
<td>14.16.1 Overview of Fast Index Creation</td>
<td>1801</td>
</tr>
<tr>
<td>14.16.2 Examples of Fast Index Creation</td>
<td>1801</td>
</tr>
<tr>
<td>14.16.3 Implementation Details of Fast Index Creation</td>
<td>1802</td>
</tr>
<tr>
<td>14.16.4 Concurrency Considerations for Fast Index Creation</td>
<td>1802</td>
</tr>
<tr>
<td>14.16.5 How Crash Recovery Works with Fast Index Creation</td>
<td>1803</td>
</tr>
<tr>
<td>14.16.6 Limitations of Fast Index Creation</td>
<td>1803</td>
</tr>
<tr>
<td>14.17 InnoDB Startup Options and System Variables</td>
<td>1804</td>
</tr>
<tr>
<td>14.18 InnoDB INFORMATION_SCHEMA Tables</td>
<td>1844</td>
</tr>
<tr>
<td>14.18.1 InnoDB INFORMATION_SCHEMA Tables about Compression</td>
<td>1844</td>
</tr>
<tr>
<td>14.18.2 InnoDB INFORMATION_SCHEMA Transaction and Locking Information</td>
<td>1846</td>
</tr>
<tr>
<td>14.18.3 InnoDB INFORMATION_SCHEMA Buffer Pool Tables</td>
<td>1851</td>
</tr>
<tr>
<td>14.19 InnoDB Integration with MySQL Performance Schema</td>
<td>1856</td>
</tr>
<tr>
<td>14.19.1 Monitoring InnoDB Mutex Waits Using Performance Schema</td>
<td>1858</td>
</tr>
<tr>
<td>14.20 InnoDB Monitors</td>
<td>1860</td>
</tr>
<tr>
<td>14.20.1 InnoDB Monitor Types</td>
<td>1860</td>
</tr>
<tr>
<td>14.20.2 Enabling InnoDB Monitors</td>
<td>1861</td>
</tr>
<tr>
<td>14.20.3 InnoDB Standard Monitor and Lock Monitor Output</td>
<td>1863</td>
</tr>
<tr>
<td>14.20.4 InnoDB Tablespace Monitor Output</td>
<td>1868</td>
</tr>
<tr>
<td>14.20.5 InnoDB Table Monitor Output</td>
<td>1870</td>
</tr>
<tr>
<td>14.21 InnoDB Backup and Recovery</td>
<td>1874</td>
</tr>
<tr>
<td>14.21.1 InnoDB Backup</td>
<td>1874</td>
</tr>
<tr>
<td>14.21.2 InnoDB Recovery</td>
<td>1875</td>
</tr>
<tr>
<td>14.22 InnoDB and MySQL Replication</td>
<td>1877</td>
</tr>
<tr>
<td>14.23 InnoDB Troubleshooting</td>
<td>1879</td>
</tr>
<tr>
<td>14.23.1 Troubleshooting InnoDB I/O Problems</td>
<td>1879</td>
</tr>
<tr>
<td>14.23.2 Forcing InnoDB Recovery</td>
<td>1880</td>
</tr>
<tr>
<td>14.23.3 Troubleshooting InnoDB Data Dictionary Operations</td>
<td>1881</td>
</tr>
<tr>
<td>14.23.4 InnoDB Error Handling</td>
<td>1883</td>
</tr>
<tr>
<td>14.24 InnoDB Limits</td>
<td>1884</td>
</tr>
<tr>
<td>14.25 InnoDB Restrictions and Limitations</td>
<td>1885</td>
</tr>
</tbody>
</table>
MySQL 5.5 Reference Manual

15 Alternative Storage Engines .................................................................................................................. 1887
  15.1 Setting the Storage Engine .................................................................................................................. 1891
  15.2 Overview of MySQL Storage Engine Architecture ............................................................................... 1892
     15.2.1 Pluggable Storage Engine Architecture ....................................................................................... 1892
     15.2.2 The Common Database Server Layer ............................................................................................ 1893
  15.3 The MyISAM Storage Engine ................................................................................................................ 1893
     15.3.1 MyISAM Startup Options ............................................................................................................... 1896
     15.3.2 Space Needed for Keys .................................................................................................................... 1898
     15.3.3 MyISAM Table Storage Formats .................................................................................................... 1898
     15.3.4 MyISAM Table Problems ............................................................................................................... 1901
  15.4 The MEMORY Storage Engine ............................................................................................................ 1902
  15.5 The CSV Storage Engine ..................................................................................................................... 1907
     15.5.1 Repairing and Checking CSV Tables ............................................................................................. 1908
     15.5.2 CSV Limitations ............................................................................................................................ 1908
  15.6 The ARCHIVE Storage Engine ............................................................................................................ 1909
  15.7 The BLACKHOLE Storage Engine ....................................................................................................... 1910
  15.8 The MERGE Storage Engine ................................................................................................................ 1913
     15.8.1 MERGE Table Advantages and Disadvantages ............................................................................. 1915
     15.8.2 MERGE Table Problems ............................................................................................................... 1916
  15.9 The FEDERATED Storage Engine ........................................................................................................ 1918
     15.9.1 FEDERATED Storage Engine Overview ....................................................................................... 1918
     15.9.2 How to Create FEDERATED Tables ............................................................................................... 1919
     15.9.3 FEDERATED Storage Engine Notes and Tips ................................................................................ 1922
     15.9.4 FEDERATED Storage Engine Resources ....................................................................................... 1923
  15.10 The EXAMPLE Storage Engine ......................................................................................................... 1923
  15.11 Other Storage Engines ...................................................................................................................... 1924
16 High Availability and Scalability ............................................................................................................ 1925
  16.1 Using ZFS Replication ......................................................................................................................... 1927
     16.1.1 Using ZFS for File System Replication ........................................................................................... 1928
     16.1.2 Configuring MySQL for ZFS Replication ....................................................................................... 1929
     16.1.3 Handling MySQL Recovery with ZFS ............................................................................................. 1930
  16.2 Using MySQL with memcached .......................................................................................................... 1930
     16.2.1 Installing memcached .................................................................................................................... 1931
     16.2.2 Using memcached ........................................................................................................................ 1933
     16.2.3 Developing a memcached Application ........................................................................................... 1952
     16.2.4 Getting memcached Statistics ...................................................................................................... 1977
     16.2.5 memcached FAQ .......................................................................................................................... 1986
17 Replication .............................................................................................................................................. 1991
  17.1 Replication Configuration ...................................................................................................................... 1992
     17.1.1 How to Set Up Replication ............................................................................................................ 1993
     17.1.2 Replication Formats ....................................................................................................................... 2002
     17.1.3 Replication and Binary Logging Options and Variables ............................................................... 2010
     17.1.4 Common Replication Administration Tasks .................................................................................... 2052
  17.2 Replication Implementation ................................................................................................................... 2055
     17.2.1 Replication Implementation Details ............................................................................................... 2055
     17.2.2 Replication Relay and Status Logs ................................................................................................. 2057
     17.2.3 How Servers Evaluate Replication Filtering Rules ......................................................................... 2060
  17.3 Replication Solutions ............................................................................................................................ 2065
     17.3.1 Using Replication for Backups ....................................................................................................... 2066
     17.3.2 Using Replication with Different Master and Slave Storage Engines ....................................... 2069
     17.3.3 Using Replication for Scale-Out .................................................................................................... 2071
     17.3.4 Replicating Different Databases to Different Slaves .................................................................... 2072
     17.3.5 Improving Replication Performance ............................................................................................... 2073
     17.3.6 Switching Masters During Failover ............................................................................................... 2074
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>2691</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA CHARACTER_SETS Table</td>
<td>2695</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA COLLATIONS Table</td>
<td>2695</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA COLLATION CHARACTER_SET_APPLICABILITY Table</td>
<td>2696</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA COLUMNS Table</td>
<td>2696</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table</td>
<td>2699</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA ENGINES Table</td>
<td>2699</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA EVENTS Table</td>
<td>2700</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables</td>
<td>2704</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables</td>
<td>2704</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table</td>
<td>2705</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA PARAMETERS Table</td>
<td>2706</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA PARTITIONS Table</td>
<td>2707</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA PLUGINS Table</td>
<td>2711</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA PROCESSLIST Table</td>
<td>2712</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA PROFILING Table</td>
<td>2713</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table</td>
<td>2714</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA ROUTINES Table</td>
<td>2715</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA SCHEMATA Table</td>
<td>2718</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table</td>
<td>2719</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA STATISTICS Table</td>
<td>2719</td>
</tr>
<tr>
<td>The INFORMATION_SCHEMA TABLES Table</td>
<td>2721</td>
</tr>
</tbody>
</table>
MySQL 5.5 Reference Manual

24.5.1 Debugging a MySQL Server ......................................................... 3009
24.5.2 Debugging a MySQL Client ........................................................... 3016
24.5.3 The DEBUG Package ................................................................. 3017
25 MySQL Enterprise Edition ................................................................. 3021
  25.1 MySQL Enterprise Monitor Overview ............................................. 3021
  25.2 MySQL Enterprise Backup Overview ............................................ 3022
  25.3 MySQL Enterprise Security Overview .......................................... 3023
  25.4 MySQL Enterprise Encryption Overview ...................................... 3023
  25.5 MySQL Enterprise Audit Overview ............................................. 3023
  25.6 MySQL Enterprise Firewall Overview ....................................... 3024
  25.7 MySQL Enterprise Thread Pool Overview .................................... 3024
  25.8 MySQL Enterprise Data Masking and De-Identification Overview .... 3024
26 MySQL Workbench ........................................................................ 3025
A MySQL 5.5 Frequently Asked Questions ........................................ 3027
  A.1 MySQL 5.5 FAQ: General .............................................................. 3027
  A.2 MySQL 5.5 FAQ: Storage Engines .............................................. 3029
  A.3 MySQL 5.5 FAQ: Server SQL Mode ............................................. 3029
  A.4 MySQL 5.5 FAQ: Stored Procedures and Functions ....................... 3030
  A.5 MySQL 5.5 FAQ: Triggers ........................................................... 3034
  A.6 MySQL 5.5 FAQ: Views ............................................................... 3036
  A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA .................................... 3037
  A.8 MySQL 5.5 FAQ: Migration .......................................................... 3037
  A.9 MySQL 5.5 FAQ: Security ........................................................... 3038
  A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster ................................. 3039
  A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets 3052
  A.12 MySQL 5.5 FAQ: Connectors & APIs ....................................... 3065
  A.13 MySQL 5.5 FAQ: C API, libmysql ............................................ 3065
  A.14 MySQL 5.5 FAQ: Replication ..................................................... 3066
  A.15 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool ....................... 3070
  A.16 MySQL 5.5 FAQ: InnoDB Change Buffer .................................... 3071
  A.17 MySQL 5.5 FAQ: Virtualization Support .................................... 3073
B Errors, Error Codes, and Common Problems .................................... 3075
  B.1 Error Message Sources and Components ................................... 3075
  B.2 Error Information Interfaces ......................................................... 3077
  B.3 Error Message Reference ............................................................ 3078
    B.3.1 Server Error Message Reference ........................................... 3079
    B.3.2 Client Error Message Reference .......................................... 3134
    B.3.3 Global Error Message Reference ......................................... 3139
  B.4 Problems and Common Errors ...................................................... 3141
    B.4.1 How to Determine What Is Causing a Problem ......................... 3141
    B.4.2 Common Errors When Using MySQL Programs ....................... 3143
    B.4.3 Administration-Related Issues .............................................. 3157
    B.4.4 Query-Related Issues ........................................................... 3165
    B.4.5 Optimizer-Related Issues ..................................................... 3173
    B.4.6 Table Definition-Related Issues .......................................... 3173
    B.4.7 Known Issues in MySQL ....................................................... 3174
C Indexes ......................................................................................... 3179
MySQL Glossary ............................................................................... 3737
Preface and Legal Notices

This is the Reference Manual for the MySQL Database System, version 5.5, through release 5.5.62. Differences between minor versions of MySQL 5.5 are noted in the present text with reference to release numbers (5.5.x). For license information, see the Legal Notices.

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Chapter 1 General Information

Table of Contents

1.1 About This Manual ................................................................. 2
1.2 Typographical and Syntax Conventions .................................................. 2
1.3 Overview of the MySQL Database Management System .................................. 4
    1.3.1 What is MySQL? .......................................................... 4
    1.3.2 The Main Features of MySQL .............................................. 6
    1.3.3 History of MySQL .......................................................... 8
1.4 What Is New in MySQL 5.5 ..................................................... 9
1.5 MySQL Information Sources .................................................................. 18
    1.5.1 MySQL Websites ................................................................ 18
    1.5.2 MySQL Community Support at the MySQL Forums ...................... 18
    1.5.3 MySQL Enterprise .............................................................. 18
1.6 How to Report Bugs or Problems ...................................................... 19
1.7 MySQL Standards Compliance ....................................................... 23
    1.7.1 MySQL Extensions to Standard SQL ...................................... 24
    1.7.2 MySQL Differences from Standard SQL ................................. 27
    1.7.3 How MySQL Deals with Constraints .................................... 29
1.8 Credits ...................................................................................... 33
    1.8.1 Contributors to MySQL ..................................................... 33
    1.8.2 Documenters and translators .............................................. 37
    1.8.3 Packages that support MySQL ......................................... 39
    1.8.4 Tools that were used to create MySQL .................................. 39
    1.8.5 Supporters of MySQL ....................................................... 40

The MySQL™ software delivers a very fast, multithreaded, multi-user, and robust SQL (Structured Query Language) database server. MySQL Server is intended for mission-critical, heavy-load production systems as well as for embedding into mass-deployed software. Oracle is a registered trademark of Oracle Corporation and/or its affiliates. MySQL is a trademark of Oracle Corporation and/or its affiliates, and shall not be used by Customer without Oracle’s express written authorization. Other names may be trademarks of their respective owners.

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The following list describes some sections of particular interest in this manual:

• For a discussion of MySQL Database Server capabilities, see Section 1.3.2, “The Main Features of MySQL”.

• For an overview of new MySQL features, see Section 1.4, “What Is New in MySQL 5.5”. For information about the changes in each version, see the Release Notes.

• For installation instructions, see Chapter 2, Installing and Upgrading MySQL. For information about upgrading MySQL, see Section 2.11, “Upgrading MySQL”.

• For a tutorial introduction to the MySQL Database Server, see Chapter 3, Tutorial.

• For information about configuring and administering MySQL Server, see Chapter 5, MySQL Server Administration.
• For information about security in MySQL, see Chapter 6, Security.

• For information about setting up replication servers, see Chapter 17, Replication.

• For information about MySQL Enterprise, the commercial MySQL release with advanced features and management tools, see Chapter 25, MySQL Enterprise Edition.

• For answers to a number of questions that are often asked concerning the MySQL Database Server and its capabilities, see Appendix A, MySQL 5.5 Frequently Asked Questions.

• For a history of new features and bug fixes, see the Release Notes.

---

Important

To report problems or bugs, please use the instructions at Section 1.6, “How to Report Bugs or Problems”. If you find a security bug in MySQL Server, please let us know immediately by sending an email message to <secalert_us@oracle.com>. Exception: Support customers should report all problems, including security bugs, to Oracle Support.

---

1.1 About This Manual

This is the Reference Manual for the MySQL Database System, version 5.5, through release 5.5.62. Differences between minor versions of MySQL 5.5 are noted in the present text with reference to release numbers (5.5.x). For license information, see the Legal Notices.

This manual is not intended for use with older versions of the MySQL software due to the many functional and other differences between MySQL 5.5 and previous versions. If you are using an earlier release of the MySQL software, please refer to the appropriate manual. For example, MySQL 5.1 Reference Manual covers the 5.1 series of MySQL software releases.

If you are using MySQL 5.6, please refer to the MySQL 5.6 Reference Manual.

Because this manual serves as a reference, it does not provide general instruction on SQL or relational database concepts. It also does not teach you how to use your operating system or command-line interpreter.

The MySQL Database Software is under constant development, and the Reference Manual is updated frequently as well. The most recent version of the manual is available online in searchable form at https://dev.mysql.com/doc/. Other formats also are available there, including HTML, PDF, and EPUB versions.

The Reference Manual source files are written in DocBook XML format. The HTML version and other formats are produced automatically, primarily using the DocBook XSL stylesheets. For information about DocBook, see http://docbook.org/

If you have questions about using MySQL, join the MySQL Community Slack, or ask in our forums; see Section 1.5.2, “MySQL Community Support at the MySQL Forums”. If you have suggestions concerning additions or corrections to the manual itself, please send them to the http://www.mysql.com/company/contact/.

This manual was originally written by David Axmark and Michael “Monty” Widenius. It is maintained by the MySQL Documentation Team, consisting of Chris Cole, Paul DuBois, Margaret Fisher, Edward Gilmore, Stefan Hinz, David Moss, Philip Olson, Daniel Price, Daniel So, and Jon Stephens.

1.2 Typographical and Syntax Conventions

This manual uses certain typographical conventions:
Typographical and Syntax Conventions

- **Text in this style** is used for SQL statements; database, table, and column names; program listings and source code; and environment variables. Example: “To reload the grant tables, use the `FLUSH PRIVILEGES` statement.”

- **Text in this style** indicates input that you type in examples.

- **Text in this style** indicates the names of executable programs and scripts, examples being `mysql` (the MySQL command-line client program) and `mysqld` (the MySQL server executable).

- **Text in this style** is used for variable input for which you should substitute a value of your own choosing.

- **Text in this style** is used for emphasis.

- **Text in this style** is used in table headings and to convey especially strong emphasis.

- **Text in this style** is used to indicate a program option that affects how the program is executed, or that supplies information that is needed for the program to function in a certain way. *Example:* “The `--host` option (short form `-h`) tells the `mysql` client program the hostname or IP address of the MySQL server that it should connect to.”

- File names and directory names are written like this: “The global `my.cnf` file is located in the `/etc` directory.”

- Character sequences are written like this: “To specify a wildcard, use the ‘%’ character.”

When commands are shown that are meant to be executed from within a particular program, the prompt shown preceding the command indicates which command to use. For example, `shell>` indicates a command that you execute from your login shell, `root-shell>` is similar but should be executed as `root`, and `mysql>` indicates a statement that you execute from the `mysql` client program:

```
shell> type a shell command here
root-shell> type a shell command as root here
mysql> type a mysql statement here
```

In some areas different systems may be distinguished from each other to show that commands should be executed in two different environments. For example, while working with replication the commands might be prefixed with `master` and `slave`:

```
master> type a mysql command on the replication master here
slave> type a mysql command on the replication slave here
```

The “shell” is your command interpreter. On Unix, this is typically a program such as `sh`, `csh`, or `bash`. On Windows, the equivalent program is `command.com` or `cmd.exe`, typically run in a console window.

When you enter a command or statement shown in an example, do not type the prompt shown in the example.

Database, table, and column names must often be substituted into statements. To indicate that such substitution is necessary, this manual uses `db_name`, `tbl_name`, and `col_name`. For example, you might see a statement like this:

```
mysql> SELECT col_name FROM db_name.tbl_name;
```

This means that if you were to enter a similar statement, you would supply your own database, table, and column names, perhaps like this:

```
mysql> SELECT author_name FROM biblio_db.author_list;
```

SQL keywords are not case-sensitive and may be written in any lettercase. This manual uses uppercase.
1.3 Overview of the MySQL Database Management System

1.3.1 What is MySQL?

MySQL, the most popular Open Source SQL database management system, is developed, distributed, and supported by Oracle Corporation.

The MySQL website (http://www.mysql.com/) provides the latest information about MySQL software.

- **MySQL is a database management system.**
  
  A database is a structured collection of data. It may be anything from a simple shopping list to a picture gallery or the vast amounts of information in a corporate network. To add, access, and process data stored in a computer database, you need a database management system such as MySQL Server. Since computers are very good at handling large amounts of data, database management systems play a central role in computing, as standalone utilities, or as parts of other applications.

- **MySQL databases are relational.**
  
  A relational database stores data in separate tables rather than putting all the data in one big storeroom. The database structures are organized into physical files optimized for speed. The logical model,
What is MySQL?

with objects such as databases, tables, views, rows, and columns, offers a flexible programming environment. You set up rules governing the relationships between different data fields, such as one-to-one, one-to-many, unique, required or optional, and “pointers” between different tables. The database enforces these rules, so that with a well-designed database, your application never sees inconsistent, duplicate, orphan, out-of-date, or missing data.

The SQL part of “MySQL” stands for “Structured Query Language”. SQL is the most common standardized language used to access databases. Depending on your programming environment, you might enter SQL directly (for example, to generate reports), embed SQL statements into code written in another language, or use a language-specific API that hides the SQL syntax.

SQL is defined by the ANSI/ISO SQL Standard. The SQL standard has been evolving since 1986 and several versions exist. In this manual, “SQL-92” refers to the standard released in 1992, “SQL:1999” refers to the standard released in 1999, and “SQL:2003” refers to the current version of the standard. We use the phrase “the SQL standard” to mean the current version of the SQL Standard at any time.

• MySQL software is Open Source.

Open Source means that it is possible for anyone to use and modify the software. Anybody can download the MySQL software from the Internet and use it without paying anything. If you wish, you may study the source code and change it to suit your needs. The MySQL software uses the GPL (GNU General Public License), http://www.fsf.org/licenses/, to define what you may and may not do with the software in different situations. If you feel uncomfortable with the GPL or need to embed MySQL code into a commercial application, you can buy a commercially licensed version from us. See the MySQL Licensing Overview for more information (http://www.mysql.com/company/legal/licensing/).

• The MySQL Database Server is very fast, reliable, scalable, and easy to use.

If that is what you are looking for, you should give it a try. MySQL Server can run comfortably on a desktop or laptop, alongside your other applications, web servers, and so on, requiring little or no attention. If you dedicate an entire machine to MySQL, you can adjust the settings to take advantage of all the memory, CPU power, and I/O capacity available. MySQL can also scale up to clusters of machines, networked together.

MySQL Server was originally developed to handle large databases much faster than existing solutions and has been successfully used in highly demanding production environments for several years. Although under constant development, MySQL Server today offers a rich and useful set of functions. Its connectivity, speed, and security make MySQL Server highly suited for accessing databases on the Internet.

• MySQL Server works in client/server or embedded systems.

The MySQL Database Software is a client/server system that consists of a multithreaded SQL server that supports different back ends, several different client programs and libraries, administrative tools, and a wide range of application programming interfaces (APIs).

We also provide MySQL Server as an embedded multithreaded library that you can link into your application to get a smaller, faster, easier-to-manage standalone product.

• A large amount of contributed MySQL software is available.

MySQL Server has a practical set of features developed in close cooperation with our users. It is very likely that your favorite application or language supports the MySQL Database Server.

The official way to pronounce “MySQL” is “My Ess Que Ell” (not “my sequel”), but we do not mind if you pronounce it as “my sequel” or in some other localized way.
1.3.2 The Main Features of MySQL

This section describes some of the important characteristics of the MySQL Database Software. In most respects, the roadmap applies to all versions of MySQL. For information about features as they are introduced into MySQL on a series-specific basis, see the “In a Nutshell” section of the appropriate Manual:

- MySQL 8.0: What Is New in MySQL 8.0
- MySQL 5.7: What Is New in MySQL 5.7
- MySQL 5.6: What Is New in MySQL 5.6
- MySQL 5.5: Section 1.4, “What Is New in MySQL 5.5”

Internals and Portability

- Written in C and C++.
- Tested with a broad range of different compilers.
- Works on many different platforms. See https://www.mysql.com/support/supportedplatforms/database.html.
- For portability, uses CMake in MySQL 5.5 and up. Previous series use GNU Automake, Autoconf, and Libtool.
- Tested with Purify (a commercial memory leakage detector) as well as with Valgrind, a GPL tool (http://developer.kde.org/~sewardj/).
- Uses multi-layered server design with independent modules.
- Designed to be fully multithreaded using kernel threads, to easily use multiple CPUs if they are available.
- Provides transactional and nontransactional storage engines.
- Uses very fast B-tree disk tables (MyISAM) with index compression.
- Designed to make it relatively easy to add other storage engines. This is useful if you want to provide an SQL interface for an in-house database.
- Uses a very fast thread-based memory allocation system.
- Executes very fast joins using an optimized nested-loop join.
- Implements in-memory hash tables, which are used as temporary tables.
- Implements SQL functions using a highly optimized class library that should be as fast as possible. Usually there is no memory allocation at all after query initialization.
- Provides the server as a separate program for use in a client/server networked environment, and as a library that can be embedded (linked) into standalone applications. Such applications can be used in isolation or in environments where no network is available.

Data Types

- Many data types: signed/unsigned integers 1, 2, 3, 4, and 8 bytes long, FLOAT, DOUBLE, CHAR, VARCHAR, BINARY, VARBINARY, TEXT, BLOB, DATE, TIME, DATETIME, TIMESTAMP, YEAR, SET, ENUM, and OpenGIS spatial types. See Chapter 11, Data Types.
• Fixed-length and variable-length string types.

**Statements and Functions**

• Full operator and function support in the **SELECT list** and **WHERE clause** of queries. For example:

```sql
mysql> SELECT CONCAT(first_name, ' ', last_name) -> FROM citizen -> WHERE income/dependents > 10000 AND age > 30;
```

• Full support for SQL **GROUP BY** and **ORDER BY** clauses. Support for group functions (**COUNT()**, **AVG()**, **STD()**, **SUM()**, **MAX()**, **MIN()**, and **GROUP_CONCAT()**).

• Support for **LEFT OUTER JOIN** and **RIGHT OUTER JOIN** with both standard SQL and ODBC syntax.

• Support for aliases on tables and columns as required by standard SQL.

• Support for **DELETE**, **INSERT**, **REPLACE**, and **UPDATE** to return the number of rows that were changed (affected), or to return the number of rows matched instead by setting a flag when connecting to the server.

• Support for MySQL-specific **SHOW** statements that retrieve information about databases, storage engines, tables, and indexes. Support for the **INFORMATION_SCHEMA** database, implemented according to standard SQL.

• An **EXPLAIN** statement to show how the optimizer resolves a query.

• Independence of function names from table or column names. For example, **ABS** is a valid column name. The only restriction is that for a function call, no spaces are permitted between the function name and the “(“ that follows it. See Section 9.3, “Keywords and Reserved Words”.

• You can refer to tables from different databases in the same statement.

**Security**

• A privilege and password system that is very flexible and secure, and that enables host-based verification.

• Password security by encryption of all password traffic when you connect to a server.

**Scalability and Limits**

• Support for large databases. We use MySQL Server with databases that contain 50 million records. We also know of users who use MySQL Server with 200,000 tables and about 5,000,000,000 rows.

• Support for up to 64 indexes per table. Each index may consist of 1 to 16 columns or parts of columns. The maximum index width for InnoDB tables is either 767 bytes or 3072 bytes. See Section 14.24, “InnoDB Limits”. The maximum index width for MyISAM tables is 1000 bytes. See Section 15.3, “The MyISAM Storage Engine”. An index may use a prefix of a column for **CHAR**, **VARCHAR**, **BLOB**, or **TEXT** column types.

**Connectivity**

• Clients can connect to MySQL Server using several protocols:

• Clients can connect using TCP/IP sockets on any platform.

• On Windows systems, clients can connect using named pipes if the server is started with the **named_pipe** system variable enabled. Windows servers also support shared-memory connections.
if started with the `shared_memory` system variable enabled. Clients can connect through shared memory by using the `--protocol=memory` option.

- On Unix systems, clients can connect using Unix domain socket files.
- MySQL client programs can be written in many languages. A client library written in C is available for clients written in C or C++, or for any language that provides C bindings.
- APIs for C, C++, Eiffel, Java, Perl, PHP, Python, Ruby, and Tcl are available, enabling MySQL clients to be written in many languages. See Chapter 23, Connectors and APIs.
- The Connector/ODBC (MyODBC) interface provides MySQL support for client programs that use ODBC (Open Database Connectivity) connections. For example, you can use MS Access to connect to your MySQL server. Clients can be run on Windows or Unix. Connector/ODBC source is available. All ODBC 2.5 functions are supported, as are many others. See MySQL Connector/ODBC Developer Guide.
- The Connector/J interface provides MySQL support for Java client programs that use JDBC connections. Clients can be run on Windows or Unix. Connector/J source is available. See MySQL Connector/J 5.1 Developer Guide.
- MySQL Connector/NET enables developers to easily create .NET applications that require secure, high-performance data connectivity with MySQL. It implements the required ADO.NET interfaces and integrates into ADO.NET aware tools. Developers can build applications using their choice of .NET languages. MySQL Connector/NET is a fully managed ADO.NET driver written in 100% pure C#. See MySQL Connector/NET Developer Guide.

Localization

- The server can provide error messages to clients in many languages. See Section 10.12, “Setting the Error Message Language”.
- Full support for several different character sets, including `latin1 (cp1252)`, `german`, `big5`, `ujis`, several Unicode character sets, and more. For example, the Scandinavian characters “å”, “ä” and “ö” are permitted in table and column names.
- All data is saved in the chosen character set.
- Sorting and comparisons are done according to the default character set and collation. It is possible to change this when the MySQL server is started (see Section 10.3.2, “Server Character Set and Collation”). To see an example of very advanced sorting, look at the Czech sorting code. MySQL Server supports many different character sets that can be specified at compile time and runtime.
- The server time zone can be changed dynamically, and individual clients can specify their own time zone. See Section 5.1.12, “MySQL Server Time Zone Support”.

Clients and Tools

- MySQL includes several client and utility programs. These include both command-line programs such as `mysqldump` and `mysqladmin`, and graphical programs such as MySQL Workbench.
- MySQL Server has built-in support for SQL statements to check, optimize, and repair tables. These statements are available from the command line through the `mysqlcheck` client. MySQL also includes `myisamchk`, a very fast command-line utility for performing these operations on MyISAM tables. See Chapter 4, MySQL Programs.
- MySQL programs can be invoked with the `--help` or `--?` option to obtain online assistance.

1.3.3 History of MySQL
We started out with the intention of using the mSQL database system to connect to our tables using our own fast low-level (ISAM) routines. However, after some testing, we came to the conclusion that mSQL was not fast enough or flexible enough for our needs. This resulted in a new SQL interface to our database but with almost the same API interface as mSQL. This API was designed to enable third-party code that was written for use with mSQL to be ported easily for use with MySQL.

MySQL is named after co-founder Monty Widenius's daughter, My.

The name of the MySQL Dolphin (our logo) is “Sakila,” which was chosen from a huge list of names suggested by users in our “Name the Dolphin” contest. The winning name was submitted by Ambrose Twabaze, an Open Source software developer from Swaziland, Africa. According to Ambrose, the feminine name Sakila has its roots in SiSwati, the local language of Swaziland. Sakila is also the name of a town in Arusha, Tanzania, near Ambrose’s country of origin, Uganda.

1.4 What Is New in MySQL 5.5

This section summarizes what has been added to, deprecated in, and removed from MySQL 5.5.

- Features Added in MySQL 5.5
- Features Deprecated in MySQL 5.5
- Features Removed in MySQL 5.5

Features Added in MySQL 5.5

The following features have been added to MySQL 5.5:

- **MySQL Enterprise Thread Pool.** The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. As of MySQL 5.5.16, MySQL Enterprise Edition distributions include a thread pool plugin that provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections. For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

- **MySQL Enterprise Audit.** MySQL Enterprise Edition now includes MySQL Enterprise Audit, implemented using a server plugin named `audit_log`. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines. When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access. For more information, see Section 6.4.2, “MySQL Enterprise Audit”.

- **Pluggable authentication.** MySQL authentication supports two new capabilities, pluggable authentication and proxy users. With pluggable authentication, the server can use plugins to authenticate incoming client connections, and clients can load an authentication plugin that interacts properly with the corresponding server plugin. This capability enables clients to connect to the MySQL server with credentials that are appropriate for authentication methods other than the built-in MySQL authentication based on native MySQL passwords stored in the `mysql.user` table. For example, plugins can be created to use external authentication methods such as LDAP, Kerberos, PAM, or Windows login IDs. Proxy user capability enables a client who connects and authenticates as one user to be treated,
for purposes of access control while connected, as having the privileges of a different user. In effect, one user impersonates another. Proxy capability depends on pluggable authentication because it is based on having an authentication plugin return to the server the user name that the connecting user impersonates. See Section 6.2.10, “Pluggable Authentication”, and Section 6.2.11, “Proxy Users”.

As of MySQL 5.5.16, MySQL Enterprise Edition includes two plugins that enable MySQL Server to use external authentication methods to authenticate MySQL users:

- **PAM (Pluggable Authentication Modules)** enables a system to access various kinds of authentication methods through a standard interface. A PAM authentication plugin enables MySQL Server to use PAM to authenticate MySQL users.

- **Distributions of MySQL for Windows include an authentication plugin that enables MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password.**

These authentication plugins enable MySQL Server to accept connections from users defined outside the MySQL grant tables. They also support the MySQL proxy-user capability. Each plugin can return to MySQL a user name different from the operating system user, which means that the plugin can return the MySQL user that defines the privileges the externally authenticated user should have.

For more information, see Section 6.4.1.4, “PAM Pluggable Authentication”, and Section 6.4.1.5, “Windows Pluggable Authentication”.

- **Multi-core scalability.** Scalability on multi-core CPUs is improved. The trend in hardware development now is toward more cores rather than continued increases in CPU clock speeds, which renders “wait until CPUs get faster” a nonviable means of improving database performance. Instead, it is necessary to make better use of multiple cores to maximally exploit the processing cycles they make available. MySQL 5.5 takes advantage of features of SMP systems and tries to eliminate bottlenecks in MySQL architecture that hinder full use of multiple cores. The focus has been on InnoDB, especially locking and memory management. See Scalability Improvements.

- **Default storage engine.** The default storage engine for new tables is InnoDB rather than MyISAM. See Section 14.1, “Introduction to InnoDB”.

- **InnoDB I/O subsystem.** InnoDB I/O subsystem changes enable more effective use of available I/O capacity. See InnoDB I/O Subsystem Changes.

- **InnoDB storage engine.** MySQL 5.5 includes several InnoDB storage engine enhancements:
  - Indexes can be added or dropped without copying the table. See Section 14.16, “InnoDB Fast Index Creation”.
  - Tables can be compressed to significantly reduce storage requirements and I/O. See Section 14.12, “InnoDB Table Compression”.
  - BLOB, TEXT, and VARCHAR columns can be stored fully off page. See Section 14.14, “InnoDB Row Formats”.
  - File format management enhancements protect upward and downward compatibility. See Section 14.13, “InnoDB File-Format Management”.
  - INFORMATION_SCHEMA tables provide information about InnoDB compression and locking. See Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”.
  - InnoDB performance and scalability enhancements:
• The **InnoDB** mutex and read/write lock implementation was improved. Use of Pthreads mutexes was replaced with calls to GCC - atomic builtins.

• The memory allocator used by **InnoDB** is configurable. See Section 14.11.3, “Configuring the Memory Allocator for InnoDB”.

• The extent to which **InnoDB** performs change buffering is configurable. See Configuring Change Buffering.

• The adaptive hash index (AHI) feature makes **InnoDB** perform more like an in-memory database on systems with appropriate combinations of workload and ample memory for the buffer pool, without sacrificing transactional features or reliability. See Section 14.8.3, “Adaptive Hash Index”.

• Different techniques can be used to limit the number of concurrently executing operating system threads to minimize context switching. See Section 14.11.4, “Configuring Thread Concurrency for InnoDB”.

• How **InnoDB** performs buffer pool read-ahead is configurable. See Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

• The number of background threads that service read and write I/O operations on data pages is configurable. See Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”.

• Asynchronous I/O is supported on Linux systems. See `innodb_use_native_aio`.

• The I/O capacity available to **InnoDB** is configurable. See Section 14.11.7, “Configuring InnoDB I/O Capacity”.

• How **InnoDB** performs buffer pool flushing is configurable. Section 14.11.2.4, “Configuring Buffer Pool Flushing”.

• The maximum delay between checking the availability of a mutex or rw-lock is configurable. See Section 14.11.8, “Configuring Spin Lock Polling”.

• **InnoDB** can be configured to minimize the amount of data brought into the buffer pool and never accessed again. See Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”.

• Crash recovery performance was improved. See Section 8.5.8, “Optimizing InnoDB Configuration Variables”.

• Certain internal **InnoDB** operations can be profiled using the Performance Schema feature. See Section 14.19, “InnoDB Integration with MySQL Performance Schema”.

• The buffer pool can be divided into separate instances to reduce contention between threads that read and write to cached pages. See Section 14.11.2.1, “Configuring Multiple Buffer Pool Instances”.

• The limit on concurrent read-write transactions was increased. See Section 14.9.7, “Undo Logs”.

• **InnoDB** can be configured to have purge operations performed by a separate thread, rather than by the master thread. See Section 14.11.9, “Purge Configuration”.

• As of MySQL 5.5.62, the **zlib library** version bundled with MySQL was raised from version 1.2.3 to version 1.2.11. MySQL implements compression with the help of the zlib library.
Features Added in MySQL 5.5

If you use InnoDB compressed tables, see Section 2.11.3, “Changes in MySQL 5.5” for related upgrade implications.

- **InnoDB** flexibility, ease of use, and reliability enhancements:
  - The `innodb_file_per_table`, `innodb_stats_on_metadata`, `innodb_lock_wait_timeout`, and `innodb_adaptive_hash_index` options can be set at runtime using a `SET` statement.
  - Operating system disk space can be reclaimed when truncating an InnoDB table. See Section 14.15.5, “Reclaiming Disk Space with TRUNCATE TABLE”.
  - InnoDB can be run in strict mode. See the `innodb_strict_mode` parameter documentation.
  - InnoDB provides greater control over the quality of optimizer statistics estimates. See Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”.
  - `SHOW ENGINE INNODB MUTEX` output is more compact. See Section 13.7.5.16, “SHOW ENGINE Statement”.
  - `SHOW ENGINE INNODB STATUS` output displays counter information for the `Innodb_buffer_pool_read_ahead` and `Innodb_buffer_pool_read_ahead_evicted` global status variables, which you can use to fine-tune the `innodb_random_read_ahead` setting and evaluate the effectiveness of the read-ahead algorithm.

- **Diagnostic improvements.** There is better access to execution and performance information. Diagnostic improvements include Performance Schema (a feature for monitoring MySQL Server execution at a low level), DTrace probes, expanded `SHOW ENGINE INNODB STATUS` output, Debug Sync, and a new status variable. See Diagnostic and Monitoring Capabilities.

- **Solaris.** Several modifications improve operation of MySQL Server on Solaris. See Enhanced Solaris Support.

- **MySQL NDB Cluster.** MySQL NDB Cluster is released as a separate product, with version 7.2 of the NDB storage engine being based on MySQL 5.5. Clustering support is not available in mainline MySQL Server 5.5 releases. For more information about MySQL NDB Cluster 7.2, see Chapter 18, MySQL NDB Cluster 7.2.

  NDB Cluster releases are identified by a 3-part NDB version number. NDB Cluster 7.5, now available as a General Availability (GA) release beginning with version 7.5.4, incorporates version 7.5 of the NDB storage engine. Previous GA releases still available for production, NDB Cluster 7.3 and NDB Cluster 7.4, incorporate NDB versions 7.3 and 7.4, respectively. For information about NDB Cluster 7.5, see MySQL NDB Cluster 7.5 and NDB Cluster 7.6. For more information about NDB Cluster 7.4 and NDB Cluster 7.3, see MySQL NDB Cluster 7.3 and NDB Cluster 7.4.

- **Semisynchronous replication.** A commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction. Semisynchronous replication is implemented through an optional plugin component. See Section 17.3.8, “Semisynchronous Replication”

- **Unicode support.** Support for supplementary Unicode characters; that is, characters outside the Basic Multilingual Plane (BMP). These new Unicode character sets include supplementary characters: `utf16`, `utf32`, and `utf8mb4`. See Section 10.9, “Unicode Support”.
• **Partitioning.** Enhancements to table partitioning:

  - Two new types of user-defined partitioning are supported: `RANGE COLUMNS` partitioning is an extension to `RANGE` partitioning; `LIST COLUMNS` partitioning is an extension to `LIST` partitioning. Each of these extensions provides two enhancements to MySQL partitioning capabilities:

    - It is possible to define partitioning ranges or lists based on `DATE`, `DATETIME`, or string values (such as `CHAR` or `VARCHAR`).

      You can also define ranges or lists based on multiple column values when partitioning tables by `RANGE COLUMNS` or `LIST COLUMNS`, respectively. Such a range or list may refer to up to 16 columns.

    - For tables defined using these partitioning types, partition pruning can now optimize queries with `WHERE` conditions that use multiple comparisons between (different) column values and constants, such as `a = 10 AND b > 5` or `a < "2005-11-25" AND b = 10 AND c = 50`.

      See Section 19.2.1, “RANGE Partitioning”, and Section 19.2.2, “LIST Partitioning”.

  - It is now possible to delete all rows from one or more partitions of a partitioned table using the `ALTER TABLE ... TRUNCATE PARTITION` statement. Executing the statement deletes rows without affecting the structure of the table. The partitions named in the `TRUNCATE PARTITION` clause do not have to be contiguous.

  - Key caches are now supported for indexes on partitioned `MyISAM` tables, using the `CACHE INDEX` and `LOAD INDEX INTO CACHE` statements. In addition, a key cache can be defined for and loaded with indexes from an entire partitioned table, or for one or more partitions. In the latter case, the partitions are not required to be contiguous.

  - The new `TO_SECONDS()` function converts a date or datetime expression to a number of seconds since the year 0. This is a general-purpose function, but is useful for partitioning. You may use it in partitioning expressions, and partition pruning is supported for tables defined using such expressions.

• **SIGNAL and RESIGNAL.** Support for the SQL standard `SIGNAL` and `RESIGNAL` statements. See Section 13.6.7, “Condition Handling”.

• **Metadata locking.** The server now prevents DDL statements from compromising transaction serializability by using a new class of locks called metadata locks. See Section 8.11.4, “Metadata Locking”.

• **IPv6 support.** MySQL Server can accept TCP/IP connections from clients connecting over IPv6. See Section 5.1.11, “IPv6 Support”.

• **XML support.** Enhancements to XML functionality, including a new `LOAD XML` statement. See Section 13.2.7, “LOAD XML Statement”.

• **Build configuration.** MySQL releases are now built using `CMake` rather than the GNU autotools. Accordingly, the instructions for installing MySQL from source have been updated to discuss how to build MySQL using `CMake`. See Section 2.9, “Installing MySQL from Source”.

  The build process is now similar enough on all platforms, including Windows, that there are no longer sections dedicated to notes for specific platforms.

## Features Deprecated in MySQL 5.5

The following features are deprecated in MySQL 5.5 and may be or will be removed in a future series. Where alternatives are shown, applications should be updated to use them.
For applications that use features deprecated in MySQL 5.5 that have been removed in a higher MySQL series, statements may fail when replicated from a MySQL 5.5 master to a higher-series slave, or may have different effects on master and slave. To avoid such problems, applications that use features deprecated in 5.5 should be revised to avoid them and use alternatives when possible.

- Relying on implicit `GROUP BY` sorting in MySQL 5.5 is deprecated. To achieve a specific sort order of grouped results, it is preferable to use an explicit `ORDER BY` clause. `GROUP BY` sorting is a MySQL extension that may change in a future release; for example, to make it possible for the optimizer to order groupings in whatever manner it deems most efficient and to avoid the sorting overhead.

- The `YEAR(2)` data type. `YEAR(2)` columns in existing tables are treated as before, but `YEAR(2)` in new or altered tables are converted to `YEAR(4)`. For more information, see Section 11.2.5, "2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR".

- The `SHOW AUTHORS` and `SHOW CONTRIBUTORS` statements.

- The `ignore_builtin_innodb` system variable. It does nothing and has no effect.

- The `--language` server option. Use the `lc_messages_dir` and `lc_messages` system variables instead.

- The `ALWAYS` value for the `--base64-output` option for `mysqlbinlog`.

- The `--config-file` option for `mysqld_multi`. Use `--defaults-extra-file` instead.

- Use of unambiguous option prefixes. If an unambiguous prefix is given, a warning occurs to provide feedback. Option prefixes are no longer supported in MySQL 5.7; only full options are accepted.

- The `engine_condition_pushdown` system variable. Use the `engine_condition_pushdown` flag of the `optimizer_switch` variable instead.

- The `timed_mutexes` system variable. It does nothing and has no effect.

- The `storage_engine` system variable. Use `default_storage_engine` instead.

- Use of the data directory as the location for `my.cnf`.

### Features Removed in MySQL 5.5

The following constructs are obsolete and have been removed in MySQL 5.5. Where alternatives are shown, applications should be updated to use them.

For MySQL 5.1 applications that use features removed in MySQL 5.5, statements may fail when replicated from a MySQL 5.1 master to a MySQL 5.5 slave, or may have different effects on master and slave. To avoid such problems, applications that use features removed in MySQL 5.5 should be revised to avoid them and use alternatives when possible.

- The `language` system variable (use `lc_messages_dir` and `lc_messages`).

- The `log_bin_trust_routine_creators` system variable (use `log_bin_trust_functionCreators`).

- The `myisam_max_extra_sort_file_size` system variable.

- The `record_buffer` system variable (use `read_buffer_size`).

- The `sql_log_update` system variable.
• The Innodb_buffer_pool_read_ahead_rnd and Innodb_buffer_pool_read_ahead_seq
  status variables (use Innodb_buffer_pool_read_ahead and
  Innodb_buffer_pool_read_ahead_evicted).
• The table_lock_wait_timeout system variable.
• The table_type system variable (use default_storage_engine).
• The FRAC_SECOND modifier for the TIMESTAMPADD() function (use MICROSECOND).
• The TYPE table option to specify the storage engine for CREATE TABLE or ALTER TABLE (use
  ENGINE).
• The SHOW TABLE TYPES SQL statement (use SHOW ENGINES).
• The SHOW INNODB STATUS and SHOW MUTEX STATUS SQL statements (use SHOW ENGINE INNODB
  STATUS and SHOW ENGINE INNODB MUTEX).
• The SHOW PLUGIN SQL statement (use SHOW PLUGINS).
• The LOAD TABLE ... FROM MASTER and LOAD DATA FROM MASTER SQL statements (use
  mysqldump or mysqlhotcopy to dump tables and mysql to reload dump files).
• The BACKUP TABLE and RESTORE TABLE SQL statements (use mysqldump or mysqlhotcopy to
  dump tables and mysql to reload dump files).
• TIMESTAMP (N) data type: The ability to specify a display width of N (use without N).
• The --default-character-set and --default-collation server options (use the
  character_set_server and collation_server system variables).
• The --default-table-type server option (use the default_storage_engine system variable).
• The --delay-key-write-for-all-tables server option (set the delay_key_write system
  variable to ALL).
• The --enable-locking and --skip-locking server options (use --external-locking and --
  skip-external-locking).
• The --log-long-format server option.
• The --log-update server option.
• The --master-xxx server options to set replication parameters (use the CHANGE MASTER TO
  statement instead): --master-host, --master-user, --master-password, --master-port,
  --master-connect-retry, --master-ssl, --master-ssl-ca, --master-ssl-capath, --
  master-ssl-cert, --master-ssl-cipher, --master-ssl-key.
• The --safe-show-database server option.
• The --skip-symlink and --use-symbolic-links server options (use --skip-symbolic-links
  and --symbolic-links).
• The --sql-bin-update-same server option.
• The --warnings server option (use --log-warnings).
• The --no-named-commands option for mysql (use --skip-named-commands).
• The --no-pager option for mysql (use --skip-pager).
• The --no-tee option for mysql (use --skip-tee).
Scalability Improvements

- The `--position` option for `mysqlbinlog` (use `--start-position`).
- The `--all` option for `mysqldump` (use `--create-options`).
- The `--first-slave` option for `mysqldump` (use `--lock-all-tables`).
- The `--config-file` option for `mysqld_multi` (use `--defaults-extra-file`).
- The `--set-variable=var_name=value` and `-O var_name=value` general-purpose options for setting program variables (use `--var_name=value`).
- The `--with-pstack` option for `configure` and the `--enable-pstack` option for `mysqld`.

Scalability Improvements

MySQL 5.5 modifications improve performance on SMP systems to increase scalability on multi-core systems. The changes affect InnoDB locking and memory management.

MySQL 5.5 incorporates changes in InnoDB that improve the performance of RW-locks by using atomic CPU instructions (on platforms where they are available), rather than less scalable mutexes. It is also possible for InnoDB memory allocation to be disabled and replaced by the normal `malloc` library, or by a different library that implements `malloc` such as `tcmalloc` on Linux or `mtmalloc` on Solaris.

The reimplementation of RW-locks requires atomic instructions. A status variable, `Innodb_have_atomic_builtins`, shows whether the server was built with atomic instructions.

InnoDB I/O Subsystem Changes

MySQL 5.5 changes to the InnoDB I/O subsystem enable more effective use of available I/O capacity. The changes also provide more control over configuration of the I/O subsystem.

Background I/O Threads

InnoDB uses background threads to perform I/O for several kinds of activities, two of which are prefetching disk blocks and flushing dirty pages. Previously, InnoDB used only one thread each to perform these activities, but that can underutilize server capacity. MySQL 5.5 enables use of multiple background read and write threads, making it possible to read and write pages faster.

The patch makes the number of background I/O threads configurable using system variables: `innodb_read_io_threads` controls the number of threads to use for read prefetch requests. `innodb_write_io_threads` controls the number of threads to use for writing dirty pages from the buffer cache to disk. The default for both variables is 4.

The ability to increase the number of I/O threads can benefit systems that use multiple disks for InnoDB. However, the type of I/O being done should be considered. On systems that use buffered writes rather than direct writes, increasing the write thread count higher than 1 might yield little benefit because writes will be quick already.

Adjustable I/O Rate

Previously, the number of input/output operations per second (IOPS) that InnoDB will perform was a compile-time parameter. The rate was chosen to prevent background I/O from exhausting server capacity and the compiled-in value of 100 reflected an assumption that the server can perform 100 IOPS. However, many modern systems can exceed this, so the value is low and unnecessarily restricts I/O utilization.

MySQL 5.5 exposes this I/O rate parameter as a system variable, `innodb_io_capacity`. This variable can be set at server startup, which enables higher values to be selected for systems capable of higher I/O rates. Having a higher I/O rate can help the server handle a higher rate of row changes because it may be able to increase dirty-page flushing, deleted-row removal, and application of changes in the change buffer.
The default value of `innodb_io_capacity` is 200. In general, you can increase the value as a function of the number of drives used for InnoDB I/O.

The ability to raise the I/O limit should be especially beneficial on platforms that support many IOPS. For example, systems that use multiple disks or solid-state disks for InnoDB are likely to benefit from the ability to control this parameter.

### Diagnostic and Monitoring Capabilities

MySQL 5.5 provides improved access to execution and performance information. Diagnostic improvements include Performance Schema, Dtrace probes, expanded `SHOW ENGINE INNODB STATUS` output, Debug Sync, and a new status variable.

#### Performance Schema

Performance Schema is a feature for monitoring MySQL Server execution at a low level. See Chapter 22, *MySQL Performance Schema*.

#### DTrace Support

The DTrace probes work on Solaris, OS X, and FreeBSD. For information on using DTrace in MySQL, see Section 5.8, "Tracing mysqld Using DTrace".

#### Enhanced `SHOW ENGINE INNODB STATUS` Output

The output from `SHOW ENGINE INNODB STATUS` includes more information due to changes made for InnoDB Plugin. A description of revisions to statement output follows.

A new `BACKGROUND THREAD` section has `srv_master_thread` lines that show work done by the main background thread.

```
--------
BACKGROUND THREAD
--------
srv_master_thread loops: 53 1_second, 44 sleeps, 5 10_second, 7 background,
   7 flush
srv_master_thread log flush and writes: 48
```

The `SEMAPHORES` section includes a line to show the number of spinlock rounds per OS wait for a mutex.

```
--------
SEMAPHORES
--------
...  
Spin rounds per wait: 0.00 mutex, 20.00 RW-shared, 0.00 RW-excl
```

#### Debug Sync

The Debug Sync facility provides synchronization points for debugging, see MySQL Internals: Test Synchronization.

#### New Status Variable

The `Innodb_have_atomic_builtins` status variable provides information about availability of atomic instructions; see Scalability Improvements.

### Enhanced Solaris Support

MySQL 5.5 incorporates several modifications for improved operation of MySQL Server on Solaris:

- DTrace support for execution monitoring. See Diagnostic and Monitoring Capabilities.
• Atomic instructions, which are needed for the improvements to RW-locking described in Scalability Improvements. Atomic instructions now are supported for Sun Studio on SPARC and x86 platforms. This extends their previous availability (supported for gcc 4.1 and up on all platforms).

• The SMP improvements described in Scalability Improvements, were originally intended for x86 platforms. In MySQL 5.5, these also work on SPARC platforms. Also, Solaris optimizations have been implemented.

• Large page support is enhanced for recent SPARC platforms. Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature can be enabled or disabled by using the \texttt{--super-large-pages} or \texttt{--skip-super-large-pages} option.

• Inline handling for InnoDB and processor instruction prefetching support, previously not enabled for builds created using Sun Studio, now are supported for that build environment.

1.5 MySQL Information Sources

This section lists sources of additional information that you may find helpful, such as MySQL websites, mailing lists, user forums, and Internet Relay Chat.

1.5.1 MySQL Websites

The primary website for MySQL documentation is \url{https://dev.mysql.com/doc/}. Online and downloadable documentation formats are available for the MySQL Reference Manual, MySQL Connectors, and more.

The MySQL developers provide information about new and upcoming features as the MySQL Server Blog.

1.5.2 MySQL Community Support at the MySQL Forums

The forums at \url{http://forums.mysql.com} are an important community resource. Many forums are available, grouped into these general categories:

• Migration
• MySQL Usage
• MySQL Connectors
• Programming Languages
• Tools
• 3rd-Party Applications
• Storage Engines
• MySQL Technology
• SQL Standards
• Business

1.5.3 MySQL Enterprise

Oracle offers technical support in the form of MySQL Enterprise. For organizations that rely on the MySQL DBMS for business-critical production applications, MySQL Enterprise is a commercial subscription offering which includes:
How to Report Bugs or Problems

• MySQL Enterprise Server
• MySQL Enterprise Monitor
• Monthly Rapid Updates and Quarterly Service Packs
• MySQL Knowledge Base
• 24x7 Technical and Consultative Support

MySQL Enterprise is available in multiple tiers, giving you the flexibility to choose the level of service that best matches your needs. For more information, see MySQL Enterprise.

1.6 How to Report Bugs or Problems

Before posting a bug report about a problem, please try to verify that it is a bug and that it has not been reported already:

• Start by searching the MySQL online manual at https://dev.mysql.com/doc/. We try to keep the manual up to date by updating it frequently with solutions to newly found problems. In addition, the release notes accompanying the manual can be particularly useful since it is quite possible that a newer version contains a solution to your problem. The release notes are available at the location just given for the manual.

• If you get a parse error for an SQL statement, please check your syntax closely. If you cannot find something wrong with it, it is extremely likely that your current version of MySQL Server doesn't support the syntax you are using. If you are using the current version and the manual doesn't cover the syntax that you are using, MySQL Server doesn't support your statement.

If the manual covers the syntax you are using, but you have an older version of MySQL Server, you should check the MySQL change history to see when the syntax was implemented. In this case, you have the option of upgrading to a newer version of MySQL Server.

• For solutions to some common problems, see Section B.4, "Problems and Common Errors".

• Search the bugs database at http://bugs.mysql.com/ to see whether the bug has been reported and fixed.

• You can also use http://www.mysql.com/search/ to search all the Web pages (including the manual) that are located at the MySQL website.

If you cannot find an answer in the manual, the bugs database, or the mailing list archives, check with your local MySQL expert. If you still cannot find an answer to your question, please use the following guidelines for reporting the bug.

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports.

Bugs posted in the bugs database at http://bugs.mysql.com/ that are corrected for a given release are noted in the release notes.

If you find a security bug in MySQL Server, please let us know immediately by sending an email message to <secalert_us@oracle.com>. Exception: Support customers should report all problems, including security bugs, to Oracle Support at http://support.oracle.com/.

To discuss problems with other users, you can use the MySQL Community Slack.
How to Report Bugs or Problems

Writing a good bug report takes patience, but doing it right the first time saves time both for us and for yourself. A good bug report, containing a full test case for the bug, makes it very likely that we will fix the bug in the next release. This section helps you write your report correctly so that you do not waste your time doing things that may not help us much or at all. Please read this section carefully and make sure that all the information described here is included in your report.

Preferably, you should test the problem using the latest production or development version of MySQL Server before posting. Anyone should be able to repeat the bug by just using `mysql test < script_file` on your test case or by running the shell or Perl script that you include in the bug report. Any bug that we are able to repeat has a high chance of being fixed in the next MySQL release.

It is most helpful when a good description of the problem is included in the bug report. That is, give a good example of everything you did that led to the problem and describe, in exact detail, the problem itself. The best reports are those that include a full example showing how to reproduce the bug or problem. See Section 24.5, “Debugging and Porting MySQL”.

Remember that it is possible for us to respond to a report containing too much information, but not to one containing too little. People often omit facts because they think they know the cause of a problem and assume that some details do not matter. A good principle to follow is that if you are in doubt about stating something, state it. It is faster and less troublesome to write a couple more lines in your report than to wait longer for the answer if we must ask you to provide information that was missing from the initial report.

The most common errors made in bug reports are (a) not including the version number of the MySQL distribution that you use, and (b) not fully describing the platform on which the MySQL server is installed (including the platform type and version number). These are highly relevant pieces of information, and in 99 cases out of 100, the bug report is useless without them. Very often we get questions like, “Why doesn't this work for me?” Then we find that the feature requested wasn't implemented in that MySQL version, or that a bug described in a report has been fixed in newer MySQL versions. Errors often are platform-dependent. In such cases, it is next to impossible for us to fix anything without knowing the operating system and the version number of the platform.

If you compiled MySQL from source, remember also to provide information about your compiler if it is related to the problem. Most compilers are under development all the time and become better version by version. To determine whether your problem depends on your compiler, we need to know what compiler you used. Note that every compiling problem should be regarded as a bug and reported accordingly.

If a program produces an error message, it is very important to include the message in your report. If we try to search for something from the archives, it is better that the error message reported exactly matches the one that the program produces. (Even the lettercase should be observed.) It is best to copy and paste the entire error message into your report. You should never try to reproduce the message from memory.

If you have a problem with Connector/ODBC (MyODBC), please try to generate a trace file and send it with your report. See How to Report Connector/ODBC Problems or Bugs.

If your report includes long query output lines from test cases that you run with the `mysql` command-line tool, you can make the output more readable by using the `--vertical` option or the `\G` statement terminator. The `EXPLAIN SELECT` example later in this section demonstrates the use of `\G`.

Please include the following information in your report:

- The version number of the MySQL distribution you are using (for example, MySQL 5.7.10). You can find out which version you are running by executing `mysqladmin version`. The `mysqladmin` program can be found in the `bin` directory under your MySQL installation directory.
- The manufacturer and model of the machine on which you experience the problem.
How to Report Bugs or Problems

- The operating system name and version. If you work with Windows, you can usually get the name and version number by double-clicking your My Computer icon and pulling down the “Help/About Windows” menu. For most Unix-like operating systems, you can get this information by executing the command `uname -a`.

- Sometimes the amount of memory (real and virtual) is relevant. If in doubt, include these values.

- The contents of the `docs/INFO_BIN` file from your MySQL installation. This file contains information about how MySQL was configured and compiled.

- If you are using a source distribution of the MySQL software, include the name and version number of the compiler that you used. If you have a binary distribution, include the distribution name.

- If the problem occurs during compilation, include the exact error messages and also a few lines of context around the offending code in the file where the error occurs.

- If `mysqld` died, you should also report the statement that crashed `mysqld`. You can usually get this information by running `mysqld` with query logging enabled, and then looking in the log after `mysqld` crashes. See Section 24.5, “Debugging and Porting MySQL”.

- If a database table is related to the problem, include the output from the `SHOW CREATE TABLE db_name.tbl_name` statement in the bug report. This is a very easy way to get the definition of any table in a database. The information helps us create a situation matching the one that you have experienced.

- The SQL mode in effect when the problem occurred can be significant, so please report the value of the `sql_mode` system variable. For stored procedure, stored function, and trigger objects, the relevant `sql_mode` value is the one in effect when the object was created. For a stored procedure or function, the `SHOW CREATE PROCEDURE` or `SHOW CREATE FUNCTION` statement shows the relevant SQL mode, or you can query `INFORMATION_SCHEMA` for the information:

  ```sql
  SELECT ROUTINE_SCHEMA, ROUTINE_NAME, SQL_MODE
  FROM INFORMATION_SCHEMA.ROUTINES;
  ```

For triggers, you can use this statement:

  ```sql
  SELECT EVENT_OBJECT_SCHEMA, EVENT_OBJECT_TABLE, TRIGGER_NAME, SQL_MODE
  FROM INFORMATION_SCHEMA.TRIGGERS;
  ```

- For performance-related bugs or problems with `SELECT` statements, you should always include the output of `EXPLAIN SELECT ...`, and at least the number of rows that the `SELECT` statement produces. You should also include the output from `SHOW CREATE TABLE tbl_name` for each table that is involved. The more information you provide about your situation, the more likely it is that someone can help you.

The following is an example of a very good bug report. The statements are run using the `mysql` command-line tool. Note the use of the `\G` statement terminator for statements that would otherwise provide very long output lines that are difficult to read.

```sql
mysql> SHOW VARIABLES;
mysql> SHOW COLUMNS FROM ...\G
  <output from SHOW COLUMNS>
mysql> EXPLAIN SELECT ...\G
  <output from EXPLAIN>
mysql> FLUSH STATUS;
mysql> SELECT ...;
  <A short version of the output from SELECT, including the time taken to run the query>
mysql> SHOW STATUS;
  <output from SHOW STATUS>
```
How to Report Bugs or Problems

• If a bug or problem occurs while running `mysqld`, try to provide an input script that reproduces the anomaly. This script should include any necessary source files. The more closely the script can reproduce your situation, the better. If you can make a reproducible test case, you should upload it to be attached to the bug report.

If you cannot provide a script, you should at least include the output from `mysqladmin variables extended-status processlist` in your report to provide some information on how your system is performing.

• If you cannot produce a test case with only a few rows, or if the test table is too big to be included in the bug report (more than 10 rows), you should dump your tables using `mysqldump` and create a README file that describes your problem. Create a compressed archive of your files using `tar` and `gzip` or `zip`. After you initiate a bug report for our bugs database at `http://bugs.mysql.com/`, click the Files tab in the bug report for instructions on uploading the archive to the bugs database.

• If you believe that the MySQL server produces a strange result from a statement, include not only the result, but also your opinion of what the result should be, and an explanation describing the basis for your opinion.

• When you provide an example of the problem, it is better to use the table names, variable names, and so forth that exist in your actual situation than to come up with new names. The problem could be related to the name of a table or variable. These cases are rare, perhaps, but it is better to be safe than sorry. After all, it should be easier for you to provide an example that uses your actual situation, and it is by all means better for us. If you have data that you do not want to be visible to others in the bug report, you can upload it using the Files tab as previously described. If the information is really top secret and you do not want to show it even to us, go ahead and provide an example using other names, but please regard this as the last choice.

• Include all the options given to the relevant programs, if possible. For example, indicate the options that you use when you start the `mysqld` server, as well as the options that you use to run any MySQL client programs. The options to programs such as `mysqld` and `mysql`, and to the `configure` script, are often key to resolving problems and are very relevant. It is never a bad idea to include them. If your problem involves a program written in a language such as Perl or PHP, please include the language processor’s version number, as well as the version for any modules that the program uses. For example, if you have a Perl script that uses the `DBI` and `DBD::mysql` modules, include the version numbers for Perl, `DBI`, and `DBD::mysql`.

• If your question is related to the privilege system, please include the output of `mysqladmin reload`, and all the error messages you get when trying to connect. When you test your privileges, you should execute `mysqladmin reload version` and try to connect with the program that gives you trouble.

• If you have a patch for a bug, do include it. But do not assume that the patch is all we need, or that we can use it, if you do not provide some necessary information such as test cases showing the bug that your patch fixes. We might find problems with your patch or we might not understand it at all. If so, we cannot use it.

If we cannot verify the exact purpose of the patch, we will not use it. Test cases help us here. Show that the patch handles all the situations that may occur. If we find a borderline case (even a rare one) where the patch will not work, it may be useless.

• Guesses about what the bug is, why it occurs, or what it depends on are usually wrong. Even the MySQL team cannot guess such things without first using a debugger to determine the real cause of a bug.

• Indicate in your bug report that you have checked the reference manual and mail archive so that others know you have tried to solve the problem yourself.
MySQL Standards Compliance

• If your data appears corrupt or you get errors when you access a particular table, first check your tables with `CHECK TABLE`. If that statement reports any errors:

  • The InnoDB crash recovery mechanism handles cleanup when the server is restarted after being killed, so in typical operation there is no need to “repair” tables. If you encounter an error with InnoDB tables, restart the server and see whether the problem persists, or whether the error affected only cached data in memory. If data is corrupted on disk, consider restarting with the `innodb_force_recovery` option enabled so that you can dump the affected tables.

  • For non-transactional tables, try to repair them with `REPAIR TABLE` or with `myisamchk`. See Chapter 5, MySQL Server Administration.

If you are running Windows, please verify the value of `lower_case_table_names` using the `SHOW VARIABLES LIKE 'lower_case_table_names'` statement. This variable affects how the server handles lettercase of database and table names. Its effect for a given value should be as described in Section 9.2.3, “Identifier Case Sensitivity”.

• If you often get corrupted tables, you should try to find out when and why this happens. In this case, the error log in the MySQL data directory may contain some information about what happened. (This is the file with the `.err` suffix in the name.) See Section 5.4.2, “The Error Log”. Please include any relevant information from this file in your bug report. Normally `mysqld` should never crash a table if nothing killed it in the middle of an update. If you can find the cause of `mysqld` dying, it is much easier for us to provide you with a fix for the problem. See Section B.4.1, “How to Determine What Is Causing a Problem”.

• If possible, download and install the most recent version of MySQL Server and check whether it solves your problem. All versions of the MySQL software are thoroughly tested and should work without problems. We believe in making everything as backward-compatible as possible, and you should be able to switch MySQL versions without difficulty. See Section 2.1.1, “Which MySQL Version and Distribution to Install”.

1.7 MySQL Standards Compliance

This section describes how MySQL relates to the ANSI/ISO SQL standards. MySQL Server has many extensions to the SQL standard, and here you can find out what they are and how to use them. You can also find information about functionality missing from MySQL Server, and how to work around some of the differences.

The SQL standard has been evolving since 1986 and several versions exist. In this manual, “SQL-92” refers to the standard released in 1992. “SQL:1999”, “SQL:2003”, “SQL:2008”, and “SQL:2011” refer to the versions of the standard released in the corresponding years, with the last being the most recent version. We use the phrase “the SQL standard” or “standard SQL” to mean the current version of the SQL Standard at any time.

One of our main goals with the product is to continue to work toward compliance with the SQL standard, but without sacrificing speed or reliability. We are not afraid to add extensions to SQL or support for non-SQL features if this greatly increases the usability of MySQL Server for a large segment of our user base. The `HANDLER` interface is an example of this strategy. See Section 13.2.4, “HANDLER Statement”.

We continue to support transactional and nontransactional databases to satisfy both mission-critical 24/7 usage and heavy Web or logging usage.

MySQL Server was originally designed to work with medium-sized databases (10-100 million rows, or about 100MB per table) on small computer systems. Today MySQL Server handles terabyte-sized databases, but the code can also be compiled in a reduced version suitable for hand-held and embedded
devices. The compact design of the MySQL server makes development in both directions possible without any conflicts in the source tree.

We are not targeting real-time support, although MySQL replication capabilities offer significant functionality.

MySQL supports ODBC levels 0 to 3.51.

MySQL supports high-availability database clustering using the NDBCLUSTER storage engine. See Chapter 18, MySQL NDB Cluster 7.2.

We are implementing XML functionality beginning in MySQL 5.1, which supports most of the W3C XPath standard. See Section 12.11, “XML Functions”.

Selecting SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the sql_mode system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

For more information on setting the SQL mode, see Section 5.1.10, “Server SQL Modes”.

Running MySQL in ANSI Mode

To run MySQL Server in ANSI mode, start mysqld with the --ansi option. Running the server in ANSI mode is the same as starting it with the following options:

```
--transaction-isolation=SERIALIZABLE --sql-mode=ANSI
```

To achieve the same effect at runtime, execute these two statements:

```
SET GLOBAL TRANSACTION ISOLATION LEVEL SERIALIZABLE;
SET GLOBAL sql_mode = 'ANSI';
```

You can see that setting the sql_mode system variable to 'ANSI' enables all SQL mode options that are relevant for ANSI mode as follows:

```
mysql> SET GLOBAL sql_mode='ANSI';
mysql> SELECT @@GLOBAL.sql_mode;
-> 'REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ANSI'
```

Running the server in ANSI mode with --ansi is not quite the same as setting the SQL mode to 'ANSI' because the --ansi option also sets the transaction isolation level.

See Section 5.1.6, “Server Command Options”.

1.7.1 MySQL Extensions to Standard SQL

MySQL Server supports some extensions that you probably will not find in other SQL DBMSs. Be warned that if you use them, your code will not be portable to other SQL servers. In some cases, you can write code that includes MySQL extensions, but is still portable, by using comments of the following form:

```
MySQL Extensions to Standard SQL

/*! MySQL-specific code */

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the STRAIGHT_JOIN keyword in the following statement, but other servers will not:

```sql
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the ! character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The KEY_BLOCK_SIZE clause in the following comment is executed only by servers from MySQL 5.1.10 or higher:

```sql
CREATE TABLE t1(a INT, KEY (a)) /*!50110 KEY_BLOCK_SIZE=1024 */;
```

The following descriptions list MySQL extensions, organized by category.

- **Organization of data on disk**
  
  MySQL Server maps each database to a directory under the MySQL data directory, and maps tables within a database to file names in the database directory. This has a few implications:

  - Database and table names are case-sensitive in MySQL Server on operating systems that have case-sensitive file names (such as most Unix systems). See Section 9.2.3, “Identifier Case Sensitivity”.

  - You can use standard system commands to back up, rename, move, delete, and copy tables that are managed by the MyISAM storage engine. For example, it is possible to rename a MyISAM table by renaming the .MYD, .MYI, and .frm files to which the table corresponds. (Nevertheless, it is preferable to use RENAME TABLE or ALTER TABLE ... RENAME and let the server rename the files.)

- **General language syntax**

  - By default, strings can be enclosed by " as well as ". If the ANSI_QUOTES SQL mode is enabled, strings can be enclosed only by ' and the server interprets strings enclosed by " as identifiers.

  - \ is the escape character in strings.

  - In SQL statements, you can access tables from different databases with the `db_name.tbl_name` syntax. Some SQL servers provide the same functionality but call this User space. MySQL Server doesn't support tablespaces such as used in statements like this: CREATE TABLE ralph.my_table ... IN my_tablespace.

- **SQL statement syntax**

  - The ANALYZE TABLE, CHECK TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements.


  - The DO statement.

  - EXPLAIN SELECT to obtain a description of how tables are processed by the query optimizer.

  - The FLUSH and RESET statements.

  - The SET statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.
• The `SHOW` statement. See Section 13.7.5, “SHOW Statements”. The information produced by many of the MySQL-specific `SHOW` statements can be obtained in more standard fashion by using `SELECT` to query `INFORMATION_SCHEMA`. See Chapter 21, `INFORMATION_SCHEMA` Tables.

• Use of `LOAD DATA`. In many cases, this syntax is compatible with Oracle `LOAD DATA`. See Section 13.2.6, “LOAD DATA Statement”.

• Use of `RENAME TABLE`. See Section 13.1.32, “RENAME TABLE Statement”.

• Use of `REPLACE` instead of `DELETE` plus `INSERT`. See Section 13.2.8, “REPLACE Statement”.

• Use of `CHANGE col_name`, `DROP col_name`, or `DROP INDEX`, `IGNORE` or `RENAME` in `ALTER TABLE` statements. Use of multiple `ADD`, `ALTER`, `DROP`, or `CHANGE` clauses in an `ALTER TABLE` statement. See Section 13.1.7, “ALTER TABLE Statement”.

• Use of index names, indexes on a prefix of a column, and use of `INDEX` or `KEY` in `CREATE TABLE` statements. See Section 13.1.17, “CREATE TABLE Statement”.

• Use of `TEMPORARY` or `IF NOT EXISTS` with `CREATE TABLE`.

• Use of `IF EXISTS` with `DROP TABLE` and `DROP DATABASE`.

• The capability of dropping multiple tables with a single `DROP TABLE` statement.

• The `ORDER BY` and `LIMIT` clauses of the `UPDATE` and `DELETE` statements.

• `INSERT INTO tbl_name SET col_name = ...` syntax.

• The `DELAYED` clause of the `INSERT` and `REPLACE` statements.

• The `LOW_PRIORITY` clause of the `INSERT`, `REPLACE`, `DELETE`, and `UPDATE` statements.

• Use of `INTO OUTFILE` or `INTO DUMPFILE` in `SELECT` statements. See Section 13.2.9, “SELECT Statement”.

• Options such as `STRAIGHT_JOIN` or `SQL_SMALL_RESULT` in `SELECT` statements.

• You don't need to name all selected columns in the `GROUP BY` clause. This gives better performance for some very specific, but quite normal queries. See Section 12.17, “Aggregate (GROUP BY) Functions”.

• You can specify `ASC` and `DESC` with `GROUP BY`, not just with `ORDER BY`.

• The ability to set variables in a statement with the `:=` assignment operator. See Section 9.4, “User-Defined Variables”.

Data types

• The `MEDIUMINT`, `SET`, and `ENUM` data types, and the various `BLOB` and `TEXT` data types.

• The `AUTO_INCREMENT`, `BINARY`, `NULL`, `UNSIGNED`, and `ZEROFILL` data type attributes.

Functions and operators

• To make it easier for users who migrate from other SQL environments, MySQL Server supports aliases for many functions. For example, all string functions support both standard SQL syntax and ODBC syntax.
MySQL Differences from Standard SQL

- MySQL Server understands the `||` and `&&` operators to mean logical OR and AND, as in the C programming language. In MySQL Server, `||` and `OR` are synonyms, as are `&&` and `AND`. Because of this nice syntax, MySQL Server doesn't support the standard SQL `||` operator for string concatenation; use `CONCAT()` instead. Because `CONCAT()` takes any number of arguments, it is easy to convert use of the `||` operator to MySQL Server.

- Use of `COUNT(DISTINCT value_list)` where `value_list` has more than one element.

- Use of `COUNT(DISTINCT value_list)` where `value_list` has more than one element.

- The `%` operator is a synonym for `MOD()`. That is, `N % M` is equivalent to `MOD(N,M)`. `%` is supported for C programmers and for compatibility with PostgreSQL.

- The `=`, `<>`, `<=`, `>=`, `>`, `>=`, `AND`, `OR`, or `LIKE` operators may be used in expressions in the output column list (to the left of the `FROM`) in `SELECT` statements. For example:

```
mysql> SELECT col1=1 AND col2=2 FROM my_table;
```

- The `LIKE` is permitted on numeric values.

- The `REGEXP` and `NOT REGEXP` extended regular expression operators.

- `CONCAT()` or `CHAR()` with one argument or more than two arguments. (In MySQL Server, these functions can take a variable number of arguments.)

- The `BIT_COUNT()`, `CASE`, `ELT()`, `FROM_DAYS()`, `FORMAT()`, `IF()`, `PASSWORD()`, `ENCRYPT()`, `MD5()`, `ENCODE()`, `DECODE()`, `PERIOD_ADD()`, `PERIOD_DIFF()`, `TO_DAYS()`, and `WEEKDAY()` functions.

- Use of `TRIM()` to trim substrings. Standard SQL supports removal of single characters only.

- The `GROUP BY` functions `STD()`, `BIT_OR()`, `BIT_AND()`, `BIT_XOR()`, and `GROUP_CONCAT()`. See Section 12.17, “Aggregate (GROUP BY) Functions”.

1.7.2 MySQL Differences from Standard SQL

We try to make MySQL Server follow the ANSI SQL standard and the ODBC SQL standard, but MySQL Server performs operations differently in some cases:

- There are several differences between the MySQL and standard SQL privilege systems. For example, in MySQL, privileges for a table are not automatically revoked when you delete a table. You must explicitly issue a `REVOKE` statement to revoke privileges for a table. For more information, see Section 13.7.1.5, “REVOKE Statement”.

- The `CAST()` function does not support cast to `REAL` or `BIGINT`. See Section 12.10, “Cast Functions and Operators”.

1.7.2.1 SELECT INTO TABLE Differences
MySQL Server doesn't support the `SELECT ... INTO TABLE` Sybase SQL extension. Instead, MySQL Server supports the `INSERT INTO ... SELECT` standard SQL syntax, which is basically the same thing. See Section 13.2.5.1, “INSERT ... SELECT Statement”. For example:

```sql
INSERT INTO tbl_temp2 (fld_id)
SELECT tbl_temp1.fld_order_id
FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

Alternatively, you can use `SELECT ... INTO OUTFILE` or `CREATE TABLE ... SELECT`.

You can use `SELECT ... INTO` with user-defined variables. The same syntax can also be used inside stored routines using cursors and local variables. See Section 13.2.9.1, “SELECT ... INTO Statement”.

### 1.7.2.2 UPDATE Differences

If you access a column from the table to be updated in an expression, `UPDATE` uses the current value of the column. The second assignment in the following statement sets `col2` to the current (updated) `col1` value, not the original `col1` value. The result is that `col1` and `col2` have the same value. This behavior differs from standard SQL.

```sql
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

### 1.7.2.3 FOREIGN KEY Constraint Differences

The MySQL implementation of foreign key constraints differs from the SQL standard in the following key respects:

- If there are several rows in the parent table with the same referenced key value, `InnoDB` performs a foreign key check as if the other parent rows with the same key value do not exist. For example, if you define a `RESTRICT` type constraint, and there is a child row with several parent rows, `InnoDB` does not permit the deletion of any of the parent rows.

- If `ON UPDATE CASCADE` or `ON UPDATE SET NULL` recurses to update the same table it has previously updated during the same cascade, it acts like `RESTRICT`. This means that you cannot use self-referential `ON UPDATE CASCADE` or `ON UPDATE SET NULL` operations. This is to prevent infinite loops resulting from cascaded updates. A self-referential `ON DELETE SET NULL`, on the other hand, is possible, as is a self-referential `ON DELETE CASCADE`. Cascading operations may not be nested more than 15 levels deep.

- In an SQL statement that inserts, deletes, or updates many rows, foreign key constraints (like unique constraints) are checked row-by-row. When performing foreign key checks, `InnoDB` sets shared row-level locks on child or parent records that it must examine. MySQL checks foreign key constraints immediately; the check is not deferred to transaction commit. According to the SQL standard, the default behavior should be deferred checking. That is, constraints are only checked after the entire SQL statement has been processed. This means that it is not possible to delete a row that refers to itself using a foreign key.

- No storage engine, including `InnoDB`, recognizes or enforces the `MATCH` clause used in referential-integrity constraint definitions. Use of an explicit `MATCH` clause does not have the specified effect, and it causes `ON DELETE` and `ON UPDATE` clauses to be ignored. Specifying the `MATCH` should be avoided.

The `MATCH` clause in the SQL standard controls how `NULL` values in a composite (multiple-column) foreign key are handled when comparing to a primary key in the referenced table. MySQL essentially implements the semantics defined by `MATCH SIMPLE`, which permits a foreign key to be all or partially `NULL`. In that case, a (child table) row containing such a foreign key can be inserted even though it does not match any row in the referenced (parent) table. (It is possible to implement other semantics using triggers.)
How MySQL Deals with Constraints

- MySQL requires that the referenced columns be indexed for performance reasons. However, MySQL does not enforce a requirement that the referenced columns be **UNIQUE** or be declared **NOT NULL**.

  A **FOREIGN KEY** constraint that references a non-**UNIQUE** key is not standard SQL but rather an **InnoDB** extension.

  The handling of foreign key references to nonunique keys or keys that contain **NULL** values is not well defined for operations such as **UPDATE** or **DELETE CASCADE**. You are advised to use foreign keys that reference only **UNIQUE** (including **PRIMARY**) and **NOT NULL** keys.

- MySQL parses but ignores “inline **REFERENCES** specifications” (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts **REFERENCES** clauses only when specified as part of a separate **FOREIGN KEY** specification. For storage engines that do not support foreign keys (such as **MyISAM**), MySQL Server parses and ignores foreign key specifications.

For information about foreign key constraints, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

1.7.2.4 ‘--’ as the Start of a Comment

Standard SQL uses the C syntax /* this is a comment */ for comments, and MySQL Server supports this syntax as well. MySQL also support extensions to this syntax that enable MySQL-specific SQL to be embedded in the comment, as described in Section 9.6, “Comment Syntax”.

Standard SQL uses “--” as a start-comment sequence. MySQL Server uses # as the start comment character. MySQL Server also supports a variant of the -- comment style. That is, the -- start-comment sequence must be followed by a space (or by a control character such as a newline). The space is required to prevent problems with automatically generated SQL queries that use constructs such as the following, where we automatically insert the value of the payment for payment:

```sql
UPDATE account SET credit=credit-payment
```

Consider about what happens if payment has a negative value such as -1:

```sql
UPDATE account SET credit=credit--1
```

credit--1 is a valid expression in SQL, but -- is interpreted as the start of a comment, part of the expression is discarded. The result is a statement that has a completely different meaning than intended:

```sql
UPDATE account SET credit=credit
```

The statement produces no change in value at all. This illustrates that permitting comments to start with -- can have serious consequences.

Using our implementation requires a space following the -- for it to be recognized as a start-comment sequence in MySQL Server. Therefore, credit--1 is safe to use.

Another safe feature is that the mysql command-line client ignores lines that start with --.

1.7.3 How MySQL Deals with Constraints

MySQL enables you to work both with transactional tables that permit rollback and with nontransactional tables that do not. Because of this, constraint handling is a bit different in MySQL than in other DBMSs. We must handle the case when you have inserted or updated a lot of rows in a nontransactional table for which changes cannot be rolled back when an error occurs.

The basic philosophy is that MySQL Server tries to produce an error for anything that it can detect while parsing a statement to be executed, and tries to recover from any errors that occur while executing the statement. We do this in most cases, but not yet for all.
How MySQL Deals with Constraints

The options MySQL has when an error occurs are to stop the statement in the middle or to recover as well as possible from the problem and continue. By default, the server follows the latter course. This means, for example, that the server may coerce invalid values to the closest valid values.

Several SQL mode options are available to provide greater control over handling of bad data values and whether to continue statement execution or abort when errors occur. Using these options, you can configure MySQL Server to act in a more traditional fashion that is like other DBMSs that reject improper input. The SQL mode can be set globally at server startup to affect all clients. Individual clients can set the SQL mode at runtime, which enables each client to select the behavior most appropriate for its requirements. See Section 5.1.10, “Server SQL Modes”.

The following sections describe how MySQL Server handles different types of constraints.

1.7.3.1 PRIMARY KEY and UNIQUE Index Constraints

Normally, errors occur for data-change statements (such as \texttt{INSERT} or \texttt{UPDATE}) that would violate primary-key, unique-key, or foreign-key constraints. If you are using a transactional storage engine such as \texttt{InnoDB}, MySQL automatically rolls back the statement. If you are using a nontransactional storage engine, MySQL stops processing the statement at the row for which the error occurred and leaves any remaining rows unprocessed.

MySQL supports an \texttt{IGNORE} keyword for \texttt{INSERT}, \texttt{UPDATE}, and so forth. If you use it, MySQL ignores primary-key or unique-key violations and continues processing with the next row. See the section for the statement that you are using (Section 13.2.5, “INSERT Statement”, Section 13.2.11, “UPDATE Statement”, and so forth).

You can get information about the number of rows actually inserted or updated with the \texttt{mysql_info()} C API function. You can also use the \texttt{SHOW WARNINGS} statement. See Section 23.7.6.35, “mysql_info()”, and Section 13.7.5.41, “SHOW WARNINGS Statement”.

Only \texttt{InnoDB} tables support foreign keys. See Section 13.1.17.6, “FOREIGN KEY Constraints”.

1.7.3.2 FOREIGN KEY Constraints

Foreign keys let you cross-reference related data across tables, and foreign key constraints help keep this spread-out data consistent.

MySQL supports \texttt{ON UPDATE} and \texttt{ON DELETE} foreign key references in \texttt{CREATE TABLE} and \texttt{ALTER TABLE} statements. The available referential actions are \texttt{RESTRICT} (the default), \texttt{CASCADE}, \texttt{SET NULL}, and \texttt{NO ACTION}.

\texttt{SET DEFAULT} is also supported by the MySQL Server but is currently rejected as invalid by \texttt{InnoDB}. Since MySQL does not support deferred constraint checking, \texttt{NO ACTION} is treated as \texttt{RESTRICT}. For the exact syntax supported by MySQL for foreign keys, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

\texttt{MATCH FULL}, \texttt{MATCH PARTIAL}, and \texttt{MATCH SIMPLE} are allowed, but their use should be avoided, as they cause the MySQL Server to ignore any \texttt{ON DELETE} or \texttt{ON UPDATE} clause used in the same statement. \texttt{MATCH} options do not have any other effect in MySQL, which in effect enforces \texttt{MATCH SIMPLE} semantics full-time.

MySQL requires that foreign key columns be indexed; if you create a table with a foreign key constraint but no index on a given column, an index is created.

You can obtain information about foreign keys from the \texttt{INFORMATION_SCHEMA.KEY_COLUMN_USAGE} table. An example of a query against this table is shown here:
### How MySQL Deals with Constraints

#### 1.7.3.3 Constraints on Invalid Data

By default, MySQL is forgiving of invalid or improper data values and coerces them to valid values for data entry. However, you can enable strict SQL mode such that the server rejects invalid values and aborts the statement in which they occur. See Section 5.1.10, “Server SQL Modes”.

This section describes the default (forgiving) behavior of MySQL, as well as the strict SQL mode and how it differs.

If you are not using strict mode, then whenever you insert an “incorrect” value into a column, such as a `NULL` into a `NOT NULL` column or a too-large numeric value into a numeric column, MySQL sets the column to the “best possible value” instead of producing an error: The following rules describe in more detail how this works:

- If you try to store an out of range value into a numeric column, MySQL Server instead stores zero, the smallest possible value, or the largest possible value, whichever is closest to the invalid value.

- For strings, MySQL stores either the empty string or as much of the string as can be stored in the column.

- If you try to store a string that does not start with a number into a numeric column, MySQL Server stores 0.

- Invalid values for `ENUM` and `SET` columns are handled as described in Section 1.7.3.4, “ENUM and SET Constraints”.

- MySQL permits you to store certain incorrect date values into `DATE` and `DATETIME` columns (such as `'2000-02-31'` or `'2000-02-00'`). In this case, when an application has not enabled strict SQL mode, it up to the application to validate the dates before storing them. If MySQL can store a date value and retrieve exactly the same value, MySQL stores it as given. If the date is totally wrong (outside the server's ability to store it), the special “zero” date value `'0000-00-00'` is stored in the column instead.

- If you try to store `NULL` into a column that doesn't take `NULL` values, an error occurs for single-row `INSERT` statements. For multiple-row `INSERT` statements or for `INSERT INTO ... SELECT` statements, MySQL Server stores the implicit default value for the column data type. In general, this is 0 for numeric types, the empty string (`''`) for string types, and the “zero” value for date and time types. Implicit default values are discussed in Section 11.5, “Data Type Default Values”.

- If an `INSERT` statement specifies no value for a column, MySQL inserts its default value if the column definition includes an explicit `DEFAULT` clause. If the definition has no such `DEFAULT` clause, MySQL inserts the implicit default value for the column data type.

The reason for using the preceding rules when strict mode is not in effect is that we cannot check these conditions until the statement has begun executing. We cannot just roll back if we encounter a problem

Only InnoDB tables support foreign keys. See Section 13.1.17.6, “FOREIGN KEY Constraints”. InnoDB.
How MySQL Deals with Constraints

after updating a few rows, because the storage engine may not support rollback. The option of terminating
the statement is not that good; in this case, the update would be “half done,” which is probably the
worst possible scenario. In this case, it is better to “do the best you can” and then continue as if nothing
happened.

You can select stricter treatment of input values by using the `STRICT_TRANS_TABLES` or
`STRICT_ALL_TABLES` SQL modes:

```sql
SET sql_mode = 'STRICT_TRANS_TABLES';
SET sql_mode = 'STRICT_ALL_TABLES';
```

`STRICT_TRANS_TABLES` enables strict mode for transactional storage engines, and also to some extent
for nontransactional engines. It works like this:

- For transactional storage engines, bad data values occurring anywhere in a statement cause the
  statement to abort and roll back.
- For nontransactional storage engines, a statement aborts if the error occurs in the first row to be inserted
  or updated. (When the error occurs in the first row, the statement can be aborted to leave the table
  unchanged, just as for a transactional table.) Errors in rows after the first do not abort the statement,
  because the table has already been changed by the first row. Instead, bad data values are adjusted
  and result in warnings rather than errors. In other words, with `STRICT_TRANS_TABLES`, a wrong value
  causes MySQL to roll back all updates done so far, if that can be done without changing the table. But
  once the table has been changed, further errors result in adjustments and warnings.

For even stricter checking, enable `STRICT_ALL_TABLES`. This is the same as `STRICT_TRANS_TABLES`
except that for nontransactional storage engines, errors abort the statement even for bad data in rows
following the first row. This means that if an error occurs partway through a multiple-row insert or update
for a nontransactional table, a partial update results. Earlier rows are inserted or updated, but those from
the point of the error on are not. To avoid this for nontransactional tables, either use single-row statements
or else use `STRICT_TRANS_TABLES` if conversion warnings rather than errors are acceptable. To avoid
problems in the first place, do not use MySQL to check column content. It is safest (and often faster) to let
the application ensure that it passes only valid values to the database.

With either of the strict mode options, you can cause errors to be treated as warnings by using `INSERT IGNORE`
or `UPDATE IGNORE` rather than `INSERT` or `UPDATE` without `IGNORE`.

### 1.7.3.4 ENUM and SET Constraints

`ENUM` and `SET` columns provide an efficient way to define columns that can contain only a given set of
values. See Section 11.3.5, “The ENUM Type”, and Section 11.3.6, “The SET Type”.

With strict mode enabled (see Section 5.1.10, “Server SQL Modes”), the definition of a `ENUM` or `SET`
column acts as a constraint on values entered into the column. An error occurs for values that do not
satisfy these conditions:

- An `ENUM` value must be one of those listed in the column definition, or the internal numeric equivalent
  thereof. The value cannot be the error value (that is, 0 or the empty string). For a column defined as
  `ENUM('a','b','c')`, values such as `'`, `'d'`, or `'ax'` are invalid and are rejected.
- A `SET` value must be the empty string or a value consisting only of the values listed in the column
  definition separated by commas. For a column defined as `SET('a','b','c')`, values such as `'d'` or
  `'a,b,c,d'` are invalid and are rejected.

Errors for invalid values can be suppressed in strict mode if you use `INSERT IGNORE` or `UPDATE
IGNORE`. In this case, a warning is generated rather than an error. For `ENUM`, the value is inserted as the
error member (0). For SET, the value is inserted as given except that any invalid substrings are deleted. For example, 'a,x,b,y' results in a value of 'a,b'.

1.8 Credits

The following sections list developers, contributors, and supporters that have helped to make MySQL what it is today.

1.8.1 Contributors to MySQL

Although Oracle Corporation and/or its affiliates own all copyrights in the MySQL server and the MySQL manual, we wish to recognize those who have made contributions of one kind or another to the MySQL distribution. Contributors are listed here, in somewhat random order:

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  SCO-related questions.

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Documenters and translators

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  General questions.

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1.8.3 Packages that support MySQL

The following is a list of creators/maintainers of some of the most important API/packages/applications that a lot of people use with MySQL.

We cannot list every possible package here because the list would then be way to hard to maintain. For other packages, please refer to the software portal at http://solutions.mysql.com/software/.

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• Giovanni Maruzzelli <maruzz@matrice.it>
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• Xavier Leroy <Xavier.Leroy@inria.fr>
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• Dorothea Lütkehaus and Andreas Zeller
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• Compaq
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• SWSoft
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• FutureQuest
  The --skip-show-database option.
Chapter 2 Installing and Upgrading MySQL

Table of Contents

2.1 General Installation Guidance ................................................................................. 44
  2.1.1 Which MySQL Version and Distribution to Install ........................................ 44
  2.1.2 How to Get MySQL .......................................................................................... 45
  2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG ......................... 45
  2.1.4 Installation Layouts ........................................................................................... 59
  2.1.5 Compiler-Specific Build Characteristics .......................................................... 59
  2.2 Installing MySQL on Unix/Linux Using Generic Binaries ........................................ 59
  2.3 Installing MySQL on Microsoft Windows ............................................................... 62
    2.3.1 MySQL Installation Layout on Microsoft Windows ........................................ 65
    2.3.2 Choosing an Installation Package .................................................................... 66
    2.3.3 MySQL Installer for Windows .......................................................................... 67
    2.3.4 Installing MySQL on Microsoft Windows Using an MSI Package .................. 94
    2.3.5 MySQL Server Instance Configuration Wizard ............................................ 101
    2.3.6 Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive .......... 118
    2.3.7 Troubleshooting a Microsoft Windows MySQL Server Installation ................ 127
    2.3.8 Windows Postinstallation Procedures .............................................................. 128
    2.3.9 Windows Platform Restrictions ...................................................................... 130
  2.4 Installing MySQL on OS X ...................................................................................... 132
    2.4.1 General Notes on Installing MySQL on OS X ................................................ 132
    2.4.2 Installing MySQL on OS X Using Native Packages ..................................... 133
    2.4.3 Installing a MySQL Launch Daemon ............................................................... 138
    2.4.4 Installing and Using the MySQL Preference Pane .......................................... 141
  2.5 Installing MySQL on Linux ..................................................................................... 146
    2.5.1 Installing MySQL on Linux Using RPM Packages ......................................... 147
    2.5.2 Installing MySQL on Linux Using Debian Packages .................................... 152
    2.5.3 Deploying MySQL on Linux with Docker ....................................................... 153
    2.5.4 Installing MySQL on Linux Using Native Package Managers ...................... 159
  2.6 Installing MySQL Using Unbreakable Linux Network (ULN) ................................. 163
  2.7 Installing MySQL on Solaris ................................................................................... 163
    2.7.1 Installing MySQL on Solaris Using a Solaris PKG .......................................... 164
  2.8 Installing MySQL on FreeBSD ............................................................................... 165
  2.9 Installing MySQL from Source .............................................................................. 166
    2.9.1 Source Installation Methods .......................................................................... 166
    2.9.2 Source Installation Prerequisites .................................................................... 167
    2.9.3 MySQL Layout for Source Installation ............................................................ 168
    2.9.4 Installing MySQL Using a Standard Source Distribution .............................. 168
    2.9.5 Installing MySQL Using a Development Source Tree .................................. 173
    2.9.6 Configuring SSL Library Support ................................................................. 175
    2.9.7 MySQL Source-Configuration Options .......................................................... 175
    2.9.8 Dealing with Problems Compiling MySQL ....................................................... 188
    2.9.9 MySQL Configuration and Third-Party Tools ............................................... 189
  2.10 Postinstallation Setup and Testing ......................................................................... 190
    2.10.1 Initializing the Data Directory .................................................................... 190
    2.10.2 Starting the Server ....................................................................................... 194
    2.10.3 Testing the Server ......................................................................................... 197
    2.10.4 Securing the Initial MySQL Accounts ....................................................... 199
    2.10.5 Starting and Stopping MySQL Automatically ................................................. 203
  2.11 Upgrading MySQL ................................................................................................. 204
This chapter describes how to obtain and install MySQL. A summary of the procedure follows and later sections provide the details. If you plan to upgrade an existing version of MySQL to a newer version rather than install MySQL for the first time, see Section 2.11, “Upgrading MySQL”, for information about upgrade procedures and about issues that you should consider before upgrading.

If you are interested in migrating to MySQL from another database system, see Section A.8, “MySQL 5.5 FAQ: Migration”, which contains answers to some common questions concerning migration issues.

If you are migrating from MySQL Enterprise Edition to MySQL Community Server, see Section 2.12.5, “Downgrading from MySQL Enterprise Edition to MySQL Community Server”.

Installation of MySQL generally follows the steps outlined here:

1. **Determine whether MySQL runs and is supported on your platform.**

   Please note that not all platforms are equally suitable for running MySQL, and that not all platforms on which MySQL is known to run are officially supported by Oracle Corporation. For information about those platforms that are officially supported, see https://www.mysql.com/support/supportedplatforms/database.html on the MySQL website.

2. **Choose which distribution to install.**

   Several versions of MySQL are available, and most are available in several distribution formats. You can choose from pre-packaged distributions containing binary (precompiled) programs or source code. When in doubt, use a binary distribution. Oracle also provides access to the MySQL source code for those who want to see recent developments and test new code. To determine which version and type of distribution you should use, see Section 2.1.1, “Which MySQL Version and Distribution to Install”.

3. **Download the distribution that you want to install.**

   For instructions, see Section 2.1.2, “How to Get MySQL”. To verify the integrity of the distribution, use the instructions in Section 2.1.3, “Verifying Package Integrity Using MD5 Checksums or GnuPG”.

4. **Install the distribution.**
To install MySQL from a binary distribution, use the instructions in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

To install MySQL from a source distribution or from the current development source tree, use the instructions in Section 2.9, “Installing MySQL from Source”.

5. **Perform any necessary postinstallation setup.**

After installing MySQL, see Section 2.10, “Postinstallation Setup and Testing” for information about making sure the MySQL server is working properly. Also refer to the information provided in Section 2.10.4, “Securing the Initial MySQL Accounts”. This section describes how to secure the initial MySQL user accounts, *which have no passwords* until you assign passwords. The section applies whether you install MySQL using a binary or source distribution.

6. If you want to run the MySQL benchmark scripts, Perl support for MySQL must be available. See Section 2.13, “Perl Installation Notes”.

Instructions for installing MySQL on different platforms and environments is available on a platform by platform basis:

- **Unix, Linux, FreeBSD**

  For instructions on installing MySQL on most Linux and Unix platforms using a generic binary (for example, a `.tar.gz` package), see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

  For information on building MySQL entirely from the source code distributions or the source code repositories, see Section 2.9, “Installing MySQL from Source”.

  For specific platform help on installation, configuration, and building from source see the corresponding platform section:

  - Linux, including notes on distribution specific methods, see Section 2.5, “Installing MySQL on Linux”.
  - Solaris, including PKG and IPS formats, see Section 2.7, “Installing MySQL on Solaris”.
  - IBM AIX, see Section 2.7, “Installing MySQL on Solaris”.
  - FreeBSD, see Section 2.8, “Installing MySQL on FreeBSD”.

- **Microsoft Windows**

  For instructions on installing MySQL on Microsoft Windows, using either the MySQL Installer standalone MSI, or Zipped binary, see Section 2.3, “Installing MySQL on Microsoft Windows”.

  For information about managing MySQL instances, see MySQL Notifier Overview.

  For details and instructions on building MySQL from source code using Microsoft Visual Studio, see Section 2.9, “Installing MySQL from Source”.

- **macOS**

  For installation on macOS, including using both the binary package and native PKG formats, see Section 2.4, “Installing MySQL on OS X”.

  For information on making use of an macOS Launch Daemon to automatically start and stop MySQL, see Section 2.4.3, “Installing a MySQL Launch Daemon”.
For information on the MySQL Preference Pane, see Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

2.1 General Installation Guidance

The immediately following sections contain the information necessary to choose, download, and verify your distribution. The instructions in later sections of the chapter describe how to install the distribution that you choose. For binary distributions, see the instructions at Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries” or the corresponding section for your platform if available. To build MySQL from source, use the instructions in Section 2.9, “Installing MySQL from Source”.

2.1.1 Which MySQL Version and Distribution to Install

MySQL is available on a number of operating systems and platforms. For information about those platforms that are officially supported, see https://www.mysql.com/support/supportedplatforms/database.html on the MySQL website.

When preparing to install MySQL, decide which version and distribution format (binary or source) to use.

First, decide whether to install a development release or a General Availability (GA) release. Development releases have the newest features, but are not recommended for production use. GA releases, also called production or stable releases, are meant for production use. We recommend using the most recent GA release.

The naming scheme in MySQL 5.5 uses release names that consist of three numbers and an optional suffix; for example, mysql-5.5.1-m2. The numbers within the release name are interpreted as follows:

- The first number (5) is the major version number.
- The second number (5) is the minor version number. Taken together, the major and minor numbers constitute the release series number. The series number describes the stable feature set.
- The third number (1) is the version number within the release series. This is incremented for each new bugfix release. In most cases, the most recent version within a series is the best choice.

Release names can also include a suffix to indicate the stability level of the release. Releases within a series progress through a set of suffixes to indicate how the stability level improves. The possible suffixes are:

- mN (for example, m1, m2, m3, ...) indicates a milestone number. MySQL development uses a milestone model, in which each milestone introduces a small subset of thoroughly tested features. Following the releases for one milestone, development proceeds with another small number of releases that focuses on the next set of features. From one milestone to the next, feature interfaces may change or features may even be removed, based on feedback provided by community members who try these early releases. Features within milestone releases may be considered to be of pre-production quality.

- rc indicates a Release Candidate (RC). Release candidates are believed to be stable, having passed all of MySQL’s internal testing. New features may still be introduced in RC releases, but the focus shifts to fixing bugs to stabilize features introduced earlier within the series.

- Absence of a suffix indicates a General Availability (GA) or Production release. GA releases are stable, having successfully passed through the earlier release stages, and are believed to be reliable, free of serious bugs, and suitable for use in production systems.

Development within a series begins with milestone releases, followed by RC releases, and finally reaches GA status releases.
After choosing which MySQL version to install, decide which distribution format to install for your operating system. For most use cases, a binary distribution is the right choice. Binary distributions are available in native format for many platforms, such as RPM packages for Linux or DMG packages for macOS. Distributions are also available in more generic formats such as Zip archives or compressed tar files. On Windows, you can use the MySQL Installer to install a binary distribution.

Under some circumstances, it may be preferable to install MySQL from a source distribution:

• You want to install MySQL at some explicit location. The standard binary distributions are ready to run at any installation location, but you might require even more flexibility to place MySQL components where you want.

• You want to configure mysqld with features that might not be included in the standard binary distributions. Here is a list of the most common extra options used to ensure feature availability:
  
  • –DWITH_LIBWRAP=1 for TCP wrappers support.
  
  • –DWITH_ZLIB={system|bundled} for features that depend on compression
  
  • –DWITH_DEBUG=1 for debugging support

  For additional information, see Section 2.9.7, “MySQL Source-Configuration Options”.

• You want to configure mysqld without some features that are included in the standard binary distributions. For example, distributions normally are compiled with support for all character sets. If you want a smaller MySQL server, you can recompile it with support for only the character sets you need.

• You want to read or modify the C and C++ code that makes up MySQL. For this purpose, obtain a source distribution.

• Source distributions contain more tests and examples than binary distributions.

### 2.1.2 How to Get MySQL

Check our downloads page at [https://dev.mysql.com/downloads/](https://dev.mysql.com/downloads/) for information about the current version of MySQL and for downloading instructions. For a complete up-to-date list of MySQL download mirror sites, see [https://dev.mysql.com/downloads/mirrors.html](https://dev.mysql.com/downloads/mirrors.html). You can also find information there about becoming a MySQL mirror site and how to report a bad or out-of-date mirror.

To obtain the latest development source, see Section 2.9.5, “Installing MySQL Using a Development Source Tree”.

### 2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG

After downloading the MySQL package that suits your needs and before attempting to install it, make sure that it is intact and has not been tampered with. There are three means of integrity checking:

• MD5 checksums

• Cryptographic signatures using GnuPG, the GNU Privacy Guard

• For RPM packages, the built-in RPM integrity verification mechanism

The following sections describe how to use these methods.

If you notice that the MD5 checksum or GPG signatures do not match, first try to download the respective package one more time, perhaps from another mirror site.
2.1.3.1 Verifying the MD5 Checksum

After you have downloaded a MySQL package, you should make sure that its MD5 checksum matches the one provided on the MySQL download pages. Each package has an individual checksum that you can verify against the package that you downloaded. The correct MD5 checksum is listed on the downloads page for each MySQL product, and you will compare it against the MD5 checksum of the file (product) that you download.

Each operating system and setup offers its own version of tools for checking the MD5 checksum. Typically the command is named `md5sum`, or it may be named `md5`, and some operating systems do not ship it at all. On Linux, it is part of the GNU Text Utilities package, which is available for a wide range of platforms. You can also download the source code from http://www.gnu.org/software/textutils/. If you have OpenSSL installed, you can use the command `openssl md5 package_name` instead. A Windows implementation of the `md5` command line utility is available from http://www.fourmilab.ch/md5/. `winMd5Sum` is a graphical MD5 checking tool that can be obtained from http://www.nullriver.com/index/products/winmd5sum. Our Microsoft Windows examples will assume the name `md5.exe`.

Linux and Microsoft Windows examples:

```
shell> md5sum mysql-standard-5.5.62-linux-i686.tar.gz
aaab65abbec64d5e907dcd41b8699945  mysql-standard-5.5.62-linux-i686.tar.gz
shell> md5.exe mysql-installer-community-5.5.62.msi
aaab65abbec64d5e907dcd41b8699945  mysql-installer-community-5.5.62.msi
```

You should verify that the resulting checksum (the string of hexadecimal digits) matches the one displayed on the download page immediately below the respective package.

**Note**

Make sure to verify the checksum of the *archive file* (for example, the `.zip`, `.tar.gz`, or `.msi` file) and not of the files that are contained inside of the archive. In other words, verify the file before extracting its contents.

2.1.3.2 Signature Checking Using GnuPG

Another method of verifying the integrity and authenticity of a package is to use cryptographic signatures. This is more reliable than using MD5 checksums, but requires more work.

We sign MySQL downloadable packages with GnuPG (GNU Privacy Guard). GnuPG is an Open Source alternative to the well-known Pretty Good Privacy (PGP) by Phil Zimmermann. Most Linux distributions ship with GnuPG installed by default. Otherwise, see http://www.gnupg.org/ for more information about GnuPG and how to obtain and install it.

To verify the signature for a specific package, you first need to obtain a copy of our public GPG build key, which you can download from http://ppg.mit.edu/. The key that you want to obtain is named `mysql-build@oss.oracle.com`. Alternatively, you can copy and paste the key directly from the following text:

```
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1

mQGiBD4+owwRBAC14GifuFycEDS1ePvEW3SAFUDjBtoqQQH/nJKZyQt7h9bPLUWC3
ROD1QReycITrrdwyKUGku2FemeVGwVnu2u2WdMqABLnnprWPkBdck96+OmSN9bZ
f2w2vUqGcmYV2hW0HyDHvUQYQA/ThQaDgj8A8W/0Lo7V1W9/8VuHPgQwOqCvZvV3
BuOxRznmCReXaAUuVYHtHCeAJooQK1L1slunZMYD1WufefXshc575/+yeJkegWN
hxwR9pRWVAnsNIJjEJRT+tff2ZOE3vpquQXQ/hnEUHJ2qQylo8tgzvxXNCc3FJYLV
KZKtKzFePF72wswEMXHhr0eKBTlGfRJ1skJ36aBgcAcLY/9bKkMPw96rZ7IYtZe
kYpxXBAcWmp88N7TkmEnPcia22oOHQDAWpUpk43I7j3DmgtohX9qmrXWw+uNDI
QJEXM5F8b0L0LLzc1N1YsaflAPEOMDMPqxAkA6k1y1sNtPvAlD8l18DbnPmWqYcefe
pvr0saxqgUcMCO3o7wqgN83POkDasb3pjqwhxvhz6/62zQ7Q2TX1UUwUgmVs
ZWFlZSBFBmpdbmVlcmuZyA8bBlXlcWtYnVpGRAb3NzLm9yYWNsZS5jb20+iGwE

```

46
Verifying Package Integrity Using MD5 Checksums or GnuPG
Verifying Package Integrity Using MD5 Checksums or GnuPG

q1+UOhnxHvZs1l+LJ059Xcd9c5BvYfahmYvG5eRs3pjl/Y+3a6wyhvY+jtNCaK Lopezd1hMGh/gzhbV9wXzmE0u8yloc2j1sPt1qoK+aSe32jw63coxVBIngku+6C+qDAOnMbL2wVhXKyFQ+7r7+bq1hj3W7lolqj0cMq3ASIEEACAAWfak/F6p8U8qAwASdQAAGCkqCm48pxRwX4vqTF/dhbn2uhB8G8LXWvYqQ3v0/QvKlhF1ZJ9MqPCaA0aAs0jhtcCNC6yBXbY/Tvm9Nd/NK6Hw0diPomrZJVFk2ygWfuItuL115sp73m25ymo1sCp5q73i1n3RQ8unjdJr9yO5FLbNmgCUA0
4E8d68BmVCCqCM5Mo1091FVkwSNshyfo77YVN5/BASj8dhynNBYQErqToOJZ6CndJhnjTf1bRfzqyyAQ3XegHbYtehEYclh7FMWFWYHNhtsnaVhYBnNzA8s81F9jd
MheAOvQQU+4z10qRvXRtLcr/ix1c+P4cm/TQqkgd6wpqkx16okB1QQQTAIAUcTX+NkIAUDABJA1AAAKCCKELhlyt FFBCBCAC+O7UdijNoqoxG1k1Y6Y9cNCL8pw+PNKW/14V7Q2DwDoRon3yogyhz4x1e0WIL1rvk6006drsIDjymhiRSmXzb/E/8pYmEuj9vth3b/FTChmSA07dJ5RK5D3da1v81sbdUqDqTxd8XZ0xRXC M22C/Ypg70uGA5aevi+l1y1sm5p4kmwVEApPzcnENMPFgph8mah9X2+J/btDBYr6lg9apkfYj1n7igtNNTn/td0MLu4a1aZecdyCvHY01NHb40/gkJa5s4FMBJg9ptc m0k04yKd1/KJXMW0DnmwUSkAfshKJ3Y30cIgm1x6tqYUTndrF4161qr1friQ1R1BBB AgMaQMBJP9T1lVBOQeA0uEUNbJeQcJuKV6B189jWIA11ld95M6EHF6PKXre1541e papsilMU/1G0T+92zCnxmFl8oz2qEoMmb3/Eik/1EZuaeBSoomCS8c2gwSFXwRl+AW Rk/pG5xSah5wSnm2FjlororrjXvqH427PLRQk9yxdw4G+9HTBoxoq82ZT9pYk A/jZzAAdyMqysrgRnoQVQWrlgs0o+jcCfQFGHq3f1aUyjvUFUomp17afofDzIM GaoSUTCXbqZcI1vfh/v1EbcU1KrvlaeeDFy7v+nH2zNKoARCLw/v+/8uB121Bz23 ip5x2tB3xuU2Q0AD0AqcLmdob14xk6bxvCtssFaLAvWWQ2m670Rj1UeWMBEBKJ A5SIEEACAEAWA1AGYVMA3wFAw4SdCAQ中华民族w1Xv9Aw5e1y6gunkiW0lVw uMnUuUs+1/42GCB+YFIPvTtccfg1JY5GamaSgp1g5z4r0Buocr1bdgjdGhtpkyK xdl1+62qMNYWHRg2P0UXVCzne12houwP0lifcmTWkAUK76TEvLSSTvL1hWqU2R yEUZ3U0TGVsuEPErjr3q603PfeFwf+NaGtye4jioLA3yawyt2ZCuZXVnnl 90K4+yraq5tlemQe6miC/kQN4usnFC PBgrjHdlExeKD1AMTcogMN4Eq7sRT yGtYtT531NYdehDnpqG0lPHuACOCH+S6lWyMbGmcbF6dV+r8drIj63M2BP/pcmjsYUF oPdTkIBtTNqQAIAUADADBgtQAUDABJA1AAAKCCKELhlyt f0mACJ1q2l1eg dB8mITIItsfqSmM3wzCvJFvEAtaY3fTK9N1uj0B3XUPOUEi3eT1eqW/50ZrQ1StF 58vHnLWb2ZrYpou202MA3plp3ucrgtrV648BrlCmWq40WMyj1NfV70atgJ ATYfQxNgwEwfCbcX0LZTLMtDcmrzcZ9NtpVgzDzxoqMGccCI2K4vq9FkCDUuApHx psq3dfG/dv0ihTcKKgCQzXN1+nqGn67peaq3Z3XWdUxFLULs3U0vDFr/1cu+u r12znd2wzr3FmVQZEV/colJg3ZJYtvAvu386/3l8+IY6y1sn/0Wv10v

Verifying Package Integrity Using MD5 Checksums or GnuPG
Verifying Package Integrity Using MD5 Checksums or GnuPG

To import the build key into your personal public GPG keyring, use `gpg --import`. For example, if you have saved the key in a file named `mysql_pubkey.asc`, the import command looks like this:

```
shell> gpg --import mysql_pubkey.asc
```

You can also download the key from the public keyservers using the public key id, `5072E1F5`:

```
shell> gpg --recv-keys 5072E1F5
```

If you want to import the key into your RPM configuration to validate RPM install packages, you should be able to import the key directly:

```
shell> rpm --import mysql_pubkey.asc
```

If you experience problems or require RPM specific information, see Section 2.1.3.4, “Signature Checking Using RPM”.

After you have downloaded and imported the public build key, download your desired MySQL package and the corresponding signature, which is also available from the download page. The signature file has the same name as the distribution file with an `.asc` extension, as shown by the examples in the following table.

### Table 2.1 MySQL Package and Signature Files for Source files

<table>
<thead>
<tr>
<th>File Type</th>
<th>File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution file</td>
<td><code>mysql-standard-5.62-linux-i686.tar.gz</code></td>
</tr>
<tr>
<td>Signature file</td>
<td><code>mysql-standard-5.62-linux-i686.tar.gz.asc</code></td>
</tr>
</tbody>
</table>

Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file:
Verifying Package Integrity Using MD5 Checksums or GnuPG

```
shell> gpg --verify package_name.asc
```

If the downloaded package is valid, you will see a "Good signature" similar to:

```
shell> gpg --verify mysql-standard-5.5.62-linux-i686.tar.gz.asc
```

```
gpg: Signature made Tue 01 Feb 2011 02:38:30 AM CST using DSA key ID 5072E1F5
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
```

The **Good signature** message indicates that the file signature is valid, when compared to the signature listed on our site. But you might also see warnings, like so:

```
shell> gpg --verify mysql-standard-5.5.62-linux-i686.tar.gz.asc
```

```
gpg: Signature made Wed 23 Jan 2013 02:25:45 AM PST using DSA key ID 5072E1F5
gpg: checking the trustdb
```

```
gpg: no ultimately trusted keys found
```

```
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
gpg: WARNING: This key is not certified with a trusted signature!
gpg: Primary key fingerprint: A4A9 4068 76FC BD3C 4567 70C8 8C71 8D3B 5072 E1F5
```

That is normal, as they depend on your setup and configuration. Here are explanations for these warnings:

- **gpg: no ultimately trusted keys found**: This means that the specific key is not "ultimately trusted" by you or your web of trust, which is okay for the purposes of verifying file signatures.

- **WARNING: This key is not certified with a trusted signature! There is no indication that the signature belongs to the owner.** This refers to your level of trust in your belief that you possess our real public key. This is a personal decision. Ideally, a MySQL developer would hand you the key in person, but more commonly, you downloaded it. Was the download tampered with? Probably not, but this decision is up to you. Setting up a web of trust is one method for trusting them.

See the GPG documentation for more information on how to work with public keys.

### 2.1.3.3 Signature Checking Using Gpg4win for Windows

The Section 2.1.3.2, "Signature Checking Using GnuPG" section describes how to verify MySQL downloads using GPG. That guide also applies to Microsoft Windows, but another option is to use a GUI tool like Gpg4win. You may use a different tool but our examples are based on Gpg4win, and utilize its bundled Kleopatra GUI.

Download and install Gpg4win, and then load Kleopatra. The dialog should look similar to:
Next, add the MySQL Release Engineering certificate. Do this by clicking File, Lookup Certificates on Server. Type “Mysql Release Engineering” into the search box and press Search.

Select the "MySQL Release Engineering" certificate. The Fingerprint and Key-ID must be "5072E1F5", or choose Details... to confirm the certificate is valid. Now, import it by clicking Import. An import dialog will be displayed, choose Okay, and this certificate will now be listed under the Imported Certificates tab.

Next, configure the trust level for our certificate. Select our certificate, then from the main menu select Certificates, Change Owner Trust... We suggest choosing I believe checks are very accurate for our certificate, as otherwise you might not be able to verify our signature. Select I believe checks are very accurate to enable “full trust” and then press OK.
Next, verify the downloaded MySQL package file. This requires files for both the packaged file, and the signature. The signature file must have the same name as the packaged file but with an appended `.asc` extension, as shown by the example in the following table. The signature is linked to on the downloads page for each MySQL product. You must create the `.asc` file with this signature.

Table 2.2 MySQL Package and Signature Files for MySQL Installer for Microsoft Windows

<table>
<thead>
<tr>
<th>File Type</th>
<th>File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution file</td>
<td>mysql-installer-community-5.5.62.msi</td>
</tr>
<tr>
<td>Signature file</td>
<td>mysql-installer-community-5.5.62.msi.asc</td>
</tr>
</tbody>
</table>

Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file. Either drag and drop the signature (`.asc`) file into Kleopatra, or load the dialog from **File, Decrypt/Verify Files...**, and then choose either the `.msi` or `.asc` file.
Click **Decrypt/Verify** to check the file. The two most common results will look like the following, and although the yellow warning looks problematic, the following means that the file check passed with success. You may now run this installer.

Seeing a red "The signature is bad" error means the file is invalid. Do not execute the MSI file if you see this error.
Verifying Package Integrity Using MD5 Checksums or GnuPG

Figure 2.6 Kleopatra: the Decrypt and Verify Results Dialog: Bad

The Section 2.1.3.2, “Signature Checking Using GnuPG” section explains why you probably don't see a green Good signature result.

2.1.3.4 Signature Checking Using RPM

For RPM packages, there is no separate signature. RPM packages have a built-in GPG signature and MD5 checksum. You can verify a package by running the following command:

```
shell> rpm --checksig package_name.rpm
```

Example:

```
shell> rpm --checksig MySQL-server-5.5.62-0.glibc23.i386.rpm
MySQL-server-5.5.62-0.glibc23.i386.rpm: md5 gpg OK
```

Note

If you are using RPM 4.1 and it complains about (GPG) NOT OK (MISSING KEYS: GPG#5072e1f5), even though you have imported the MySQL public build key into your own GPG keyring, you need to import the key into the RPM keyring first. RPM 4.1 no longer uses your personal GPG keyring (or GPG itself). Rather, RPM maintains a separate keyring because it is a system-wide application and a user's GPG public keyring is a user-specific file. To import the MySQL public key into the RPM keyring, first obtain the key, then use rpm --import to import the key. For example:

```
shell> gpg --export -a 5072e1f5 > 5072e1f5.asc
shell> rpm --import 5072e1f5.asc
```
Alternatively, rpm also supports loading the key directly from a URL, and you can use this manual page:

```shell
```

If you need to obtain the MySQL public key, see Section 2.1.3.2, “Signature Checking Using GnuPG”.

## 2.1.4 Installation Layouts

The installation layout differs for different installation types (for example, native packages, binary tarballs, and source tarballs), which can lead to confusion when managing different systems or using different installation sources. The individual layouts are given in the corresponding installation type or platform chapter, as described following. Note that the layout of installations from vendors other than Oracle may differ from these layouts.

- Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”
- Section 2.9.3, “MySQL Layout for Source Installation”
- Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”
- Table 2.12, “MySQL Installation Layout for Linux RPM Packages”
- Table 2.11, “MySQL Installation Layout on OS X”

## 2.1.5 Compiler-Specific Build Characteristics

In some cases, the compiler used to build MySQL affects the features available for use. The notes in this section apply for binary distributions provided by Oracle Corporation or that you compile yourself from source.

### icc (Intel C++ Compiler) Builds

A server built with icc has these characteristics:

- SSL support is not included.

## 2.2 Installing MySQL on Unix/Linux Using Generic Binaries

Oracle provides a set of binary distributions of MySQL. These include generic binary distributions in the form of compressed tar files (files with a .tar.gz extension) for a number of platforms, and binaries in platform-specific package formats for selected platforms.

This section covers the installation of MySQL from a compressed tar file binary distribution. For other platform-specific package formats, see the other platform-specific sections. For example, for Windows distributions, see Section 2.3, “Installing MySQL on Microsoft Windows”.

To obtain MySQL, see Section 2.1.2, “How to Get MySQL”.

MySQL compressed tar file binary distributions have names of the form `mysql-VERSION-OS.tar.gz`, where `VERSION` is a number (for example, 5.5.62), and `OS` indicates the type of operating system for which the distribution is intended (for example, `pc-linux-i686` or `winx64`).

### Warnings

- If you have previously installed MySQL using your operating system native package management system, such as Yum or APT, you may experience
problems installing using a native binary. Make sure your previous MySQL installation has been removed entirely (using your package management system), and that any additional files, such as old versions of your data files, have also been removed. You should also check for configuration files such as /etc/my.cnf or the /etc/mysql directory and delete them.

- MySQL has a dependency on the libaio library. Data directory initialization and subsequent server startup steps will fail if this library is not installed locally. If necessary, install it using the appropriate package manager. For example, on Yum-based systems:

```shell
shell> yum search libaio  # search for info
shell> yum install libaio  # install library
```

Or, on APT-based systems:

```shell
shell> apt-cache search libaio  # search for info
shell> apt-get install libaio1  # install library
```

- SLES 11: As of MySQL 5.5.57, the Linux Generic tarball package format is EL6 instead of EL5. As a side effect, the MySQL client bin/mysql needs libtinfo.so.5.

A workaround is to create a symlink, such as `ln -s libncurses.so.5.6 /lib64/libtinfo.so.5` on 64-bit systems or `ln -s libncurses.so.5.6 /lib/libtinfo.so.5` on 32-bit systems.

To install a compressed tar file binary distribution, unpack it at the installation location you choose (typically /usr/local/mysql). This creates the directories shown in the following table.

### Table 2.3 MySQL Installation Layout for Generic Unix/Linux Binary Package

<table>
<thead>
<tr>
<th>Directory</th>
<th>Contents of Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>bin, scripts</td>
<td>mysqlld server, client and utility programs</td>
</tr>
<tr>
<td>data</td>
<td>Log files, databases</td>
</tr>
<tr>
<td>docs</td>
<td>MySQL manual in Info format</td>
</tr>
<tr>
<td>man</td>
<td>Unix manual pages</td>
</tr>
<tr>
<td>include</td>
<td>Include (header) files</td>
</tr>
<tr>
<td>lib</td>
<td>Libraries</td>
</tr>
<tr>
<td>share</td>
<td>Miscellaneous support files, including error messages, sample configuration files, SQL for database installation</td>
</tr>
<tr>
<td>sql-bench</td>
<td>Benchmarks</td>
</tr>
</tbody>
</table>

Debug versions of the mysqlld binary are available as mysqlld-debug. To compile your own debug version of MySQL from a source distribution, use the appropriate configuration options to enable debugging support. See Section 2.9, “Installing MySQL from Source”.

To install and use a MySQL binary distribution, the command sequence looks like this:

```shell
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
shell> cd /usr/local
shell> tar zxf /path/to/mysql-VERSION-OS.tar.gz
shell> ln -s full-path-to-mysql-VERSION-OS mysql
shell> cd mysql
```
### Create a mysql User and Group

If your system does not already have a user and group to use for running `mysqld`, you may need to create them. The following commands add the `mysql` group and the `mysql` user. You might want to call the user and group something else instead of `mysql`. If so, substitute the appropriate name in the following instructions. The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix/Linux, or they may have different names such as `adduser` and `addgroup`.

```shell
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
```

**Note**

Because the user is required only for ownership purposes, not login purposes, the `useradd` command uses the `-r` and `-s /bin/false` options to create a user that does not have login permissions to your server host. Omit these options if your `useradd` does not support them.

### Obtain and Unpack the Distribution

Pick the directory under which you want to unpack the distribution and change location into it. The example here unpacks the distribution under `/usr/local`. The instructions, therefore, assume that you have permission to create files and directories in `/usr/local`. If that directory is protected, you must perform the installation as root.

```shell
shell> cd /usr/local
```

Obtain a distribution file using the instructions in Section 2.1.2, “How to Get MySQL”. For a given release, binary distributions for all platforms are built from the same MySQL source distribution.

Unpack the distribution, which creates the installation directory. Then create a symbolic link to that directory. `tar` can uncompress and unpack the distribution if it has `z` option support:

```shell
shell> tar zxfv /path/to/mysql-VERSION-OS.tar.gz
shell> ln -s full-path-to-mysql-VERSION-OS mysql
```
Perform Postinstallation Setup

The `tar` command creates a directory named `mysql-VERSION-OS`. The `ln` command makes a symbolic link to that directory. This enables you to refer more easily to the installation directory as `/usr/local/mysql`.

To install MySQL from a compressed `tar` file binary distribution, your system must have GNU `gunzip` to uncompress the distribution and a reasonable `tar` to unpack it. If your `tar` program supports the `z` option, it can both uncompress and unpack the file.

GNU `tar` is known to work. The standard `tar` provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU `tar`, or if available, use a preinstalled version of GNU `tar`. Usually this is available as `gnutar`, `gtar`, or as `tar` within a GNU or Free Software directory, such as `/usr/sfw/bin` or `/usr/local/bin`. GNU `tar` is available from http://www.gnu.org/software/tar/.

If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it. Replace the preceding `tar` command with the following alternative command to uncompress and extract the distribution:

```
shell> gunzip < /path/to/mysql-VERSION-OS.tar.gz | tar xvf -
```

Perform Postinstallation Setup

The remainder of the installation process involves setting distribution ownership and access permissions, initializing the data directory, starting the MySQL server, and setting up the configuration file. For instructions, see Section 2.10, “Postinstallation Setup and Testing”.

2.3 Installing MySQL on Microsoft Windows

**Important**

MySQL Community 5.5 Server requires the Microsoft Visual C++ 2008 Redistributable Package to run on Windows platforms. Users should make sure the package has been installed on the system before installing the server. The package is available at the Microsoft Download Center.

MySQL is available for Microsoft Windows, for both 32-bit and 64-bit versions. For supported Windows platform information, see https://www.mysql.com/support/supportedplatforms/database.html.

There are different methods to install MySQL on Microsoft Windows.

MySQL Installer Method

The simplest and recommended method is to download MySQL Installer (for Windows) and let it install and configure all of the MySQL products on your system. Here is how:


   **Note**

   Unlike the standard MySQL Installer, the smaller "web-community" version does not bundle any MySQL applications but it will download the MySQL products you choose to install.

2. Choose the appropriate **Setup Type** for your system. Typically you will choose **Developer Default** to install MySQL server and other MySQL tools related to MySQL development, helpful tools like MySQL Workbench. Or, choose the **Custom** setup type to manually select your desired MySQL products.
Multiple versions of MySQL server can exist on a single system. You can choose one or multiple versions.

3. Complete the installation process by following the instructions. This will install several MySQL products and start the MySQL server.

MySQL is now installed. If you configured MySQL as a service, then Windows will automatically start MySQL server every time you restart your system.

You probably also installed other helpful MySQL products like MySQL Workbench and MySQL Notifier on your system. Consider loading Chapter 26, MySQL Workbench and MySQL Notifier Overview to view the connection’s status. By default, these two programs automatically start after installing MySQL.

This process also installs the MySQL Installer application on your system, and later you can use MySQL Installer to upgrade or reconfigure your MySQL products.

Additional Installation Information

It is possible to run MySQL as a standard application or as a Windows service. By using a service, you can monitor and control the operation of the server through the standard Windows service management tools. For more information, see Section 2.3.6.7, “Starting MySQL as a Windows Service”.

Generally, you should install MySQL on Windows using an account that has administrator rights. Otherwise, you may encounter problems with certain operations such as editing the PATH environment variable or accessing the Service Control Manager. When installed, MySQL does not need to be executed using a user with Administrator privileges.

For a list of limitations on the use of MySQL on the Windows platform, see Section 2.3.9, “Windows Platform Restrictions”.

In addition to the MySQL Server package, you may need or want additional components to use MySQL with your application or development environment. These include, but are not limited to:

- To connect to the MySQL server using ODBC, you must have a Connector/ODBC driver. For more information, including installation and configuration instructions, see MySQL Connector/ODBC Developer Guide.

MySQL Installer will install and configure Connector/ODBC for you.

- To use MySQL server with .NET applications, you must have the Connector/.NET driver. For more information, including installation and configuration instructions, see MySQL Connector/.NET Developer Guide.

MySQL Installer will install and configure MySQL Connector/.NET for you.
MySQL distributions for Windows can be downloaded from https://dev.mysql.com/downloads/. See Section 2.1.2, “How to Get MySQL”.

MySQL for Windows is available in several distribution formats, detailed here. Generally speaking, you should use MySQL Installer. It contains more features and MySQL products than the older MSI, is simpler to use than the compressed file, and you need no additional tools to get MySQL up and running. MySQL Installer automatically installs MySQL Server and additional MySQL products, creates an options file, starts the server, and enables you to create default user accounts. For more information on choosing a package, see Section 2.3.2, “Choosing an Installation Package”.

- Binary installer distributions. There are two different installable distributions that come packaged as a Microsoft Windows Installer (MSI) package that you can install manually or automatically on your systems. The preferred MySQL Installer package includes MySQL Server and additional MySQL products including MySQL Workbench, MySQL Notifier, and MySQL for Excel. MySQL Installer can also be used to upgrade these products in the future. The older MSI package contains all the files you need to install and configure MySQL server, but no additional components.

  For instructions on installing MySQL using MySQL Installer, see Section 2.3.3, “MySQL Installer for Windows”.

- The standard binary distribution (packaged as a compressed file) contains all of the necessary files that you unpack into your chosen location. This package contains all of the files in the full Windows MSI Installer package, but does not include an installation program.

  For instructions on installing MySQL using the compressed file, see Section 2.3.6, “Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive”.

- The source distribution format contains all the code and support files for building the executables using the Visual Studio compiler system.

  For instructions on building MySQL from source on Windows, see Section 2.9, “Installing MySQL from Source”.

MySQL on Windows Considerations

- Large Table Support

  If you need tables with a size larger than 4 GB, install MySQL on an NTFS or newer file system. Do not forget to use `MAX_ROWS` and `AVG_ROW_LENGTH` when you create tables. See Section 13.1.17, “CREATE TABLE Statement”.

  **Note**

  InnoDB tablespace files cannot exceed 4 GB on Windows 32-bit systems.

- MySQL and Virus Checking Software

  Virus-scanning software such as Norton/Symantec Anti-Virus on directories containing MySQL data and temporary tables can cause issues, both in terms of the performance of MySQL and the virus-scanning software misidentifying the contents of the files as containing spam. This is due to the fingerprinting mechanism used by the virus-scanning software, and the way in which MySQL rapidly updates different files, which may be identified as a potential security risk.

  After installing MySQL Server, it is recommended that you disable virus scanning on the main directory (`datadir`) used to store your MySQL table data. There is usually a system built into the virus-scanning software to enable specific directories to be ignored.
In addition, by default, MySQL creates temporary files in the standard Windows temporary directory. To prevent the temporary files also being scanned, configure a separate temporary directory for MySQL temporary files and add this directory to the virus scanning exclusion list. To do this, add a configuration option for the `tmpdir` parameter to your `my.ini` configuration file. For more information, see Section 2.3.6.2, “Creating an Option File”.

- **Running MySQL on a 4K Sector Hard Drive**

Running the MySQL server on a 4K sector hard drive on Windows is not supported with `innodb_flush_method=async_unbuffered`, which is the default setting. The workaround is to use `innodb_flush_method=normal`.

### 2.3.1 MySQL Installation Layout on Microsoft Windows

For MySQL 5.5 on Windows, the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.5` for installations performed with MySQL Installer or the MSI package. If you use the ZIP archive method to install MySQL, you may prefer to install in `C:\mysql`. However, the layout of the subdirectories remains similar (exceptions are indicated).

All of the files are located within this parent directory, using the structure shown in the following table.

<table>
<thead>
<tr>
<th>Directory</th>
<th>Contents of Directory</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bin</code> and <code>scripts</code></td>
<td><code>mysql</code> server, client and utility programs</td>
<td></td>
</tr>
<tr>
<td><code>%ALLUSERSPROFILE%\MySQL\MySQL Server 5.5\</code></td>
<td>Log files, databases (Windows XP, Windows Server 2003)</td>
<td>The Windows system variable <code>%ALLUSERSPROFILE%</code> defaults to C:\Documents and Settings\All Users \Application Data.</td>
</tr>
<tr>
<td><code>%PROGRAMDATA%\MySQL\MySQL Server 5.5\</code></td>
<td>Log files, databases (Vista, Windows 7, Windows Server 2008, and newer)</td>
<td>The Windows system variable <code>%PROGRAMDATA%</code> defaults to C:\ProgramData.</td>
</tr>
<tr>
<td><code>data</code></td>
<td>Pristine templates</td>
<td></td>
</tr>
<tr>
<td><code>docs</code></td>
<td>Release documentation</td>
<td>With MySQL Installer, use the Modify operation to select this optional folder.</td>
</tr>
<tr>
<td><code>include</code></td>
<td>Include (header) files</td>
<td></td>
</tr>
<tr>
<td><code>lib</code></td>
<td>Libraries</td>
<td></td>
</tr>
<tr>
<td><code>share</code></td>
<td>Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation</td>
<td></td>
</tr>
<tr>
<td><code>mysql-test, scripts, and sql-bench</code></td>
<td>Debug binaries and test suite</td>
<td>ZIP archive only.</td>
</tr>
</tbody>
</table>

The packages create and set up the data directory that the installed server will use, but as of MySQL 5.5.5, it also creates a pristine “template” data directory named `data` under the installation directory. This directory can be useful when the machine will be used to run multiple instances of MySQL. After an
installation has been performed using an MSI package, the template data directory can be copied to set up additional MySQL instances. See Section 5.7, “Running Multiple MySQL Instances on One Machine”.

2.3.2 Choosing an Installation Package

For MySQL 5.5, there are multiple installation package formats to choose from when installing MySQL on Windows.

- **MySQL Installer**: This package has a file name similar to `mysql-installer-community-5.5.62.0.msi` or `mysql-installer-commercial-5.5.62.0.msi`, and utilizes MSIs to automatically install MySQL server and other products. It will download and apply updates to itself, and for each of the installed products. It also configures the installed MySQL server.

  MySQL Installer can install and manage (add, modify, upgrade, and remove) many other MySQL products, including:

  - Applications – MySQL Workbench, MySQL for Visual Studio, MySQL Notifier, MySQL for Excel, MySQL Utilities
  - Connectors – MySQL Connector/C++, MySQL Connector/NET, Connector/ODBC, MySQL Connector/Python, MySQL Connector/J
  - Documentation – MySQL Manual (PDF format), samples and examples

MySQL Installer will run on all Windows platforms that are supported by MySQL (see https://www.mysql.com/support/supportedplatforms/database.html).

- **The Complete Package (MSI Installer)**: This package has a file name similar to `mysql-5.5.62-win32.msi` or `mysql-5.5.62-winx64.msi`, and contains all files needed for a complete Windows installation, including the Configuration Wizard. This package includes optional components such as the embedded server and benchmark suite.

- **The noinstall ZIP Archive**: This package has a file name similar to `mysql-5.5.62-win32.zip` or `mysql-5.5.62-winx64.zip`, and contains all the files found in the complete installation package, with the exception of the GUI. It also contains PDB files. This package does not include an automated installer, and must be manually installed and configured.
MySQL Installer is recommended for most users.

Your choice of install package affects the installation process you must follow. If you choose to use MySQL Installer, see Section 2.3.3, “MySQL Installer for Windows”. If you choose to install a standard MSI package, see Section 2.3.4, “Installing MySQL on Microsoft Windows Using an MSI Package”. If you choose to install a noinstall ZIP archive, see Section 2.3.6, “Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive”.

2.3.3 MySQL Installer for Windows

MySQL Installer is a standalone application designed to ease the complexity of installing and configuring MySQL products that run on Microsoft Windows. It supports the following MySQL products:

• MySQL Servers

MySQL Installer can install and manage multiple, separate MySQL server instances on the same host at the same time. For example, MySQL Installer can install, configure, and upgrade a separate instance of MySQL 5.6, MySQL 5.7, and MySQL 8.0 on the same host. MySQL Installer does not permit server upgrades between major and minor version numbers, but does permit upgrades within a release series (such as 5.7.18 to 5.7.19).

Note

MySQL Installer cannot install both Community and Commercial (Standard Edition and Enterprise Edition) releases of MySQL server on the same host. If you require both releases on the same host, consider using the ZIP archive distribution to install one of the releases.

• MySQL Applications

MySQL Workbench, MySQL Shell, MySQL Router, MySQL for Visual Studio, MySQL for Excel, MySQL Notifier, and MySQL Utilities.

• MySQL Connectors

MySQL Connector/.NET, MySQL Connector/Python, MySQL Connector/ODBC, MySQL Connector/J, and MySQL Connector/C++.

Note

To install MySQL Connector/Node.js, see https://dev.mysql.com/downloads/connector/nodejs/. Connector/Node.js does not provide an .msi file for use with MySQL Installer.

• Documentation and Samples

MySQL Reference Manuals (by version) in PDF format and MySQL database samples (by version).

Installation Requirements

MySQL Installer requires Microsoft .NET Framework 4.5.2 or later. If this version is not installed on the host computer, you can download it by visiting the Microsoft website.

MySQL Installer Community Release

Download software from https://dev.mysql.com/downloads/installer/ to install the Community release of all MySQL products for Windows. Select one of the following MySQL Installer package options:
MySQL Installer for Windows

- **Web**: Contains MySQL Installer and configuration files only. The web package downloads only the MySQL products you select to install, but it requires an internet connection for each download. The size of this file is approximately 2 MB; the name of the file has the form `mysql-installer-community-web-VERSION.N.msi` where `VERSION` is the MySQL server version number such as 8.0 and `N` is the package number, which begins at 0.

- **Full or Current Bundle**: Bundles all of the MySQL products for Windows (including the MySQL server). The file size is over 300 MB, and the name has the form `mysql-installer-community-VERSION.N.msi` where `VERSION` is the MySQL Server version number such as 8.0 and `N` is the package number, which begins at 0.

**MySQL Installer Commercial Release**

Download software from `https://edelivery.oracle.com/` to install the Commercial (Standard Edition or Enterprise Edition) release of MySQL products for Windows. The Commercial release includes all of the current and previous GA versions in the Community release (excludes development-milestone versions) and also includes the following products:

- Workbench SE/EE
- MySQL Enterprise Backup
- MySQL Enterprise Firewall

The Commercial release integrates with your My Oracle Support (MOS) account. For knowledge-base content and patches, see **My Oracle Support**.

**2.3.3.1 MySQL Installer Initial Setup**

- **Choosing a Setup Type**
- **Path Conflicts**
- **Check Requirements**
- **MySQL Installer Configuration Files**

When you download MySQL Installer for the first time, a setup wizard guides you through the initial installation of MySQL products. As the following figure shows, the initial setup is a one-time activity in the overall process. MySQL Installer detects existing MySQL products installed on the host during its initial setup and adds them to the list of products to be managed.

**Figure 2.7 MySQL Installer Process Overview**

MySQL Installer extracts configuration files (described later) to the hard drive of the host during the initial setup. Although MySQL Installer is a 32-bit application, it can install both 32-bit and 64-bit binaries.

The initial setup adds a link to the Start menu under the **MySQL** group. Click **Start, All Programs, MySQL, MySQL Installer** to open MySQL Installer.
Choosing a Setup Type

During the initial setup, you are prompted to select the MySQL products to be installed on the host. One alternative is to use a predetermined setup type that matches your setup requirements. By default, both GA and pre-release products are included in the download and installation with the Developer Default, Client only, and Full setup types. Select the Only install GA products option to restrict the product set to include GA products only when using these setup types.

Choosing one of the following setup types determines the initial installation only and does not limit your ability to install or update MySQL products for Windows later:

• **Developer Default**: Install the following products that compliment application development with MySQL:
  - MySQL Server (Installs the version that you selected when you downloaded MySQL Installer.)
  - MySQL Shell
  - MySQL Router
  - MySQL Workbench
  - MySQL for Visual Studio
  - MySQL for Excel
  - MySQL Notifier
  - MySQL Connectors (for .NET / Python / ODBC / Java / C++)
  - MySQL Utilities
  - MySQL Documentation
  - MySQL Samples and Examples

• **Server only**: Only install the MySQL server. This setup type installs the general availability (GA) or development release server that you selected when you downloaded MySQL Installer. It uses the default installation and data paths.

• **Client only**: Only install the most recent MySQL applications and MySQL connectors. This setup type is similar to the Developer Default type, except that it does not include MySQL server or the client programs typically bundled with the server, such as mysql or mysqladmin.

• **Full**: Install all available MySQL products.

• **Custom**: The custom setup type enables you to filter and select individual MySQL products from the MySQL Installer catalog.

Use the Custom setup type to install:

• A product or product version that is not available from the usual download locations. The catalog contains all product releases, including the other releases between pre-release (or development) and GA.

• An instance of MySQL server using an alternative installation path, data path, or both. For instructions on how to adjust the paths, see Section 2.3.3.2, “Setting Alternative Server Paths with MySQL Installer”.
• Two or more MySQL server versions on the same host at the same time (for example, 5.6, 5.7, and 8.0).

• A specific combination of products and features not offered as a predetermine setup type. For example, you can install a single product, such as MySQL Workbench, instead of installing all client applications for Windows.

Path Conflicts

When the default installation or data folder (required by MySQL server) for a product to be installed already exists on the host, the wizard displays the Path Conflict step to identify each conflict and enable you to take action to avoid having files in the existing folder overwritten by the new installation. You see this step in the initial setup only when MySQL Installer detects a conflict.

To resolve the path conflict, do one of the following:

• Select a product from the list to display the conflict options. A warning symbol indicates which path is in conflict. Use the browse button to choose a new path and then click Next.

• Click Back to choose a different setup type or product version, if applicable. The Custom setup type enables you to select individual product versions.

• Click Next to ignore the conflict and overwrite files in the existing folder.

• Delete the existing product. Click Cancel to stop the initial setup and close MySQL Installer. Open MySQL Installer again from the Start menu and delete the installed product from the host using the Delete operation from the dashboard.

Check Requirements

MySQL Installer uses entries in the package-rules.xml file to determine whether the prerequisite software for each product is installed on the host. When the requirements check fails, MySQL Installer displays the Check Requirements step to help you update the host. Requirements are evaluated each time you download a new product (or version) for installation. The following figure identifies and describes the key areas of this step.
Figure 2.8 Check Requirements

Description of Check Requirements Elements

1. Shows the current step in the initial setup. Steps in this list may change slightly depending on the products already installed on the host, the availability of prerequisite software, and the products to be installed on the host.

2. Lists all pending installation requirements by product and indicates the status as follows:
   - A blank space in the **Status** column means that MySQL Installer can attempt to download and install the required software for you.
   - The word **Manual** in the **Status** column means that you must satisfy the requirement manually. Select each product in the list to see its requirement details.

3. Describes the requirement in detail to assist you with each manual resolution. When possible, a download URL is provided. After you download and install the required software, click **Check** to verify that the requirement has been met.

4. Provides the following set operations to proceed:
   - **Back** – Return to the previous step. This action enables you to select a different the setup type.
   - **Execute** – Have MySQL Installer attempt to download and install the required software for all items without a manual status. Manual requirements are resolved by you and verified by clicking **Check**.
   - **Next** – Do not execute the request to apply the requirements automatically and proceed to the installation without including the products that fail the check requirements step.
   - **Cancel** – Stop the installation of MySQL products. Because MySQL Installer is already installed, the initial setup begins again when you open MySQL Installer from the Start menu and click **Add** from the dashboard. For a description of the available management operations, see **Product Catalog**.
MySQL Installer Configuration Files

All MySQL Installer files are located within the `C:\Program Files (x86)` and `C:\ProgramData` folders. The following table describes the files and folders that define MySQL Installer as a standalone application.

Note

Installed MySQL products are neither altered nor removed when you update or uninstall MySQL Installer.

Table 2.5 MySQL Installer Configuration Files

<table>
<thead>
<tr>
<th>File or Folder</th>
<th>Description</th>
<th>Folder Hierarchy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MySQL Installer for Windows</td>
<td>This folder contains all of the files needed to run MySQL Installer and MySQLInstallerConsole.exe, a command-line program with similar functionality.</td>
<td>C:\Program Files (x86)</td>
</tr>
<tr>
<td>Templates</td>
<td>The Templates folder has one file for each version of MySQL server. Template files contain keys and formulas to calculate some values dynamically.</td>
<td>C:\ProgramData\MySQL\MySQL Installer for Windows\Manifest</td>
</tr>
<tr>
<td>package-rules.xml</td>
<td>This file contains the prerequisites for every product to be installed.</td>
<td>C:\ProgramData\MySQL\MySQL Installer for Windows\Manifest</td>
</tr>
<tr>
<td>products.xml</td>
<td>The products file (or product catalog) contains a list of all products available for download.</td>
<td>C:\ProgramData\MySQL\MySQL Installer for Windows\Manifest</td>
</tr>
<tr>
<td>Product Cache</td>
<td>The Product Cache folder contains all standalone <code>.msi</code> files bundled with the full package or downloaded afterward.</td>
<td>C:\ProgramData\MySQL\MySQL Installer for Windows</td>
</tr>
</tbody>
</table>

2.3.3.2 Setting Alternative Server Paths with MySQL Installer

You can change the default installation path, the data path, or both when you install MySQL server. After you have installed the server, the paths cannot be altered without removing and reinstalling the server instance.

To change paths for MySQL server

1. Identify the MySQL server to change and display the Advanced Options link.
   a. Navigate to the Select Products and Features step by doing one of the following:
      i. If this is an initial setup of MySQL Installer, select the Custom setup type and click Next.
      ii. If MySQL Installer is installed already, launch it from the Start menu and then click Add from the dashboard.
   b. Click Edit to apply a filter on the product list shown in Available Products (see Locating Products to Install).
   c. With the server instance selected, use the arrow to move the selected server to the Products/Features To Be Installed list.
d. Click the server to select it. When you select the server, the Advanced Options link appears. For details, see the figure that follows.

2. Click Advanced Options to open a dialog box where you can enter alternative path names. After the path names are validated, click Next to continue with the configuration steps.

Figure 2.9 Change MySQL Server Path

2.3.3.3 Installation Workflow with MySQL Installer

MySQL Installer provides a wizard-like tool to install and configure new MySQL products for Windows. Unlike the initial setup, which runs only once, MySQL Installer invokes the wizard each time you download or install a new product. For first-time installations, the steps of the initial setup proceed directly into the steps of the installation. For assistance with product selection, see Locating Products to Install.

Note

Full permissions are granted to the user executing MySQL Installer to all generated files, such as my.ini. This does not apply to files and directories for specific products, such as the MySQL server data directory in %ProgramData% that is owned by SYSTEM.

Products installed and configured on a host follow a general pattern that might require your input during the various steps. If you attempt to install a product that is incompatible with the existing MySQL server version (or a version selected for upgrade), you are alerted about the possible mismatch.

MySQL Installer loads all selected products together using the following workflow:

- **Product download.** If you installed the full (not web) MySQL Installer package, all .msi files were loaded to the Product Cache folder during the initial setup and are not downloaded again. Otherwise,
MySQL Installer for Windows

click **Execute** to begin the download. The status of each product changes from **Downloading** to **Downloaded**.

- **Product installation.** The status of each product in the list changes from **Ready to Install**, to **Installing**, and lastly to **Complete**. During the process, click **Show Details** to view the installation actions.

If you cancel the installation at this point, the products are installed, but the server (if installed) is not yet configured. To restart the server configuration, open MySQL Installer from the Start menu and click the **Reconfigure** link next to the appropriate server in the dashboard.

- **Product configuration.** This step applies to MySQL Server, MySQL Router, and samples only. The status for each item in the list should indicate **Ready to Configure**.

Click **Next** to start the configuration wizard for all items in the list. The configuration options presented during this step are specific to the version of database or router that you selected to install.

Click **Execute** to begin applying the configuration options or click **Back** (repeatedly) to return to each configuration page. Click **Finish** to open the **MySQL Installer dashboard**.

- **Installation complete.** This step finalizes the installation for products that do not require configuration. It enables you to copy the log to a clipboard and to start certain applications, such as MySQL Workbench and MySQL Shell. Click **Finish** to open the **MySQL Installer dashboard**.

**MySQL Server Configuration with MySQL Installer**

MySQL Installer performs the initial configuration of the MySQL server. For example:

- For the MySQL 8.0 release series, a server can be configured to run as a standalone database, as a sandbox InnoDB cluster on a single host, or to create a production InnoDB cluster inside a local network (see **High Availability**).

- It creates the configuration file (**my.ini**) that is used to configure the MySQL server. The values written to this file are influenced by choices you make during the installation process. Some definitions are host dependent. For example, query_cache is enabled if the host has fewer than three cores.

  **Note**
  
  Query cache was deprecated in MySQL 5.7 and removed in MySQL 8.0 (and later).

- By default, a Windows service for the MySQL server is added.

- Provides default installation and data paths for MySQL server. For instructions on how to change the default paths, see Section 2.3.3.2, “Setting Alternative Server Paths with MySQL Installer”.

- It can optionally create MySQL server user accounts with configurable permissions based on general roles, such as DB Administrator, DB Designer, and Backup Admin. It optionally creates a Windows user named **MysqlSys** with limited privileges, which would then run the MySQL Server.

  User accounts may also be added and configured in MySQL Workbench.

- Checking **Show Advanced Options** enables additional **Logging Options** to be set. This includes defining custom file paths for the error log, general log, slow query log (including the configuration of seconds it requires to execute a query), and the binary log.

During the configuration process, click **Next** to proceed to the next step or **Back** to return to the previous step. Click **Execute** at the final step to apply the server configuration.
MySQL Installer for Windows

The sections that follow describe the server configuration options that apply to MySQL server on Windows. The server version you installed will determine which steps and options you can configure. Configuring MySQL server may include some or all of the steps.

**High Availability**

MySQL Installer enables you to install, configure, and deploy MySQL Server as a standalone instance or as a member of a highly available cluster using MySQL Group Replication. In either case, MySQL Installer restricts the installation and configuration of the server (or servers) to the local Windows host computer.

- **Standalone MySQL Server / Classic MySQL Replication (default)**

  Select this option to configure one MySQL instance to run as a standalone database server. This option is ideal if you intend to set up classic replication later and then to include this server in your custom solution. The remaining configuration steps are described in the sections that follow, starting with **Type and Networking**.

- **InnoDB cluster**

  Select this option to create or extend an InnoDB cluster solution that is based on MySQL Group Replication (see **Introducing InnoDB Cluster**). You can configure (or reconfigure) a minimum of three server instances to perform a basic setup as a test-only sandbox cluster on a single computer or to create a production cluster inside a local network.

  **InnoDB Cluster Log Verbosity Level.** This configuration step includes an adjustable log that captures information during the configuration of each server instance in the production or sandbox cluster. The values are: MINIMAL, MEDIUM (default), and DEBUG. If the cluster configuration fails, use the **Reconfigure** action from the MySQL Installer dashboard to restart the configuration and then set the verbosity level to DEBUG to gather additional information during your next attempt.

MySQL Installer provides the following configuration variations to deploy an InnoDB cluster:

- **Set Up a Local Server Cluster for Testing Only**

  Select **Create a Sandbox InnoDB cluster for Testing** to enable this option. When prompted, define the number of server sandbox instances in the cluster, set a password for the root user, and adjust the InnoDB cluster log verbosity level as needed. For a more detailed description of the configuration, see **Deploying a Sandbox InnoDB Cluster with MySQL Installer**. This setup requires MySQL 5.7.17 or higher.

- **Create or Join an InnoDB cluster**

  To set up a highly available InnoDB cluster using MySQL Installer, you must have a minimum of three computers on a local network. If you require a more advanced setup, use MySQL Shell to configure some or all of the server instances in the cluster. For details about how to perform a local-network cluster setup, see **Setting up an InnoDB cluster with MySQL Installer**. This setup requires MySQL 8.0.0 or higher.

InnoDB cluster was designed to operate with MySQL Shell, which enables you to perform advanced cluster administration, and MySQL Router to automate the connections made between client applications and server instances. Neither MySQL Shell nor MySQL Router are required to deploy a cluster on Windows using MySQL Installer.

**Deploying a Sandbox InnoDB Cluster with MySQL Installer**

A sandbox deployment includes multiple server sandbox instances that run together on the same computer. Because all server instances reside on the same computer, a sandbox cluster does not meet the
requirements of a highly available solution. Instead, this deployment option simulates an environment from which you can explore the techniques associated with InnoDB cluster administration.

When you select Create a Sandbox InnoDB cluster for Testing, a follow-on step prompts you to select a cluster consisting of three, five, seven, or nine MySQL server instances. Unlike the other server setups provided by MySQL Installer, the sandbox deployment skips the usual server configuration steps (except Authentication Method). The resulting cluster, named sandboxCluster, is available on selected ports that are configured for you.

Note
MySQL Installer deletes ports 3310 to 3390 during the configuration, if those ports were set for the sandbox InnoDB cluster manually using MySQL Shell.

Each sandbox instance is configured to run as a process (not a Windows service). You must start each instance in the sandbox cluster manually after restarting the computer.

After you create the test cluster, click the Summary tab to view the specific ports that apply to your cluster. To modify the number of server instances within the existing cluster or to adjust the logging level, use the Reconfigure quick action from the MySQL Installer dashboard.

Warning
MySQL Installer deletes all existing sandbox cluster data when the cluster is reconfigured or when the server instances within the sandbox cluster are upgraded.

MySQL Installer stores all sandbox InnoDB cluster configuration entries in the installer_config.xml file. By default, MySQL Installer creates the sandbox instances in %userprofile%\MySQL\mysql-sandboxes on the local host.

Setting up InnoDB Cluster with MySQL Installer

To create a single InnoDB cluster, select InnoDB Cluster as the High Availability option and then select Create a New InnoDB Cluster. Adjust the log verbosity level (as needed), and click Next to configure the first server instance. This setup process involves installing and running MySQL Installer on multiple computers.

Define the first server instance (or seed) by providing the following configuration information:

• InnoDB Cluster Name:
  The default cluster name is myCluster. If you intend to configure multiple clusters, replace the default name with one that is meaningful within your solution. Alphanumeric characters, spaces, and underscore (_) characters are valid for this field. The limit is 40 characters.

• Cluster Admin User Name:
  The default cluster administrator name is ic. You can reuse the same MySQL administrative account across multiple clusters. You will be prompted for this account name (and password) later when you configure other server instances to join the cluster. The limit is 32 characters.

• Cluster Admin Password:
  Enter a password for the cluster administrator account (minimum length is four characters). MySQL Installer will evaluate the strength of the MySQL password as you type. Use the Repeat Password field to confirm the password.

• Host Address:
Select the host name or IP address of the local host from the list. When joining additional server instances to the cluster, you will be prompted to identify the seed instance by the host name or IP address.

- **Server ID:**

  The default value is 1. This identifier is required to record the events of a server instance in the binary log. The ID of each server instance within a cluster must be unique; however, you can reuse the same number in a different cluster. The server ID you specify in this field also appears later in Advanced Options step. If you change the value in Advanced Option, the number is changed for the InnoDB cluster Setup too.

Click **Next** and then complete the remaining configuration steps, which are described in the sections that follow, starting with **Type and Networking**. After the seed instance is added and the cluster is created, it requires more instances for full tolerance. At this point, the status is **OK_NO_TOLERANCE**.

To add the second and third server instances to the cluster, you must use a separate computer inside the local network for each. Some of the configuration details of the seed instance are required to complete the join operation.

After you start MySQL Installer and install the server instance on the next computer, begin the configuration by selecting **InnoDB Cluster** as the High Availability option and then select **Add Local MySQL Server Instance to an InnoDB Cluster**. Adjust the **InnoDB Cluster Log Verbosity Level** (as needed) and then click **Next**.

Define the joining server instance by providing the following configuration information:

- **Seed Instance Address:**

  Enter the host name or IP address of the computer that hosts the seed instance.

- **Seed Instance Port:**

  The default value is 3306, which is the port for classic MySQL. Use the same TCP port that you configured for the seed instance.

- **Cluster Admin User Name:**

  The default cluster administrator name is ic. If you assigned a different name when you configured the seed instance, enter the alternative cluster administrator name.

- **Cluster Admin Password:**

  Enter the password assigned to the cluster administrator account.

- **Host Address:**

  Select the host name or IP address of the local host from the list.

- **Server ID:**

  The default value is 1. This identifier is required to record the events of a server instance in the binary log. The ID of each server instance within a cluster must be unique; however, you can reuse the same number in a different cluster. The server ID you specify in this field also appears later in Advanced Options step. If you change the value in Advanced Option, the number is changed for the InnoDB cluster Setup too.
• **Test Connection**

Use this button to verify the connection between the local server instance and the seed instance defined for the cluster. A valid connection is required to proceed.

Click **Next** and then complete the remaining configuration steps, which are described in the sections that follow, starting with **Type and Networking**.

With one seed instance and a second server instance in the cluster, the status is **OK_NO_TOLERANCE**. After you add the third server instance, the status is **OK**, which indicates that the cluster now is tolerant to the failure of one instance.

### Type and Networking

• **Server Configuration Type**

Choose the MySQL server configuration type that describes your setup. This setting defines the amount of system resources (memory) to assign to your MySQL server instance.

• **Development**: A computer that hosts many other applications, and typically this is your personal workstation. This setting configures MySQL to use the least amount of memory.

• **Server**: Several other applications are expected to run on this computer, such as a web server. The Server setting configures MySQL to use a medium amount of memory.

• **Dedicated**: A computer that is dedicated to running the MySQL server. Because no other major applications run on this server, this setting configures MySQL to use the majority of available memory.

• **Connectivity**

Connectivity options control how the connection to MySQL is made. Options include:

• **TCP/IP**: This option is selected by default. You may disable TCP/IP Networking to permit local host connections only. With the TCP/IP connection option selected, you can modify the following items:
  - **Port** for the classic MySQL protocol connections. The default value is **3306**.
  - **X Protocol Port** shown when configuring MySQL 8.0 server only.
  - **Open Windows Firewall port for network access**, which is selected by default for TCP/IP.

If a port number is in use already, you will see the information icon (⚠️) next to the default value and **Next** is disabled until you provide a new port number.

• **Named Pipe**: Enable and define the pipe name, similar to setting the **named_pipe** system variable. The default name is **MySQL**.

• **Shared Memory**: Enable and define the memory name, similar to setting the **shared_memory** system variable. The default name is **MySQL**.

• **Advanced Configuration**

Check **Show Advanced and Logging Options** to set custom logging and advanced options in later steps. The Logging Options step enables you to define custom file paths for the error log, general log, slow query log (including the configuration of seconds it requires to execute a query), and the binary log. The Advanced Options step enables you to set the unique server ID required when binary logging is enabled in a replication topology.
MySQL Enterprise Firewall (Enterprise Edition only)

The Enable MySQL Enterprise Firewall check box is deselected by default. Select this option to enable a security whitelist that offers protection against certain types of attacks. Additional post-installation configuration is required (see MySQL Enterprise Firewall).

Important

There is an issue for MySQL 8.0.19 that prevents the server from starting if MySQL Enterprise Firewall is selected during the server configuration steps. If the server startup operation fails, click Cancel to end the configuration process and return to the dashboard. You must uninstall the server.

The workaround is to run MySQL Installer without MySQL Enterprise Firewall selected. (That is, do not select the Enable MySQL Enterprise Firewall check box.) Then install MySQL Enterprise Firewall afterward using the instructions for manual installation (see Installing or Uninstalling MySQL Enterprise Firewall).

Authentication Method

The Authentication Method step is visible only during the installation or upgrade of MySQL 8.0.4 or higher. It introduces a choice between two server-side authentication options. The MySQL user accounts that you create in the next step will use the authentication method that you select in this step.

MySQL 8.0 connectors and community drivers that use libmysqlclient 8.0 now support the mysql_native_password default authentication plugin. However, if you are unable to update your clients and applications to support this new authentication method, you can configure the MySQL server to use mysql_native_password for legacy authentication. For more information about the implications of this change, see caching_sha2_password as the Preferred Authentication Plugin.

If you are installing or upgrading to MySQL 8.0.4 or higher, select one of the following authentication methods:

• Use Strong Password Encryption for Authentication (RECOMMENDED)

MySQL 8.0 supports a new authentication based on improved, stronger SHA256-based password methods. It is recommended that all new MySQL server installations use this method going forward.

Important

The caching_sha2_password authentication plugin on the server requires new versions of connectors and clients, which add support for the new MySQL 8.0 default authentication.

• Use Legacy Authentication Method (Retain MySQL 5.x Compatibility)

Using the old MySQL 5.x legacy authentication method should be considered only in the following cases:

• Applications cannot be updated to use MySQL 8.0 connectors and drivers.
• Recompilation of an existing application is not feasible.
• An updated, language-specific connector or driver is not available yet.

Accounts and Roles

• Root Account Password
Assigning a root password is required and you will be asked for it when performing other MySQL Installer operations. Password strength is evaluated when you repeat the password in the box provided. For descriptive information regarding password requirements or status, move your mouse pointer over the information icon (⚠️) when it appears.

MySQL User Accounts (Optional)

Click Add User or Edit User to create or modify MySQL user accounts with predefined roles. Next, enter the required account credentials:

- **User Name**: MySQL user names can be up to 32 characters long.

- **Host**: Select localhost for local connections only or <All Hosts (%)> when remote connections to the server are required.

- **Role**: Each predefined role, such as DB Admin, is configured with its own set of privileges. For example, the DB Admin role has more privileges than the DB Designer role. The Role drop-down list contains a description of each role.

- **Password**: Password strength assessment is performed while you type the password. Passwords must be confirmed. MySQL permits a blank or empty password (considered to be insecure).

MySQL Installer Commercial Release Only: MySQL Enterprise Edition for Windows, a commercial product, also supports an authentication method that performs external authentication on Windows. Accounts authenticated by the Windows operating system can access the MySQL server without providing an additional password.

To create a new MySQL account that uses Windows authentication, enter the user name and then select a value for Host and Role. Click Windows authentication to enable the authentication_windows plugin. In the Windows Security Tokens area, enter a token for each Windows user (or group) who can authenticate with the MySQL user name. MySQL accounts can include security tokens for both local Windows users and Windows users that belong to a domain. Multiple security tokens are separated by the semicolon character (;) and use the following format for local and domain accounts:

- **Local account**
  
  Enter the simple Windows user name as the security token for each local user or group; for example, finley;jeffrey;admin.

- **Domain account**

  Use standard Windows syntax (domain\domainuser) or MySQL syntax (domain\domainuser) to enter Windows domain users and groups.

  For domain accounts, you may need to use the credentials of an administrator within the domain if the account running MySQL Installer lacks the permissions to query the Active Directory. If this is the case, select Validate Active Directory users with to activate the domain administrator credentials.

Windows authentication permits you to test all of the security tokens each time you add or modify a token. Click Test Security Tokens to validate (or revalidate) each token. Invalid tokens generate a descriptive error message along with a red x icon and red token text. When all tokens resolve as valid (green text without an x icon), you can click OK to save the changes.
Windows Service

On the Windows platform, MySQL server can run as a named service managed by the operating system and be configured to start up automatically when Windows starts. Alternatively, you can configure MySQL server to run as an executable program that requires manual configuration.

• **Configure MySQL server as a Windows service** (Selected by default.)

  When the default configuration option is selected, you can also select the following:

  • **Start the MySQL Server at System Startup**

    When selected (default), the service startup type is set to Automatic; otherwise, the startup type is set to Manual.

  • **Run Windows Service as**

    When **Standard System Account** is selected (default), the service logs on as Network Service.

    The **Custom User** option must have privileges to log on to Microsoft Windows as a service. The **Next** button will be disabled until this user is configured with the required privileges.

    A custom user account is configured in Windows by searching for “local security policy” in the Start menu. In the Local Security Policy window, select **Local Policies, User Rights Assignment**, and then **Log On As A Service** to open the property dialog. Click **Add User or Group** to add the custom user and then click **OK** in each dialog to save the changes.

• Deselect the Windows Service option

Logging Options

This step is available if the **Show Advanced Configuration** check box was selected during the **Type and Networking** step. To enable this step now, click **Back** to return to the **Type and Networking** step and select the check box.

Advanced configuration options are related to the following MySQL log files:

• **Error Log**
• **General Log**
• **Slow Query Log**
• **Bin Log**

  **Note**

  The binary log is enabled by default for MySQL 5.7 and higher.

Advanced Options

This step is available if the **Show Advanced Configuration** check box was selected during the **Type and Networking** step. To enable this step now, click **Back** to return to the **Type and Networking** step and select the check box.

The advanced-configuration options include:
• **Server ID**

Set the unique identifier used in a replication topology. If binary logging is enabled, you must specify a server ID. The default ID value depends on the server version. For more information, see the description of the `server_id` system variable.

**Tip**

If you specified an ID for a server instance of an InnoDB cluster, then MySQL Installer adjusts the ID (shown on this page) to match the previous identifier.

• **Table Names Case**

You can set the following options during the initial and subsequent configuration the server. For the MySQL 8.0 release series, these options apply only to the initial configuration of the server.

• **Lower Case**

Sets the `lower_case_table_names` option value to 1 (default), in which table names are stored in lowercase on disk and comparisons are not case-sensitive.

• **Preserve Given Case**

Sets the `lower_case_table_names` option value to 2, in which table names are stored as given but compared in lowercase.

**Apply Server Configuration**

All configuration settings are applied to the MySQL server when you click Execute. Use the **Configuration Steps** tab to follow the progress of each action; the icon for each toggles from white to green (with a check mark) on success. Otherwise, the process stops and displays an error message if an individual action times out. Click the **Log** tab to view the log.

When the installation completes successfully and you click **Finish**, MySQL Installer and the installed MySQL products are added to the Microsoft Windows Start menu under the **MySQL** group. Opening MySQL Installer loads the dashboard where installed MySQL products are listed and other MySQL Installer operations are available.

**MySQL Router Configuration with MySQL Installer**

MySQL Installer downloads and installs a suite of tools for developing and managing business-critical applications on Windows. The suite consist of applications, connectors, documentation, and samples.

During the **initial setup**, choose any predetermined setup type, except **Server only**, to install the latest GA version of the tools. Use the **Custom** setup type to install an individual tool or specific version. If MySQL Installer is installed on the host already, use the **Add** operation to select and install tools from the MySQL Installer dashboard.

**MySQL Router Configuration**

MySQL Installer provides a configuration wizard that can bootstrap an installed instance of MySQL Router 8.0 or later to route traffic between MySQL applications and an InnoDB cluster. When configured, MySQL Router runs as a local Windows service. For detailed information about using MySQL Router with an InnoDB cluster, see **Routing for MySQL InnoDB cluster**.
To configure MySQL Router, do the following:

1. Set up InnoDB cluster. For instructions on how to configure a sandbox InnoDB cluster on the local host using MySQL Installer, see High Availability.

For general InnoDB cluster information, see InnoDB Cluster.

2. Using MySQL Installer, download and install the MySQL Router application. After the installation finishes, the configuration wizard prompts you for information. Select the **Configure MySQL Router for InnoDB cluster** check box to begin the configuration and provide the following configuration values:

   - **Hostname**: Host name of the primary (seed) server in the InnoDB cluster (**localhost** by default).
   - **Port**: The port number of the primary (seed) server in the InnoDB cluster (**3310** by default).
   - **Management User**: An administrative user with root-level privileges.
   - **Password**: The password for the management user.
   - **Classic MySQL protocol connections to InnoDB cluster**

   **Read/Write**: Set the first base port number to one that is unused (between 80 and 65532) and the wizard will select the remaining ports for you.

The figure that follows shows an example of the MySQL Router configuration page, with the first base port number specified as 6446 and the remaining ports set by the wizard as 6447, 6448, and 6449.
3. Click **Next** and then **Execute** to apply the configuration. Click **Finish** to close MySQL Installer or return to the MySQL Installer dashboard.

After installing a production cluster with MySQL Router, the root account only exists in the user table as **root@localhost** (local), instead of **root@%** (remote). Regardless of where the router or client are located, even if both are located on the same host as the seed server, any connection that passes through the router is viewed by server as being remote, not local. As a result, a connection made to the server using the local host (see the example that follows), does not authenticate.

```shell
\c root@localhost:6446
```

### 2.3.3.4 MySQL Installer Product Catalog and Dashboard

- **Product Catalog**
- **MySQL Installer Dashboard**
- **Locating Products to Install**
- **Upgrading MySQL Installer**

This section describes the MySQL Installer product catalog and the dashboard.

#### Product Catalog

The product catalog stores the complete list of released MySQL products for Microsoft Windows that are available to download from [MySQL Downloads](#). By default, and when an Internet connection is present, MySQL Installer updates the catalog daily. You can also update the catalog manually from the dashboard (described later).

An up-to-date catalog performs the following actions:
• Populates the **Available Products** pane of the Select Products and Features step. This step appears when you select:
  - The **Custom** setup type during the **initial setup**.
  - The **Add** operation from the dashboard.

• Identifies when product updates are available for the installed products listed in the dashboard.

The catalog includes all development releases (Pre-Release), general releases (Current GA), and minor releases (Other Releases). Products in the catalog will vary somewhat, depending on the MySQL Installer release that you download.

**MySQL Installer Dashboard**

The MySQL Installer dashboard is the default view that you see when you start MySQL Installer after the **initial setup** finishes. If you closed MySQL Installer before the setup was finished, MySQL Installer resumes the initial setup before it displays the dashboard.

**Figure 2.11 MySQL Installer Dashboard Elements**

![MySQL Installer Dashboard Elements](image)

**Description of MySQL Installer Dashboard Elements**

1. **MySQL Installer dashboard operations** provide a variety of actions that apply to installed products or products listed in the catalog. To initiate the following operations, first click the operation link and then select the product or products to manage:

   • **Add**: This operation opens the Select Products and Features page. From there, you can filter the product in the product catalog, select one or more products to download (as needed), and begin the installation. For hints about using the filter, see **Locating Products to Install**.
**Modify**: Use this operation to add or remove the features associated with installed products. Features that you can modify vary in complexity by product. When the Program Shortcut check box is selected, the product appears in the Start menu under the MySQL group.

**Upgrade**: This operation loads the Select Products to Upgrade page and populates it with all the upgrade candidates. An installed product can have more than one upgrade version and requires a current product catalog.

**Important server upgrade conditions:**

- MySQL Installer does not permit server upgrades between major release versions or minor release versions, but does permit upgrades within a release series, such as an upgrade from 5.7.18 to 5.7.19.

- Upgrades between milestone releases (or from a milestone release to a GA release) are not supported. Significant development changes take place in milestone releases and you may encounter compatibility issues or problems starting the server.

- For upgrades to MySQL 8.0.16 server and higher, a check box enables you to skip the upgrade check and process for system tables, while checking and processing data dictionary tables normally. MySQL Installer does not prompt you with the check box when the previous server upgrade was skipped or when the server was configured as a sandbox InnoDB cluster. This behavior represents a change in how MySQL Server performs an upgrade (see What the MySQL Upgrade Process Upgrades) and it alters the sequence of steps that MySQL Installer applies to the configuration process.

If you select **Skip system tables upgrade check and process. (Not recommended)**, MySQL Installer starts the upgraded server with the --upgrade=MINIMAL server option, which upgrades the data dictionary only. If you stop and then restart the server without the --upgrade=MINIMAL option, the server upgrades the system tables automatically, if needed.

The following information appears in the Log tab and log file after the upgrade configuration (with system tables skipped) is complete:

```plaintext
WARNING: The system tables upgrade was skipped after upgrading MySQL Server. The server will be started now with the --upgrade=MINIMAL option, but then each time the server is started it will attempt to upgrade the system tables, unless you modify the Windows service (command line) to add --upgrade=MINIMAL to bypass the upgrade.

FOR THE BEST RESULTS: Run mysqld.exe --upgrade=FORCE on the command line to upgrade the system tables manually.
```

To choose a new product version:

a. Click Upgrade. Confirm that the check box next to product name in the Upgradeable Products pane has a check mark. Deselect the products that you do not intend to upgrade at this time.

**Note**

For server milestone releases in the same release series, MySQL Installer deselects the server upgrade and displays a warning to indicate that the upgrade is not supported, identifies the risks of continuing, and provides a summary of the steps to perform a logical upgrade manually. You can reselect server upgrade at your own risk. For instructions on how to perform a logical upgrade with a milestone release, see Logical Upgrade.
b. Click a product in the list to highlight it. This action populates the **Upgradeable Versions** pane with the details of each available version for the selected product: version number, published date, and a **Changes** link to open the release notes for that version.

MySQL Installer upgrades all of the selected products in one action. Click **Show Details** to view the actions performed by MySQL Installer.

- **Remove**: This operation opens the Remove Products page and populates it with the MySQL products installed on the host. Select the MySQL products you want to remove (uninstall) and then click **Execute** to begin the removal process. During the operation, an indicator shows the number of steps that are executed as a percentage of all steps.

To select products to remove, do one of the following:

- Select the check box for one or more products.
- Select the **Product** check box to select all products.

To remove a local MySQL server:

a. Determine whether the local data directory should be removed. If you retain the data directory, another server installation can reuse the data. This option is enabled by default (removes the data directory).

b. If the local server is a member of an InnoDB cluster, reconfigure the cluster as follows:

   i. Type the administrator password for the cluster affected when the local server is removed and then click **Test Connection** to verify the credentials. MySQL Installer can perform the following actions, depending on the configuration of the existing cluster:

      • If the local server is a seed instance and the number of instances in the cluster is one, dissolve the cluster when you remove the local server.

      • If the local server is a seed instance and the number of instances in the cluster is greater than one, remove the instance from the cluster or dissolve the cluster when you remove the local server.

      • If the local server is a slave instance within the cluster and the number of instances in the cluster is greater than two, remove the local instance from the cluster. (A single slave instance within a cluster reverts to a seed instance automatically.)

      • If the local server is configured as a sandbox InnoDB cluster, remove all instances created for the sandbox server installation.

   ii. When prompted, do one of the following:

      • Select an action to apply to the cluster and click **Next**.

      • Click **Next** without selecting an action. In most cases, MySQL Group Replication can manage the cluster when the local server becomes unavailable. A warning message
reminds you that skipping the step may result in an inconsistent InnoDB cluster configuration.

c. Click **Execute** to begin uninstalling the local server. Note that all products that you selected to remove are also uninstalled at this time.

d. (Optional) Click the **Log** tab to display the current actions performed by MySQL Installer.

2. The **Reconfigure** link in the Quick Action column next to each installed server loads the current configuration values for the server and then cycles through all configuration steps enabling you to change the options and values. You must provide credentials with root privileges to reconfigure these items. Click the **Log** tab to show the output of each configuration step performed by MySQL Installer.

On completion, MySQL Installer stops the server, applies the configuration changes, and restarts the server for you. For a description of each configuration option, see MySQL Server Configuration with MySQL Installer. Installed **Samples and Examples** associated with a specific MySQL server version can be also be reconfigured to apply new feature settings, if any.

3. The **Catalog** link enables you to download the latest catalog of MySQL products manually and then to integrate those product changes with MySQL Installer. The catalog-download action does not perform an upgrade of the products already installed on the host. Instead, it returns to the dashboard and displays an arrow icon in the Version column for each installed product that has a newer version. Use the **Upgrade** operation to install the newer product version.

You can also use the **Catalog** link to display the current change history of each product without downloading the new catalog. Select the **Do not update at this time** check box to view the change history only.

4. The MySQL Installer About icon (-question mark-) shows the current version of MySQL Installer and general information about MySQL. The version number is located above the **Back** button.

   **Tip**

   Always include this version number when reporting a problem with MySQL Installer.

   In addition to the About MySQL information (-question mark-), you can also select the following icons from the side panel:

   • License icon (-question mark-) for MySQL Installer.

   This product may include third-party software, used under license. If you are using a Commercial release of MySQL Installer, the icon opens the MySQL Installer Commercial License Information User Manual for licensing information, including licensing information relating to third-party software that may be included in this Commercial release. If you are using a Community release of MySQL Installer, the icon opens the MySQL Installer Community License Information User Manual for licensing information, including licensing information relating to third-party software that may be included in this Community release.

   • Resource links icon (-question mark-) to the latest MySQL product documentation, blogs, webinars, and more.

5. The MySQL Installer Options icon (-question mark-) includes the following tabs:
MySQL Installer for Windows

- **Product Catalog**: Manages the daily automatic catalog updates. By default, catalog updates are scheduled at a fixed hour. When new products or product versions are available, MySQL Installer adds them to the catalog and then displays an arrow icon (📍) next to the version number of installed products listed in the dashboard.

  Use this option to enable or disable automatic catalog updates and to reset the time of day when the MySQL Installer updates the catalog automatically. For specific settings, see the task named `ManifestUpdate` in the Windows Task Scheduler.

- **Connectivity Settings**: Several operations performed by MySQL Installer require internet access. This option enables you to use a default value to validate the connection or to use a different URL, one selected from a list or added by you manually. With the Manual option selected, new URLs can be added and all URLs in the list can be moved or deleted. When the Automatic option is selected, MySQL Installer attempts to connect to each default URL in the list (in order) until a connection is made. If no connection can be made, it raises an error.

### Locating Products to Install

MySQL products in the catalog are listed by category: MySQL Servers, Applications, MySQL Connectors, and Documentation. Only the latest GA versions appear in the Available Products pane by default. If you are looking for a pre-release or older version of a product, it may not be visible in the default list.

To change the default product list, click **Add** on the dashboard to open the Select Products and Features page, and then click **Edit** to open the filter dialog box (see the figure that follows). Modify the product values and then click **Filter**.

**Figure 2.12 Filter Available Products**

![Filter Available Products](image)

Reset one or more of the following values to filter the list of available products:

- **Text**: Filter by text.
- **Category**: All Software (default), MySQL Servers, Applications, MySQL Connectors, or Documentation (for samples and documentation).
- **Maturity**: Current Bundle (appears initially with the full package only), Pre-Release, Current GA, or Other Releases.
MySQL Installer for Windows

Note
The Commercial release of MySQL Installer does not display any MySQL products when you select the Pre-Release age filter. Products in development are available from the Community release of MySQL Installer only.

- Already Downloaded (the check box is deselected by default).
- Architecture: Any (default), 32-bit, or 64-bit.

Upgrading MySQL Installer

MySQL Installer remains installed on your computer, and like other software, MySQL Installer can be upgraded from the previous version. In some cases, other MySQL software may require that you upgrade MySQL Installer for compatibility. This section describes how to identify the current version of MySQL Installer and how to upgrade MySQL Installer manually.

To locate the installed version of MySQL Installer:
1. Start MySQL Installer from the search menu. The MySQL Installer dashboard opens.
2. Click the MySQL Installer About icon. The version number is located above the Back button.

To initiate an on-demand upgrade of MySQL Installer:
1. Connect the computer with MySQL Installer installed to the internet.
2. Start MySQL Installer from the search menu. The MySQL Installer dashboard opens.
3. Click Catalog on the bottom of the dashboard to open the Update Catalog window.
4. Click Execute to begin the process. If the installed version of MySQL Installer can be upgraded, you will be prompted to start the upgrade.
5. Click Next to review all changes to the catalog and then click Finish to return to the dashboard.
6. Verify the (new) installed version of MySQL Installer (see the previous procedure).

2.3.3.5 MySQLInstallerConsole Reference

MySQLInstallerConsole.exe provides command-line functionality that is similar to MySQL Installer. It is installed when MySQL Installer is initially executed and then available within the MySQL Installer directory. Typically, that is in C:\Program Files (x86)\MySQL\MySQL Installer, and the console must be executed with administrative privileges.

To use, invoke the command prompt with administrative privileges by choosing Start, Accessories, then right-click on Command Prompt and choose Run as administrator. And from the command line, optionally change the directory to where MySQLInstallerConsole.exe is located:

```
C:\> cd Program Files (x86)\MySQL\MySQL Installer for Windows
C:\Program Files (x86)\MySQL\MySQL Installer for Windows> MySQLInstallerConsole.exe help
------------------------ Start Initialization ------------------------
MySQL Installer is running in Community mode

Attempting to update manifest.
Initializing product requirements
Loading product catalog
Checking for product catalog snippets
Checking for product packages in the bundle
Categorizing product catalog
```
MySQL Installer for Windows

Finding all installed packages.
Your product catalog was last updated at 11/1/2016 4:10:38 PM
=================== End Initialization ===================

The following commands are available:

- **Configure** - Configures one or more of your installed programs.
- **Help** - Provides list of available commands.
- **Install** - Install and configure one or more available MySQL programs.
- **List** - Provides an interactive way to list all products available.
- **Modify** - Modifies the features of installed products.
- **Remove** - Removes one or more products from your system.
- **Status** - Shows the status of all installed products.
- **Update** - Update the current product catalog.
- **Upgrade** - Upgrades one or more of your installed programs.

MySQLInstallerConsole.exe supports the following commands:

**Note**
Configuration block values that contain a colon (";") must be wrapped in double quotes. For example, installdir="C:\MySQL\MySQL Server 8.0".

- **configure** [product1]:[setting]=[value]; [product2]:[setting]=[value]; […]

Configure one or more MySQL products on your system. Multiple setting=value pairs can be configured for each product.

Switches include:

- **-showsettings** : Displays the available options for the selected product, by passing in the product name after `-showsettings`.

- **-silent** : Disable confirmation prompts.

```
C:\> MySQLInstallerConsole configure -showsettings server
C:\> MySQLInstallerConsole configure server:port=3307
```

- **help** [command]

Displays a help message with usage examples, and then exits. Pass in an additional command to receive help specific to that command.

```
C:\> MySQLInstallerConsole help
C:\> MySQLInstallerConsole help install
```

- **install** [product]:[features]:[config block]:[config block]:[config block]; […]

Install one or more MySQL products on your system. If pre-release products are available, both GA and pre-release products are installed when the value of the `-type` switch is `Developer`, `Client`, or `Full`. Use the `-only_ga_products` switch to restrict the product set to GA products only when using these setup types.

Switches and syntax options include:

- **-only_ga_products** : Restricts the product set to include GA products only.

- **-type=[SetupType]** : Installs a predefined set of software. The "SetupType" can be one of the following:
MySQL Installer for Windows

Note
Non-custom setup types can only be chosen if no other MySQL products are installed.

- **Developer**: Installs a complete development environment.
- **Server**: Installs a single MySQL server
- **Client**: Installs client programs and libraries
- **Full**: Installs everything
- **Custom**: Installs user selected products. This is the default option.

- **-showsettings**: Displays the available options for the selected product, by passing in the product name after `-showsettings`.
- **-silent**: Disable confirmation prompts.
- **[config block]**: One or more configuration blocks can be specified. Each configuration block is a semicolon separated list of key value pairs. A block can include either a "config" or "user" type key, where "config" is the default type if one is not defined.

Configuration block values that contain a colon character (:) must be wrapped in double quotes. For example, `installdir="C:\MySQL\MySQL Server 8.0"`.

Only one "config" type block can be defined per product. A "user" block should be defined for each user that should be created during the product's installation.

Note
Adding users is not supported when a product is being reconfigured.

- **[feature]**: The feature block is a semicolon separated list of features, or an asterisk character (*) to select all features.

```
C:\> MySQLInstallerConsole install server;5.6.25:*:port=3307;serverid=2:type=user;username=foo;password=bar;role=DBManager
```

C:\> MySQLInstallerConsole install server;5.6.25;x64 -silent

An example that passes in additional configuration blocks, separated by ^ to fit:

```
C:\> MySQLInstallerConsole install server;5.6.25;x64:*:type=config;openfirewall=true; ^
genrallog=true;binlog=true;serverid=3306;enable_tcpip=true;port=3306;rootpasswd=pass; ^
installidir="C:\MySQL\MySQL Server 5.6":type=user;datadir="C:\MySQL\data":username=foo;password=bar
```

- **list**

Lists an interactive console where all of the available MySQL products can be searched. Execute `MySQLInstallerConsole list` to launch the console, and enter in a substring to search.

```
C:\> MySQLInstallerConsole list
```
MySQL Installer for Windows

- **modify** [product1:-removelist|+addlist] [product2:-removelist|+addlist] [...]  
  
  Modifies or displays features of a previously installed MySQL product.  
  
  - **-silent**: Disable confirmation prompts.

  ```
  C:\> MySQLInstallerConsole modify server  
  C:\> MySQLInstallerConsole modify server:+documentation  
  C:\> MySQLInstallerConsole modify server:-debug  
  ```

- **remove** [product1] [product2] [...]  
  
  Removes one or more products from your system.  
  
  - **-continue**: Continue the operation even if an error occurs.  
  - **-silent**: Disable confirmation prompts.

  ```
  C:\> MySQLInstallerConsole remove *  
  C:\> MySQLInstallerConsole remove server  
  ```

- **status**  
  
  Provides a quick overview of the MySQL products that are installed on the system. Information includes product name and version, architecture, date installed, and install location.

  ```
  C:\> MySQLInstallerConsole status  
  ```

- **update**  
  
  Downloads the latest MySQL product catalog to your system. On success, the download catalog will be applied the next time either MySQLInstaller or MySQLInstallerConsole is executed.

  ```
  C:\> MySQLInstallerConsole update  
  ```

  **Note**  
  
  The Automatic Catalog Update GUI option executes this command from the Windows Task Scheduler.

- **upgrade** [product1:version] [product2:version] [...]  
  
  Upgrades one or more products on your system. Syntax options include:  
  
  - **-continue**: Continue the operation even if an error occurs.  
  - **-silent**: Disable confirmation prompts.

  ```
  C:\> MySQLInstallerConsole upgrade *  
  C:\> MySQLInstallerConsole upgrade workbench:6.3.5  
  C:\> MySQLInstallerConsole upgrade workbench:!  
  C:\> MySQLInstallerConsole upgrade workbench:6.3.5 excel:1.3.2  
  ```
2.3.4 Installing MySQL on Microsoft Windows Using an MSI Package

The MSI package is designed to install and configure MySQL in such a way that you can immediately get started using MySQL.

The MySQL Installation Wizard and MySQL Configuration Wizard are available in the Complete install package, which is recommended for most standard MySQL installations. Exceptions include users who need to install multiple instances of MySQL on a single server host and advanced users who want complete control of server configuration.

- For information on installing using the GUI MSI installer process, see Section 2.3.4.1, “Using the MySQL Installation Wizard”.

- For information on installing using the command line using the MSI package, see Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”.

- If you have previously installed MySQL using the MSI package and want to remove MySQL, see Section 2.3.4.3, “Removing MySQL When Installed from the MSI Package”.

The workflow sequence for using the installer is shown in the figure below:
Microsoft Windows XP and later include a firewall which specifically blocks ports. If you plan on using MySQL through a network port then you should open and create an exception for this port before performing the installation. To check and if necessary add an exception to the firewall settings:

1. First ensure that you are logged in as an Administrator or a user with Administrator privileges.
2. Go to the Control Panel, and double click the Windows Firewall icon.
3. Choose the Allow a program through Windows Firewall option and click the Add port button.
4. Enter MySQL into the Name text box and 3306 (or the port of your choice) into the Port number text box.
5. Also ensure that the TCP protocol radio button is selected.

6. If you wish, you can also limit access to the MySQL server by choosing the Change scope button.

7. Confirm your choices by clicking the OK button.

Additionally, when running the MySQL Installation Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.

Note

When using Windows Vista or newer, you may want to disable User Account Control (UAC) before performing the installation. If you do not do so, then MySQL may be identified as a security risk, which will mean that you need to enable MySQL. You can disable the security checking by following these instructions:

1. Open Control Panel.

2. Under the User Accounts and Family Safety, select Add or remove user accounts.

3. Click the Got to the main User Accounts page link.

4. Click on Turn User Account Control on or off. You may be prompted to provide permission to change this setting. Click Continue.

5. Deselect or uncheck the check box next to Use User Account Control (UAC) to help protect your computer. Click OK to save the setting.

You will need to restart to complete the process. Click Restart Now to reboot the machine and apply the changes. You can then follow the instructions below for installing Windows.

2.3.4.1 Using the MySQL Installation Wizard

MySQL Installation Wizard is an installer for the MySQL server that uses the latest installer technologies for Microsoft Windows. The MySQL Installation Wizard, in combination with the MySQL Configuration Wizard, enables a user to install and configure a MySQL server that is ready for use immediately after installation.

The MySQL Installation Wizard is the standard installer for all MySQL server distributions, version 4.1.5 and higher. Users of previous versions of MySQL need to shut down and remove their existing MySQL installations manually before installing MySQL with the MySQL Installation Wizard. See Upgrading MySQL with the Installation Wizard, for more information on upgrading from a previous version.

Microsoft has included an improved version of their Microsoft Windows Installer (MSI) in the recent versions of Windows. MSI has become the de-facto standard for application installations on Windows 2000, Windows XP, and Windows Server 2003. The MySQL Installation Wizard makes use of this technology to provide a smoother and more flexible installation process.

The Microsoft Windows Installer Engine was updated with the release of Windows XP; those using a previous version of Windows can reference this Microsoft Knowledge Base article for information on upgrading to the latest version of the Windows Installer Engine.
In addition, Microsoft has introduced the WiX (Windows Installer XML) toolkit recently. This is the first highly acknowledged Open Source project from Microsoft. We have switched to WiX because it is an Open Source project and it enables us to handle the complete Windows installation process in a flexible manner using scripts.

Improving the MySQL Installation Wizard depends on the support and feedback of users like you. If you find that the MySQL Installation Wizard is lacking some feature important to you, or if you discover a bug, please report it in our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”.

Downloading and Starting the MySQL Installation Wizard

The MySQL installation packages can be downloaded from https://dev.mysql.com/downloads/. If the package you download is contained within a ZIP archive, you need to extract the archive first.

Note

If you are installing on Windows Vista or newer, it is best to open a network port before beginning the installation. To do this, first ensure that you are logged in as an Administrator, go to the Control Panel, and double-click the Windows Firewall icon. Choose the Allow a program through Windows Firewall option and click the Add port button. Enter MySQL into the Name text box and 3306 (or the port of your choice) into the Port number text box. Also ensure that the TCP protocol radio button is selected. If you wish, you can also limit access to the MySQL server by choosing the Change scope button. Confirm your choices by clicking the OK button. If you do not open a port prior to installation, you cannot configure the MySQL server immediately after installation. Additionally, when running the MySQL Installation Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.

The process for starting the wizard depends on the contents of the installation package you download. If there is a setup.exe file present, double-click it to start the installation process. If there is an .msi file present, double-click it to start the installation process.

Choosing an Install Type

There are three installation types available: Typical, Complete, and Custom.

The Typical installation type installs the MySQL server, the mysql command-line client, and the command-line utilities. The command-line clients and utilities include mysqldump, myisamchk, and several other tools to help you manage the MySQL server.

The Complete installation type installs all components included in the installation package. The full installation package includes components such as the embedded server library, the benchmark suite, support scripts, and documentation.

The Custom installation type gives you complete control over which packages you wish to install and the installation path that is used. See The Custom Install Dialog, for more information on performing a custom install.

If you choose the Typical or Complete installation types and click the Next button, you advance to the confirmation screen to verify your choices and begin the installation. If you choose the Custom installation type and click the Next button, you advance to the custom installation dialog, described in The Custom Install Dialog.
The Custom Install Dialog

If you wish to change the installation path or the specific components that are installed by the MySQL Installation Wizard, choose the **Custom** installation type.

**Caution**

To avoid having user data removed unintentionally during an upgrade, do not use the server installation folder as the destination folder for the server data files, which you can configure in the MySQL Server 5.5 Setup dialog.

A tree view on the left side of the custom install dialog lists all available components. Components that are not installed have a red X icon; components that are installed have a gray icon. To change whether a component is installed, click that component's icon and choose a new option from the drop-down list that appears.

You can change the default installation path by clicking the **Change...** button to the right of the displayed installation path.

After choosing your installation components and installation path, click the **Next** button to advance to the confirmation dialog.

The Confirmation Dialog

After you choose an installation type and optionally choose your installation components, you advance to the confirmation dialog. Your installation type and installation path are displayed for you to review.

To install MySQL if you are satisfied with your settings, click the **Install** button. To change your settings, click the **Back** button. To exit the MySQL Installation Wizard without installing MySQL, click the **Cancel** button.

The final screen of the installer provides a summary of the installation and gives you the option to launch the MySQL Configuration Wizard, which you can use to create a configuration file, install the MySQL service, and configure security settings.

Changes Made by MySQL Installation Wizard

When you click the **Install** button, the MySQL Installation Wizard begins the installation process and makes certain changes to your system which are described in the sections that follow.

Changes to the Registry

The MySQL Installation Wizard creates one Windows registry key in a typical install situation, located in **HKEY_LOCAL_MACHINE\SOFTWARE\MySQL AB**.

The MySQL Installation Wizard creates a key named after the release series of the server that is being installed, such as **MySQL Server 5.5**. It contains two string values, **Location** and **Version**. The **Location** string contains the path to the installation directory. In a default installation it contains **C:\Program Files\MySQL\MySQL Server 5.5**. The **Version** string contains the release number. For example, for an installation of MySQL Server 5.5.62, the key contains a value of **5.5.62**.

These registry keys are used to help external tools identify the installed location of the MySQL server, preventing a complete scan of the hard-disk to determine the installation path of the MySQL server. The registry keys are not required to run the server, and if you install MySQL using the **noinstall** ZIP archive, the registry keys are not created.
Installing MySQL on Microsoft Windows Using an MSI Package

Changes to the Start Menu

The MySQL Installation Wizard creates a new entry in the Windows Start menu under a common MySQL menu heading named after the release series of MySQL that you have installed. For example, if you install MySQL 5.5, the MySQL Installation Wizard creates a MySQL Server 5.5 section in the Start menu.

The following entries are created within the new Start menu section:

• **MySQL Command-Line Client**: This is a shortcut to the mysql command-line client and is configured to connect as the root user. The shortcut prompts for a root user password when you connect.

• **MySQL Server Instance Config Wizard**: This is a shortcut to the MySQL Configuration Wizard. Use this shortcut to configure a newly installed server, or to reconfigure an existing server.

• **MySQL Documentation**: This is a link to the MySQL server documentation that is stored locally in the MySQL server installation directory.

Changes to the File System

The MySQL Installation Wizard by default installs the MySQL 5.5 server to C:\Program Files\MySQL\MySQL Server 5.5, where Program Files is the default location for applications in your system, and 5.5 is the release series of your MySQL server. This is the recommended location for the MySQL server, replacing the former default location C:\mysql.

By default, all MySQL applications are stored in a common directory at C:\Program Files\MySQL, where Program Files is the default location for applications in your Windows installation. A typical MySQL installation on a developer machine might look like this:

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:\Program Files\MySQL\MySQL Server 5.5</td>
<td>MySQL server installation directory</td>
</tr>
<tr>
<td>C:\Program Files\MySQL\MySQL Workbench 5.1 OSS</td>
<td>MySQL Workbench installation directory</td>
</tr>
</tbody>
</table>

This approach makes it easier to manage and maintain all MySQL applications installed on a particular system.

The default location of the data directory is the AppData directory configured for the user that installed the MySQL application.

Upgrading MySQL with the Installation Wizard

The MySQL Installation Wizard can perform server upgrades automatically using the upgrade capabilities of MSI. That means you do not need to remove a previous installation manually before installing a new release. The installer automatically shuts down and removes the previous MySQL service before installing the new version.

**Warning**

If you selected the server installation folder as the destination folder for your server data files during the previous installation, move or back up your data folder before beginning the upgrade on Windows. The Installation Wizard overwrites the data folder during the upgrade. Using the installation folder for data files is not recommended.

Automatic upgrades are available only when upgrading between installations that have the same major and minor version numbers. For example, you can upgrade automatically from MySQL 5.5.5 to MySQL 5.5.6, but not from MySQL 5.1 to MySQL 5.5.

See Section 2.11.5, “Upgrading MySQL on Windows”. 
2.3.4.2 Automating MySQL Installation on Microsoft Windows Using the MSI Package

The Microsoft Installer (MSI) supports both a *quiet* and a *passive* mode that can be used to install MySQL automatically without requiring intervention. You can use this either in scripts to automatically install MySQL or through a terminal connection such as Telnet where you do not have access to the standard Windows user interface. The MSI packages can also be used in combination with Microsoft's Group Policy system (part of Windows Server 2003 and Windows Server 2008) to install MySQL across multiple machines.

To install MySQL from one of the MSI packages automatically from the command line (or within a script), you need to use the `msiexec.exe` tool. For example, to perform a quiet installation (which shows no dialog boxes or progress):

```
shell> msiexec /i mysql-5.5.62.msi /quiet
```

The `/i` indicates that you want to perform an installation. The `/quiet` option indicates that you want no interactive elements.

To provide a dialog box showing the progress during installation, and the dialog boxes providing information on the installation and registration of MySQL, use `/passive` mode instead of `/quiet`:

```
shell> msiexec /i mysql-5.5.62.msi /passive
```

Regardless of the mode of the installation, installing the package in this manner performs a 'Typical' installation, and installs the default components into the standard location.

You can also use this method to uninstall MySQL by using the `/uninstall` or `/x` options:

```
shell> msiexec /x mysql-5.5.62.msi /uninstall
```

To install MySQL and configure a MySQL instance from the command line, see Section 2.3.5.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”.

For information on using MSI packages to install software automatically using Group Policy, see How to use Group Policy to remotely install software in Windows Server 2003.

2.3.4.3 Removing MySQL When Installed from the MSI Package

To uninstall MySQL when you installed it using the MSI package, you must use the *Add/Remove Programs* tool within *Control Panel*. To do this:

1. Right-click the **start** menu and choose **Control Panel**.

2. If the Control Panel is set to category mode (you will see **Pick a category** at the top of the **Control Panel** window), double-click **Add or Remove Programs**. If the Control is set to classic mode, double-click the **Add or Remove Programs** icon.

3. Find MySQL in the list of installed software. MySQL Server is installed against release series numbers (MySQL 5.1, MySQL 5.5, etc.). Select the version that you want to remove and click **Remove**.

4. You will be prompted to confirm the removal. Click **Yes** to remove MySQL.

When MySQL is removed using this method, only the installed components are removed. Any database information (including the tables and data), import or export files, log files, and binary logs produced during execution are kept in their configured location.
If you try to install MySQL again the information will be retained and you will be prompted to enter the password configured with the original installation.

If you want to delete MySQL completely:

- Delete the associated data directory. On Windows XP and Windows Server 2003, the default data directory is the configured AppData directory, which is `C:\Documents and Settings\All Users \Application Data\MySQL` by default.

- On Windows 7 and Windows Server 2008, the default data directory location is `C:\ProgramData \Mysql`.

Note

The `C:\ProgramData` directory is hidden by default. You must change your folder options to view the hidden file. Choose Organize, Folder and search options, Show hidden folders.

2.3.5 MySQL Server Instance Configuration Wizard

The MySQL Server Instance Configuration Wizard helps automate the process of configuring your server. It creates a custom MySQL configuration file (`my.ini` or `my.cnf`) by asking you a series of questions and then applying your responses to a template to generate the configuration file that is tuned to your installation.

The MySQL Server Instance Configuration Wizard is included with the MySQL 5.5 server. The MySQL Server Instance Configuration Wizard is only available for Windows.

2.3.5.1 Starting the MySQL Server Instance Configuration Wizard

The MySQL Server Instance Configuration Wizard is normally started as part of the installation process. You should only need to run the MySQL Server Instance Configuration Wizard again when you need to change the configuration parameters of your server.

If you chose not to open a port prior to installing MySQL on Windows Vista or newer, you can choose to use the MySQL Server Configuration Wizard after installation. However, you must open a port in the Windows Firewall. To do this see the instructions given in Downloading and Starting the MySQL Installation Wizard. Rather than opening a port, you also have the option of adding MySQL as a program that bypasses the Windows Firewall. One or the other option is sufficient—you need not do both. Additionally, when running the MySQL Server Configuration Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.
You can launch the MySQL Configuration Wizard by clicking the **MySQL Server Instance Config Wizard** entry in the **MySQL** section of the Windows **Start** menu.

Alternatively, you can navigate to the **bin** directory of your MySQL installation and launch the **MySQLInstanceConfig.exe** file directly.

The MySQL Server Instance Configuration Wizard places the **my.ini** file in the installation directory for the MySQL server. This helps associate configuration files with particular server instances.

To ensure that the MySQL server knows where to look for the **my.ini** file, an argument similar to this is passed to the MySQL server as part of the service installation:

```
--defaults-file="C:\Program Files\MySQL\MySQL Server 5.5\my.ini"
```

Here, **C:\Program Files\MySQL\MySQL Server 5.5** is replaced with the installation path to the MySQL Server. The **--defaults-file** option instructs the MySQL server to read the specified file for configuration options when it starts.

Apart from making changes to the **my.ini** file by running the MySQL Server Instance Configuration Wizard again, you can modify it by opening it with a text editor and making any necessary changes. You can also modify the server configuration with the [http://www.mysql.com/products/administrator/](http://www.mysql.com/products/administrator/) utility. For more information about server configuration, see Section 5.1.6, “Server Command Options”.
MySQL clients and utilities such as the `mysql` and `mysqldump` command-line clients are not able to locate the `my.ini` file located in the server installation directory. To configure the client and utility applications, create a new `my.ini` file in the Windows installation directory (for example, `C:\WINDOWS`).

Under Windows Server 2003, Windows Server 2000, Windows XP, and Windows Vista, MySQL Server Instance Configuration Wizard will configure MySQL to work as a Windows service. To start and stop MySQL you use the `Services` application that is supplied as part of the Windows Administrator Tools.

### 2.3.5.2 Choosing a Maintenance Option

If the MySQL Server Instance Configuration Wizard detects an existing configuration file, you have the option of either reconfiguring your existing server, or removing the server instance by deleting the configuration file and stopping and removing the MySQL service.

To reconfigure an existing server, choose the **Re-configure Instance** option and click the **Next** button. Any existing configuration file is not overwritten, but renamed (within the same directory) using a timestamp (Windows) or sequential number (Linux). To remove the existing server instance, choose the **Remove Instance** option and click the **Next** button.

If you choose the **Remove Instance** option, you advance to a confirmation window. Click the **Execute** button. The MySQL Server Configuration Wizard stops and removes the MySQL service, and then deletes the configuration file. The server installation and its `data` folder are not removed.

If you choose the **Re-configure Instance** option, you advance to the **Configuration Type** dialog where you can choose the type of installation that you wish to configure.

### 2.3.5.3 Choosing a Configuration Type

When you start the MySQL Server Instance Configuration Wizard for a new MySQL installation, or choose the **Re-configure Instance** option for an existing installation, you advance to the **Configuration Type** dialog.
There are two configuration types available: Detailed Configuration and Standard Configuration. The Standard Configuration option is intended for new users who want to get started with MySQL quickly without having to make many decisions about server configuration. The Detailed Configuration option is intended for advanced users who want more fine-grained control over server configuration.

If you are new to MySQL and need a server configured as a single-user developer machine, the Standard Configuration should suit your needs. Choosing the Standard Configuration option causes the MySQL Configuration Wizard to set all configuration options automatically with the exception of Service Options and Security Options.

The Standard Configuration sets options that may be incompatible with systems where there are existing MySQL installations. If you have an existing MySQL installation on your system in addition to the installation you wish to configure, the Detailed Configuration option is recommended.

To complete the Standard Configuration, please refer to the sections on Service Options and Security Options in Section 2.3.5.10, "The Service Options Dialog", and Section 2.3.5.11, "The Security Options Dialog", respectively.
2.3.5.4 The Server Type Dialog

There are three different server types available to choose from. The server type that you choose affects the decisions that the MySQL Server Instance Configuration Wizard makes with regard to memory, disk, and processor usage.

**Figure 2.16 Server Type**

- **Developer Machine**: Choose this option for a typical desktop workstation where MySQL is intended only for personal use. It is assumed that many other desktop applications are running. The MySQL server is configured to use minimal system resources.

- **Server Machine**: Choose this option for a server machine where the MySQL server is running alongside other server applications such as FTP, email, and Web servers. The MySQL server is configured to use a moderate portion of the system resources.

- **Dedicated MySQL Server Machine**: Choose this option for a server machine that is intended to run only the MySQL server. It is assumed that no other applications are running. The MySQL server is configured to use all available system resources.

**Note**

By selecting one of the preconfigured configurations, the values and settings of various options in your `my.cnf` or `my.ini` will be altered accordingly. The
default values and options as described in the reference manual may therefore be different to the options and values that were created during the execution of the configuration wizard.

2.3.5.5 The Database Usage Dialog

The **Database Usage** dialog enables you to indicate the storage engines that you expect to use when creating MySQL tables. The option you choose determines whether the **InnoDB** storage engine is available and what percentage of the server resources are available to **InnoDB**.

![Figure 2.17 Database Usage](image)

- **Multifunctional Database**: This option enables both the **InnoDB** and **MyISAM** storage engines and divides resources evenly between the two. This option is recommended for users who use both storage engines on a regular basis.

- **Transactional Database Only**: This option enables both the **InnoDB** and **MyISAM** storage engines, but dedicates most server resources to the **InnoDB** storage engine. This option is recommended for users who use **InnoDB** almost exclusively and make only minimal use of **MyISAM**.

- **Non-Transactional Database Only**: This option disables the **InnoDB** storage engine completely and dedicates all server resources to the **MyISAM** storage engine. This option is recommended for users who do not use **InnoDB**.
MySQL Server Instance Configuration Wizard

The Configuration Wizard uses a template to generate the server configuration file. The **Database Usage** dialog sets one of the following option strings:

<table>
<thead>
<tr>
<th>Option Description</th>
<th>Option String</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multifunctional Database:</td>
<td>MIXED</td>
</tr>
<tr>
<td>Transactional Database Only:</td>
<td>INNODB</td>
</tr>
<tr>
<td>Non-Transactional Database Only:</td>
<td>MYISAM</td>
</tr>
</tbody>
</table>

When these options are processed through the default template (my-template.ini) the result is:

**Multifunctional Database:**
```
default-storage-engine=InnoDB
_myisam_pct=50
```

**Transactional Database Only:**
```
default-storage-engine=InnoDB
_myisam_pct=5
```

**Non-Transactional Database Only:**
```
default-storage-engine=MyISAM
_myisam_pct=100
skip-innodb
```

The **_myisam_pct** value is used to calculate the percentage of resources dedicated to **MyISAM**. The remaining resources are allocated to **InnoDB**.

### 2.3.5.6 The InnoDB Tablespace Dialog

Some users may want to locate the **InnoDB** tablespace files in a different location than the MySQL server data directory. Placing the tablespace files in a separate location can be desirable if your system has a higher capacity or higher performance storage device available, such as a RAID storage system.
To change the default location for the InnoDB tablespace files, choose a new drive from the drop-down list of drive letters and choose a new path from the drop-down list of paths. To create a custom path, click the ... button.

If you are modifying the configuration of an existing server, you must click the Modify button before you change the path. In this situation you must move the existing tablespace files to the new location manually before starting the server.

### 2.3.5.7 The Concurrent Connections Dialog

To prevent the server from running out of resources, it is important to limit the number of concurrent connections to the MySQL server that can be established. The Concurrent Connections dialog enables you to choose the expected usage of your server, and sets the limit for concurrent connections accordingly. It is also possible to set the concurrent connection limit manually.
Figure 2.19 Concurrent Connections

- **Decision Support (DSS)/OLAP**: Choose this option if your server does not require a large number of concurrent connections. The maximum number of connections is set at 100, with an average of 20 concurrent connections assumed.

- **Online Transaction Processing (OLTP)**: Choose this option if your server requires a large number of concurrent connections. The maximum number of connections is set at 500.

- **Manual Setting**: Choose this option to set the maximum number of concurrent connections to the server manually. Choose the number of concurrent connections from the drop-down box provided, or enter the maximum number of connections into the drop-down box if the number you desire is not listed.

### 2.3.5.8 The Networking and Strict Mode Options Dialog

Use the **Networking Options** dialog to enable or disable TCP/IP networking and to configure the port number that is used to connect to the MySQL server.
TCP/IP networking is enabled by default. To disable TCP/IP networking, uncheck the box next to the **Enable TCP/IP Networking** option.

Port 3306 is used by default. To change the port used to access MySQL, choose a new port number from the drop-down box or type a new port number directly into the drop-down box. If the port number you choose is in use, you are prompted to confirm your choice of port number.

Set the **Server SQL Mode** to either enable or disable strict mode. Enabling strict mode (default) makes MySQL behave more like other database management systems. *If you run applications that rely on MySQL’s old “forgiving” behavior, make sure to either adapt those applications or to disable strict mode.* For more information about strict mode, see Section 5.1.10, “Server SQL Modes”.

### 2.3.5.9 The Character Set Dialog

The MySQL server supports multiple character sets and it is possible to set a default server character set that is applied to all tables, columns, and databases unless overridden. Use the **Character Set** dialog to change the default character set of the MySQL server.
Figure 2.21 Character Set

- **Standard Character Set**: Choose this option if you want to use `latin1` as the default server character set. `latin1` is used for English and many Western European languages.

- **Best Support For Multilingualism**: Choose this option if you want to use `utf8` as the default server character set. This is a Unicode character set that can store characters from many different languages.

- **Manual Selected Default Character Set / Collation**: Choose this option if you want to pick the server's default character set manually. Choose the desired character set from the provided drop-down list.

### 2.3.5.10 The Service Options Dialog

On Windows platforms, the MySQL server can be installed as a Windows service. When installed this way, the MySQL server can be started automatically during system startup, and even restarted automatically by Windows in the event of a service failure.

The MySQL Server Instance Configuration Wizard installs the MySQL server as a service by default, using the service name `MySQL`. If you do not wish to install the service, uncheck the box next to the **Install As Windows Service** option. You can change the service name by picking a new service name from the drop-down box provided or by entering a new service name into the drop-down box.
Note
Service names can include any legal character except forward (/) or backward (\) slashes, and must be less than 256 characters long.

Warning
If you are installing multiple versions of MySQL onto the same machine, you must choose a different service name for each version that you install. If you do not choose a different service for each installed version then the service manager information will be inconsistent and this will cause problems when you try to uninstall a previous version.

If you have already installed multiple versions using the same service name, you must manually edit the contents of the HKEY_LOCAL_MACHINE\SYSTEM \CurrentControlSet\Services parameters within the Windows registry to update the association of the service name with the correct server version.

Typically, when installing multiple versions you create a service name based on the version information. For example, you might install MySQL 5.x as mysql5, or specific versions such as MySQL 5.5.0 as mysql50500.

To install the MySQL server as a service but not have it started automatically at startup, uncheck the box next to the Launch the MySQL Server Automatically option.

2.3.5.11 The Security Options Dialog

The content of the security options portion of the MySQL Server Instance Configuration Wizard will depend on whether this is a new installation, or modifying an existing installation.

• Setting the root password for a new installation

  It is strongly recommended that you set a root password for your MySQL server, and the MySQL Server Instance Config Wizard requires by default that you do so. If you do not wish to set a root password, uncheck the box next to the Modify Security Settings option.
Figure 2.22 Security Options

MySQL Server Instance Configuration

Configure the MySQL Server 5.0 server instance.

Please set the security options.

- **Modify Security Settings**
  - New root password: [Field]
    - Enter the root password.
  - Confirm: [Field]
    - Retype the password.
  - [Checkbox] Enable root access from remote machines

- **Create An Anonymous Account**
  - This option will create an anonymous account on this server. Please note that this can lead to an insecure system.

[Buttons]: < Back, Next >, Cancel
• To set the root password, enter the desired password into both the New root password and Confirm boxes.

Setting the root password for an existing installation

If you are modifying the configuration of an existing configuration, or you are installing an upgrade and the MySQL Server Instance Configuration Wizard has detected an existing MySQL system, then you must enter the existing password for root before changing the configuration information.

Figure 2.23 Root Password

If you want to change the current root password, enter the desired new password into both the New root password and Confirm boxes.

To permit root logins from across the network, check the box next to the Enable root access from remote machines option. This decreases the security of your root account.

To create an anonymous user account, check the box next to the Create An Anonymous Account option. Creating an anonymous account can decrease server security and cause login and permission difficulties. For this reason, it is not recommended.

2.3.5.12 The Confirmation Dialog

The final dialog in the MySQL Server Instance Configuration Wizard is the Confirmation Dialog. To start the configuration process, click the Execute button. To return to a previous dialog, click the Back button.
To exit the MySQL Server Instance Configuration Wizard without configuring the server, click the **Cancel** button.

**Figure 2.24 Confirmation**

After you click the **Execute** button, the MySQL Server Instance Configuration Wizard performs a series of tasks and displays the progress onscreen as the tasks are performed.

The MySQL Server Instance Configuration Wizard first determines configuration file options based on your choices using a template prepared by MySQL developers and engineers. This template is named `my-template.ini` and is located in your server installation directory.

The MySQL Configuration Wizard then writes these options to the corresponding configuration file.

If you chose to create a service for the MySQL server, the MySQL Server Instance Configuration Wizard creates and starts the service. If you are reconfiguring an existing service, the MySQL Server Instance Configuration Wizard restarts the service to apply your configuration changes.

If you chose to set a **root** password, the MySQL Configuration Wizard connects to the server, sets your new **root** password, and applies any other security settings you may have selected.

After the MySQL Server Instance Configuration Wizard has completed its tasks, it displays a summary. Click the **Finish** button to exit the MySQL Server Configuration Wizard.
2.3.5.13 MySQL Server Instance Config Wizard: Creating an Instance from the Command Line

In addition to using the GUI interface to the MySQL Server Instance Config Wizard, you can also create instances automatically from the command line.

To use the MySQL Server Instance Config Wizard on the command line, you need to use the MySQLInstanceConfig.exe command that is installed with MySQL in the bin directory within the installation directory. MySQLInstanceConfig.exe takes a number of command-line arguments that set the properties that would normally be selected through the GUI interface, and then creates a new configuration file (my.ini) by combining these selections with a template configuration file to produce the working configuration file.

The main command line options are provided in the table below. Some of the options are required, while some options are optional.

Table 2.6 MySQL Server Instance Config Wizard Required Command-Line Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-nPRODUCTNAME</td>
<td>The name of the instance when installed</td>
</tr>
<tr>
<td>-pPATH</td>
<td>Path of the base directory for installation. This is equivalent to the directory when using the basedir configuration parameter</td>
</tr>
<tr>
<td>-vVERSION</td>
<td>The version tag to use for this installation</td>
</tr>
</tbody>
</table>

Table 2.7 MySQL Server Instance Config Wizard Action-Specifier Command-Line Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-i</td>
<td>Install an instance</td>
</tr>
<tr>
<td>-r</td>
<td>Remove an instance</td>
</tr>
<tr>
<td>-s</td>
<td>Stop an existing instance</td>
</tr>
<tr>
<td>-q</td>
<td>Perform the operation quietly</td>
</tr>
<tr>
<td>-lFILENAME</td>
<td>Save the installation progress in a logfile</td>
</tr>
</tbody>
</table>

Table 2.8 MySQL Server Instance Config Wizard Configuration File Command-Line Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-tFILENAME</td>
<td>Path to the template config file that will be used to generate the installed configuration file</td>
</tr>
<tr>
<td>-cFILENAME</td>
<td>Path to a config file to be generated</td>
</tr>
</tbody>
</table>

The -t and -c options work together to set the configuration parameters for a new instance. The -t option specifies the template configuration file to use as the basic configuration, which are then merged with the configuration parameters generated by the MySQL Server Instance Config Wizard into the configuration file specified by the -c option.

A sample template file, my-template.ini is provided in the toplevel MySQL installation directory. The file contains elements are replaced automatically by the MySQL Server Instance Config Wizard during configuration.

If you specify a configuration file that already exists, the existing configuration file will be saved in the file with the original, with the date and time added. For example, the mysql.ini will be copied to mysql 2009-10-27 1646.ini.bak.
The parameters that you can specify on the command line are listed in the table below.

### Table 2.9 MySQL Server Instance Config Wizard Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ServiceName=$</td>
<td>Specify the name of the service to be created</td>
</tr>
<tr>
<td>AddBinToPath={yes</td>
<td>no}</td>
</tr>
<tr>
<td>ServerType={DEVELOPMENT</td>
<td>SERVER</td>
</tr>
<tr>
<td>DatabaseType={MIXED</td>
<td>INNODB</td>
</tr>
<tr>
<td>ConnectionUsage={DSS</td>
<td>OLTP}</td>
</tr>
<tr>
<td>ConnectionCount=#</td>
<td>Specify the number of concurrent connections to support. For more information, see Section 2.3.5.4, “The Server Type Dialog”</td>
</tr>
<tr>
<td>SkipNetworking={yes</td>
<td>no}</td>
</tr>
<tr>
<td>Port=#</td>
<td>Specify the network port number to use for network connections. For more information, see Section 2.3.5.8, “The Networking and Strict Mode Options Dialog”</td>
</tr>
<tr>
<td>StrictMode={yes</td>
<td>no}</td>
</tr>
<tr>
<td>Charset=$</td>
<td>Specify the default character set. For more information, see Section 2.3.5.9, “The Character Set Dialog”</td>
</tr>
<tr>
<td>RootPassword=$</td>
<td>Specify the root password</td>
</tr>
<tr>
<td>RootCurrentPassword=$</td>
<td>Specify the current root password then stopping or reconfiguring an existing service</td>
</tr>
</tbody>
</table>

**Note**

When specifying options on the command line, you can enclose the entire command-line option and the value you are specifying using double quotation marks. This enables you to use spaces in the options. For example, "-cC: \mysql.ini".

The following command installs a MySQL Server 5.5 instance from the directory C:\Program Files \MySQL\MySQL Server 5.5 using the service name MySQL55 and setting the root password to 1234.

```
shell> MySQLInstanceConfig.exe -i -q "-lC:\mysql_install_log.txt" »
"-nMySQL Server 5.5" "-pC:\Program Files\MySQL\MySQL Server 5.5" -v5.5.62 »
"-tmy-template.ini" "-cC:\mytest.ini" ServerType=DEVELOPMENT DatabaseType=MIXED »
ConnectionUsage=DSS Port=3311 ServiceName=MySQL55 RootPassword=1234
```

In the above example, a log file will be generated in mysql_install_log.txt containing the information about the instance creation process. The log file generated by the above example is shown below:
Welcome to the MySQL Server Instance Configuration Wizard 1.0.16.0
Date: 2009-10-27 17:07:21

Installing service ...

Product Name:         MySQL Server 5.5
Version:              5.5.62
Installation Path:    C:\Program Files\MySQL\MySQL Server 5.5\

Creating configuration file C:\mytest.ini using template my-template.ini.
Options:
DEVELOPMENT
MIXED
DSS
STRICTMODE

Variables:
port: 3311
default-character-set: latin1
basedir: "C:/Program Files/MySQL/MySQL Server 5.5/"
datadir: "C:/Program Files/MySQL/MySQL Server 5.5/Data/"

Creating Windows service entry.
Service name: "MySQL55"
Parameters:   "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --defaults-file="C:\mytest.ini" MySQL55.
Windows service MySQL55 installed.

When using the command line, the return values in the following table indicate an error performing the specified option.

Table 2.10 Return Value from MySQL Server Instance Config Wizard

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Configuration template file cannot be found</td>
</tr>
<tr>
<td>3</td>
<td>The Windows service entry cannot be created</td>
</tr>
<tr>
<td>4</td>
<td>Could not connect to the Service Control Manager</td>
</tr>
<tr>
<td>5</td>
<td>The MySQL service cannot be started</td>
</tr>
<tr>
<td>6</td>
<td>The MySQL service cannot be stopped</td>
</tr>
<tr>
<td>7</td>
<td>The security settings cannot be applied</td>
</tr>
<tr>
<td>8</td>
<td>The configuration file cannot be written</td>
</tr>
<tr>
<td>9</td>
<td>The Windows service entry cannot be removed</td>
</tr>
</tbody>
</table>

You can perform an installation of MySQL automatically using the MSI package. For more information, see Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”.

### 2.3.6 Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive

Users who are installing from the `noinstall` package can use the instructions in this section to manually install MySQL. The process for installing MySQL from a ZIP Archive package is as follows:

1. Extract the archive to the desired install directory
2. Create an option file
3. Choose a MySQL server type
4. Start the MySQL server
5. Secure the default user accounts

This process is described in the sections that follow.

### 2.3.6.1 Extracting the Install Archive

To install MySQL manually, do the following:

1. If you are upgrading from a previous version please refer to Section 2.11.5, “Upgrading MySQL on Windows”, before beginning the upgrade process.
2. Make sure that you are logged in as a user with administrator privileges.
3. Choose an installation location. Traditionally, the MySQL server is installed in \`C:\mysql\`. The MySQL Installation Wizard installs MySQL under `C:\Program Files\MySQL`. If you do not install MySQL at `C:\mysql`, you must specify the path to the install directory during startup or in an option file. See Section 2.3.6.2, “Creating an Option File”.

<table>
<thead>
<tr>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>The MySQL Installer installs MySQL under <code>C:\Program Files\MySQL</code>.</td>
</tr>
</tbody>
</table>

4. Extract the install archive to the chosen installation location using your preferred file-compression tool. Some tools may extract the archive to a folder within your chosen installation location. If this occurs, you can move the contents of the subfolder into the chosen installation location.

### 2.3.6.2 Creating an Option File

If you need to specify startup options when you run the server, you can indicate them on the command line or place them in an option file. For options that are used every time the server starts, you may find it most convenient to use an option file to specify your MySQL configuration. This is particularly true under the following circumstances:

- The installation or data directory locations are different from the default locations (`C:\Program Files \MySQL\MySQL Server 5.5` and `C:\Program Files\MySQL\MySQL Server 5.5\data`).
- You need to tune the server settings, such as memory, cache, or InnoDB configuration information.

When the MySQL server starts on Windows, it looks for option files in several locations, such as the Windows directory, `C:\`, and the MySQL installation directory (for the full list of locations, see Section 4.2.2.2, “Using Option Files”). The Windows directory typically is named something like `C:\WINDOWS`. You can determine its exact location from the value of the `WINDIR` environment variable using the following command:

```
C:\> echo %WINDIR%
```

MySQL looks for options in each location first in the `my.ini` file, and then in the `my.cnf` file. However, to avoid confusion, it is best if you use only one file. If your PC uses a boot loader where `C:` is not the boot drive, your only option is to use the `my.ini` file. Whichever option file you use, it must be a plain text file.

<table>
<thead>
<tr>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>When using the MySQL Installer to install MySQL Server, it will create the <code>my.ini</code> at the default location. And as of MySQL Server 5.5.27, the user running MySQL Installer is granted full permissions to this new <code>my.ini</code>.</td>
</tr>
</tbody>
</table>
In other words, be sure that the MySQL Server user has permission to read the my.ini file.

You can also make use of the example option files included with your MySQL distribution; see Section 5.1.2, "Server Configuration Defaults".

An option file can be created and modified with any text editor, such as Notepad. For example, if MySQL is installed in E:\mysql and the data directory is in E:\mydata\data, you can create an option file containing a [mysqld] section to specify values for the basedir and datadir options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=E:/mydata/data
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=E:\mysql
# set datadir to the location of your data directory
datadir=E:\mydata\data
```

The rules for use of backslash in option file values are given in Section 4.2.2.2, "Using Option Files".

The data directory is located within the AppData directory for the user running MySQL.

If you would like to use a data directory in a different location, you should copy the entire contents of the data directory to the new location. For example, if you want to use E:\mydata as the data directory instead, you must do two things:

1. Move the entire data directory and all of its contents from the default location (for example C:\Program Files\MySQL\MySQL Server 5.5\data) to E:\mydata.

2. Use a --datadir option to specify the new data directory location each time you start the server.

### 2.3.6.3 Selecting a MySQL Server Type

The following table shows the available servers for Windows in MySQL 5.5.

<table>
<thead>
<tr>
<th>Binary</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mysqld</td>
<td>Optimized binary with named-pipe support</td>
</tr>
<tr>
<td>mysqld-debug</td>
<td>Like mysqld, but compiled with full debugging and automatic memory allocation checking</td>
</tr>
</tbody>
</table>

All of the preceding binaries are optimized for modern Intel processors, but should work on any Intel i386-class or higher processor.

Each of the servers in a distribution support the same set of storage engines. The SHOW ENGINES statement displays which engines a given server supports.

All Windows MySQL 5.5 servers have support for symbolic linking of database directories.

MySQL supports TCP/IP on all Windows platforms. MySQL servers on Windows also support named pipes, if you start the server with the named_pipe system variable enabled. It is necessary to enable this
variable explicitly because some users have experienced problems with shutting down the MySQL server when named pipes were used. The default is to use TCP/IP regardless of platform because named pipes are slower than TCP/IP in many Windows configurations.

2.3.6.4 Starting the Server for the First Time

This section gives a general overview of starting the MySQL server. The following sections provide more specific information for starting the MySQL server from the command line or as a Windows service.

The information here applies primarily if you installed MySQL using the noinstall version, or if you wish to configure and test MySQL manually rather than with the GUI tools.

**Note**

MySQL server will automatically start after using MySQL Installer, and MySQL Notifier can be used to start/stop/restart at any time.

The examples in these sections assume that MySQL is installed under the default location of $C:\Program Files\MySQL\MySQL Server 5.5$. Adjust the path names shown in the examples if you have MySQL installed in a different location.

Clients have two options. They can use TCP/IP, or they can use a named pipe if the server supports named-pipe connections.

MySQL for Windows also supports shared-memory connections if the server is started with the `shared_memory` system variable enabled. Clients can connect through shared memory by using the `--protocol=MEMORY` option.

For information about which server binary to run, see Section 2.3.6.3, “Selecting a MySQL Server Type”.

Testing is best done from a command prompt in a console window (or “DOS window”). In this way you can have the server display status messages in the window where they are easy to see. If something is wrong with your configuration, these messages make it easier for you to identify and fix any problems.

To start the server, enter this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --console
```

For a server that includes InnoDB support, you should see the messages similar to those following as it starts (the path names and sizes may differ):

```
InnoDB: The first specified datafile c:\ibdata\ibdata1 did not exist:
InnoDB: a new database to be created!
InnoDB: Setting file c:\ibdata\ibdata1 size to 209715200
InnoDB: Database physically writes the file full: wait...
InnoDB: Log file c:\iblogs\ib_logfile0 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile0 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile1 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile1 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile2 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile2 size to 31457280
InnoDB: Doublewrite buffer not found: creating new
InnoDB: Doublewrite buffer created
InnoDB: creating foreign key constraint system tables
InnoDB: foreign key constraint system tables created
011024 10:58:25  InnoDB: Started
```

When the server finishes its startup sequence, you should see something like this, which indicates that the server is ready to service client connections:

```
mysqld: ready for connections
```
Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive

Version: '5.5.62' socket: '' port: 3306

The server continues to write to the console any further diagnostic output it produces. You can open a new console window in which to run client programs.

If you omit the --console option, the server writes diagnostic output to the error log in the data directory (C:\Program Files\MySQL\MySQL Server 5.5\data by default). The error log is the file with the .err extension, and may be set using the --log-error option.

Note
The accounts that are listed in the MySQL grant tables initially have no passwords. After starting the server, you should set up passwords for them using the instructions in Section 2.10.4, "Securing the Initial MySQL Accounts".

2.3.6.5 Starting MySQL from the Windows Command Line

The MySQL server can be started manually from the command line. This can be done on any version of Windows.

Note
MySQL Notifier can also be used to start/stop/restart the MySQL server.

To start the mysqld server from the command line, you should start a console window (or “DOS window”) and enter this command:

C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"

The path to mysqld may vary depending on the install location of MySQL on your system.

You can stop the MySQL server by executing this command:

C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin" -u root shutdown

Note
If the MySQL root user account has a password, you need to invoke mysqladmin with the -p option and supply the password when prompted.

This command invokes the MySQL administrative utility mysqladmin to connect to the server and tell it to shut down. The command connects as the MySQL root user, which is the default administrative account in the MySQL grant system.

Note
Users in the MySQL grant system are wholly independent from any operating system users under Microsoft Windows.

If mysqld doesn't start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. By default, the error log is located in the C:\Program Files\MySQL\MySQL Server 5.5\data directory. It is the file with a suffix of .err, or may be specified by passing in the --log-error option. Alternatively, you can try to start the server with the --console option; in this case, the server may display some useful information on the screen that will help solve the problem.

The last option is to start mysqld with the --standalone and --debug options. In this case, mysqld writes a log file C:\mysqld.trace that should contain the reason why mysqld doesn't start. See Section 24.5.3, "The DBUG Package".
Use `mysqld --verbose --help` to display all the options that `mysqld` supports.

### 2.3.6.6 Customizing the PATH for MySQL Tools

To make it easier to invoke MySQL programs, you can add the path name of the MySQL `bin` directory to your Windows system `PATH` environment variable:

- On the Windows desktop, right-click the `My Computer` icon, and select `Properties`.
- Next select the `Advanced` tab from the `System Properties` menu that appears, and click the `Environment Variables` button.
- Under `System Variables`, select `Path`, and then click the `Edit` button. The `Edit System Variable` dialogue should appear.
- Place your cursor at the end of the text appearing in the space marked `Variable Value`. (Use the `End` key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL `bin` directory (for example, `C:\Program Files\MySQL\MySQL Server 5.5\bin`)

**Note**

There must be a semicolon separating this path from any values present in this field.

Dismiss this dialogue, and each dialogue in turn, by clicking `OK` until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the `mysql` client, and all MySQL command-line utilities such as `mysqladmin` and `mysqldump`.

You should not add the MySQL `bin` directory to your Windows `PATH` if you are running multiple MySQL servers on the same machine.

**Warning**

You must exercise great care when editing your system `PATH` by hand; accidental deletion or modification of any portion of the existing `PATH` value can leave you with a malfunctioning or even unusable system.

### 2.3.6.7 Starting MySQL as a Windows Service

On Windows, the recommended way to run MySQL is to install it as a Windows service, so that MySQL starts and stops automatically when Windows starts and stops. A MySQL server installed as a service can also be controlled from the command line using `SC` commands, `NET` commands, or the graphical `Services` utility. Generally, to install MySQL as a Windows service you should be logged in using an account that has administrator rights.

**Note**

`MySQL Notifier` can also be used to monitor the status of the MySQL service.

The `Services` utility (the Windows `Service Control Manager`) can be found in the Windows Control Panel. To avoid conflicts, it is advisable to close the `Services` utility while performing server installation or removal operations from the command line.
Installing the service

Before installing MySQL as a Windows service, you should first stop the current server if it is running by using the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin" -u root shutdown
```

**Note**

If the MySQL root user account has a password, you need to invoke `mysqladmin` with the `-p` option and supply the password when prompted.

This command invokes the MySQL administrative utility `mysqladmin` to connect to the server and tell it to shut down. The command connects as the MySQL root user, which is the default administrative account in the MySQL grant system.

**Note**

Users in the MySQL grant system are wholly independent from any operating system users under Windows.

Install the server as a service using this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --install
```

The service-installation command does not start the server. Instructions for that are given later in this section.

To make it easier to invoke MySQL programs, you can add the path name of the MySQL bin directory to your Windows system PATH environment variable:

- On the Windows desktop, right-click the My Computer icon, and select Properties.
- Next select the Advanced tab from the System Properties menu that appears, and click the Environment Variables button.
- Under System Variables, select Path, and then click the Edit button. The Edit System Variable dialogue should appear.
- Place your cursor at the end of the text appearing in the space marked Variable Value. (Use the End key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL bin directory (for example, `C:\Program Files\MySQL\MySQL Server 5.5\bin`), and there should be a semicolon separating this path from any values present in this field. Dismiss this dialogue, and each dialogue in turn, by clicking OK until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the `mysql` client, and all MySQL command-line utilities such as `mysqladmin` and `mysqldump`.

You should not add the MySQL bin directory to your Windows PATH if you are running multiple MySQL servers on the same machine.

**Warning**

You must exercise great care when editing your system PATH by hand; accidental deletion or modification of any portion of the existing PATH value can leave you with a malfunctioning or even unusable system.
The following additional arguments can be used when installing the service:

- You can specify a service name immediately following the `--install` option. The default service name is `MySQL`.

- If a service name is given, it can be followed by a single option. By convention, this should be `--defaults-file=file_name` to specify the name of an option file from which the server should read options when it starts.

  The use of a single option other than `--defaults-file` is possible but discouraged. `--defaults-file` is more flexible because it enables you to specify multiple startup options for the server by placing them in the named option file.

- You can also specify a `--local-service` option following the service name. This causes the server to run using the LocalService Windows account that has limited system privileges. This account is available only for Windows XP or newer. If both `--defaults-file` and `--local-service` are given following the service name, they can be in any order.

For a MySQL server that is installed as a Windows service, the following rules determine the service name and option files that the server uses:

- If the service-installation command specifies no service name or the default service name (`MySQL`) following the `--install` option, the server uses the service name of `MySQL` and reads options from the `[mysqld]` group in the standard option files.

- If the service-installation command specifies a service name other than `MySQL` following the `--install` option, the server uses that service name. It reads options from the `[mysqld]` group and the group that has the same name as the service in the standard option files. This enables you to use the `[mysqld]` group for options that should be used by all MySQL services, and an option group with the service name for use by the server installed with that service name.

- If the service-installation command specifies a `--defaults-file` option after the service name, the server reads options the same way as described in the previous item, except that it reads options only from the named file and ignores the standard option files.

As a more complex example, consider the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"
     --install MySQL --defaults-file=C:\my-opts.cnf
```

Here, the default service name (`MySQL`) is given after the `--install` option. If no `--defaults-file` option had been given, this command would have the effect of causing the server to read the `[mysqld]` group from the standard option files. However, because the `--defaults-file` option is present, the server reads options from the `[mysqld]` option group, and only from the named file.

**Note**

On Windows, if the server is started with the `--defaults-file` and `--install` options, `--install` must be first. Otherwise, `mysqld.exe` will attempt to start the MySQL server.

You can also specify options as Start parameters in the Windows Services utility before you start the MySQL service.

Finally, before trying to start the MySQL service, make sure the user variables `%TEMP%` and `%TMP%` (and also `%TMPDIR%`, if it has ever been set) for the operating system user who is to run the service are pointing to a folder to which the user has write access. The default user for running the MySQL service
Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive

is `LocalSystem`, and the default value for its `%TEMP%` and `%TMP%` is `C:\Windows\Temp`, a directory `LocalSystem` has write access to by default. However, if there are any changes to that default setup (for example, changes to the user who runs the service or to the mentioned user variables, or the `--tmpdir` option has been used to put the temporary directory somewhere else), the MySQL service might fail to run because write access to the temporary directory has not been granted to the proper user.

Starting the service

After a MySQL server instance has been installed as a service, Windows starts the service automatically whenever Windows starts. The service also can be started immediately from the Services utility, or by using an `sc start mysqld_service_name` or `NET START mysqld_service_name` command. SC and NET commands are not case-sensitive.

When run as a service, `mysqld` has no access to a console window, so no messages can be seen there. If `mysqld` does not start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. The error log is located in the MySQL data directory (for example, `C:\Program Files\MySQL\MySQL Server 5.5\data`). It is the file with a suffix of `.err`.

When a MySQL server has been installed as a service, and the service is running, Windows stops the service automatically when Windows shuts down. The server also can be stopped manually using the Services utility, the `sc stop mysqld_service_name` command, the `NET START mysqld_service_name` command, or the `mysqladmin shutdown` command.

You also have the choice of installing the server as a manual service if you do not wish for the service to be started automatically during the boot process. To do this, use the `--install-manual` option rather than the `--install` option:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --install-manual
```

Removing the service

To remove a server that is installed as a service, first stop it if it is running by executing `SC STOP mysqld_service_name` or `NET STOP mysqld_service_name`. Then use `SC DELETE mysqld_service_name` to remove it:

```
C:\> SC DELETE mysql
```

Alternatively, use the `mysqld --remove` option to remove the service.

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --remove
```

If `mysqld` is not running as a service, you can start it from the command line. For instructions, see Section 2.3.6.5, “Starting MySQL from the Windows Command Line”.

If you encounter difficulties during installation, see Section 2.3.7, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

For more information about stopping or removing a Windows service, see Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”.

2.3.6.8 Testing The MySQL Installation

You can test whether the MySQL server is working by executing any of the following commands:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqlshow"
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqlshow" -u root mysql
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin" version status proc
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysql" test
```
If `mysqld` is slow to respond to TCP/IP connections from client programs, there is probably a problem with your DNS. In this case, start `mysqld` with the `skip_name_resolve` system variable enabled and use only `localhost` and IP addresses in the Host column of the MySQL grant tables. (Be sure that an account exists that specifies an IP address or you may not be able to connect.)

You can force a MySQL client to use a named-pipe connection rather than TCP/IP by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying . (period) as the host name. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

If you have set a password for the root account, deleted the anonymous account, or created a new user account, then to connect to the MySQL server you must use the appropriate `-u` and `-p` options with the commands shown previously. See Section 4.2.4, “Connecting to the MySQL Server Using Command Options”. For more information about `mysqlshow`, see Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”.

2.3.7 Troubleshooting a Microsoft Windows MySQL Server Installation

When installing and running MySQL for the first time, you may encounter certain errors that prevent the MySQL server from starting. This section helps you diagnose and correct some of these errors.

Your first resource when troubleshooting server issues is the error log. The MySQL server uses the error log to record information relevant to the error that prevents the server from starting. The error log is located in the data directory specified in your `my.ini` file. The default data directory location is `C:\Program Files\MySQL\MySQL Server 5.5\data`, or `C:\ProgramData\MySQL\mysql` on Windows 7 and Windows Server 2008. The `C:\ProgramData` directory is hidden by default. You need to change your folder options to see the directory and contents. For more information on the error log and understanding the content, see Section 5.4.2, “The Error Log”.

For information regarding possible errors, also consult the console messages displayed when the MySQL service is starting. Use the `SC START mysqld_service_name` or `NET START mysqld_service_name` command from the command line after installing `mysqld` as a service to see any error messages regarding the starting of the MySQL server as a service. See Section 2.3.6.7, “Starting MySQL as a Windows Service”.

The following examples show other common error messages you might encounter when installing MySQL and starting the server for the first time:

- If the MySQL server cannot find the `mysql` privileges database or other critical files, it displays these messages:

  System error 1067 has occurred.
  Fatal error: Can't open and lock privilege tables:
  Table 'mysql.user' doesn't exist

  These messages often occur when the MySQL base or data directories are installed in different locations than the default locations (`C:\Program Files\MySQL\MySQL Server 5.5\data` and `C:\Program Files\MySQL\MySQL Server 5.5\data`, respectively).

  This situation can occur when MySQL is upgraded and installed to a new location, but the configuration file is not updated to reflect the new location. In addition, old and new configuration files might conflict. Be sure to delete or rename any old configuration files when upgrading MySQL.

  If you have installed MySQL to a directory other than `C:\Program Files\MySQL\MySQL Server 5.5`, ensure that the MySQL server is aware of this through the use of a configuration (`my.ini`) file. Put
the `my.ini` file in your Windows directory, typically \C:\WINDOWS. To determine its exact location from the value of the `WINDIR` environment variable, issue the following command from the command prompt:

```
C:\> echo %WINDIR%
```

You can create or modify an option file with any text editor, such as Notepad. For example, if MySQL is installed in `E:\mysql` and the data directory is `D:\MySQLdata`, you can create the option file and set up a `[mysqld]` section to specify values for the `basedir` and `datadir` options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=D:/MySQLdata
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=C:\Program Files\MySQL\MySQL Server 5.5
# set datadir to the location of your data directory
datadir=D:\MySQLdata
```

The rules for use of backslash in option file values are given in Section 4.2.2.2, “Using Option Files”.

If you change the `datadir` value in your MySQL configuration file, you must move the contents of the existing MySQL data directory before restarting the MySQL server.

See Section 2.3.6.2, “Creating an Option File”.

- If you reinstall or upgrade MySQL without first stopping and removing the existing MySQL service and install MySQL using the MySQL Installer, you might see this error:

```
Error: Cannot create Windows service for MySql. Error: 0
```

This occurs when the Configuration Wizard tries to install the service and finds an existing service with the same name.

One solution to this problem is to choose a service name other than `mysql` when using the configuration wizard. This enables the new service to be installed correctly, but leaves the outdated service in place. Although this is harmless, it is best to remove old services that are no longer in use.

To permanently remove the old `mysql` service, execute the following command as a user with administrative privileges, on the command line:

```
C:\> SC DELETE mysql
[SC] DeleteService SUCCESS
```

If the `SC` utility is not available for your version of Windows, download the `delsrv` utility from [http://www.microsoft.com/windows2000/techinfo/reskit/tools/existing/delsrv-o.asp](http://www.microsoft.com/windows2000/techinfo/reskit/tools/existing/delsrv-o.asp) and use the `delsrv mysql` syntax.

### 2.3.8 Windows Postinstallation Procedures

GUI tools exist that perform most of the tasks described in this section, including:

- **MySQL Installer**: Used to install and upgrade MySQL products.
- **MySQL Workbench**: Manages the MySQL server and edits SQL statements.
• MySQL Notifier: Starts, stops, or restarts the MySQL server, and monitors its status.

• MySQL for Excel: Edits MySQL data with Microsoft Excel.

On Windows, you need not create the data directory and the grant tables. MySQL distributions for Windows include the grant tables with a set of preinitialized accounts in the `mysql` database under the data directory.

Regarding passwords, if you installed MySQL using the MySQL Installer, you may have already assigned passwords to the accounts. (See Section 2.3.3, “MySQL Installer for Windows”.) Otherwise, use the password-assignment procedure given in Section 2.10.4, “Securing the Initial MySQL Accounts”.

Before assigning passwords, you might want to try running some client programs to make sure that you can connect to the server and that it is operating properly. Make sure that the server is running (see Section 2.3.6.4, “Starting the Server for the First Time”). You can also set up a MySQL service that runs automatically when Windows starts (see Section 2.3.6.7, “Starting MySQL as a Windows Service”).

These instructions assume that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

If you installed MySQL using MySQL Installer (see Section 2.3.3, “MySQL Installer for Windows”), the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.5`:

```
c:\> cd "C:\Program Files\MySQL\MySQL Server 5.5"
```

A common installation location for installation from a ZIP archive is `C:\mysql`:

```
c:\> cd C:\mysql
```

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your command interpreter to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 2.3.6.6, “Customizing the PATH for MySQL Tools”.

With the server running, issue the following commands to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
c:\> bin\mysqlshow
```

```
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| test               |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

The preceding command (and commands for other MySQL programs such as `mysql`) may not work if the correct MySQL account does not exist. For example, the program may fail with an error, or you may not be able to view all databases. If you installed MySQL using MySQL Installer, the `root` user will have been created automatically with the password you supplied. In this case, you should use the `-u root` and `-p` options. (You must use those options if you have already secured the initial MySQL accounts.) With `-p`, the client program prompts for the `root` password. For example:
2.3.9 Windows Platform Restrictions

The following restrictions apply to use of MySQL on the Windows platform:

- **Process memory**

  On Windows 32-bit platforms, it is not possible by default to use more than 2GB of RAM within a single process, including MySQL. This is because the physical address limit on Windows 32-bit is 4GB and...
the default setting within Windows is to split the virtual address space between kernel (2GB) and user applications (2GB).

Some versions of Windows have a boot time setting to enable larger applications by reducing the kernel application. Alternatively, to use more than 2GB, use a 64-bit version of Windows.

**File system aliases**

When using **MyISAM** tables, you cannot use aliases within Windows link to the data files on another volume and then link back to the main MySQL **datadir** location.

This facility is often used to move the data and index files to a RAID or other fast solution, while retaining the main **.frm** files in the default data directory configured with the **datadir** option.

**Limited number of ports**

Windows systems have about 4,000 ports available for client connections, and after a connection on a port closes, it takes two to four minutes before the port can be reused. In situations where clients connect to and disconnect from the server at a high rate, it is possible for all available ports to be used up before closed ports become available again. If this happens, the MySQL server appears to be unresponsive even though it is running. Ports may be used by other applications running on the machine as well, in which case the number of ports available to MySQL is lower.

For more information about this problem, see [http://support.microsoft.com/default.aspx?scid=kb;en-us;196271](http://support.microsoft.com/default.aspx?scid=kb;en-us;196271).

**DATA DIRECTORY and INDEX DIRECTORY**

The **DATA DIRECTORY** and **INDEX DIRECTORY** options for **CREATE TABLE** are ignored on Windows, because MySQL does not support Windows symbolic links. These options also are ignored on systems that have a nonfunctional **realpath()** call.

**DROP DATABASE**

You cannot drop a database that is in use by another session.

**Case-insensitive names**

File names are not case-sensitive on Windows, so MySQL database and table names are also not case-sensitive on Windows. The only restriction is that database and table names must be specified using the same case throughout a given statement. See Section 9.2.3, “Identifier Case Sensitivity”.

**Directory and file names**

On Windows, MySQL Server supports only directory and file names that are compatible with the current ANSI code pages. For example, the following Japanese directory name will not work in the Western locale (code page 1252):

```
C:/私たちのプロジェクトのデータ*
```

The same limitation applies to directory and file names referred to in SQL statements, such as the data file path name in **LOAD DATA**.

**The \\ path name separator character**

Path name components in Windows are separated by the \ character, which is also the escape character in MySQL. If you are using **LOAD DATA** or **SELECT ... INTO OUTFILE**, use Unix-style file names with / characters:
Installing MySQL on OS X

Alternatively, you must double the \ character:

```sql
mysql> LOAD DATA INFILE 'C:\\tmp\\skr.txt' INTO TABLE skr;
mysql> SELECT * INTO OUTFILE 'C:\\tmp\\skr.txt' FROM skr;
```

• Problems with pipes

Pipes do not work reliably from the Windows command-line prompt. If the pipe includes the character `^Z` or `CHAR(24)`, Windows thinks that it has encountered end-of-file and aborts the program.

This is mainly a problem when you try to apply a binary log as follows:

```
C:\> mysqlbinlog binary_log_file | mysql --user=root
```

If you have a problem applying the log and suspect that it is because of a `^Z` or `CHAR(24)` character, you can use the following workaround:

```
C:\> mysqlbinlog binary_log_file --result-file=/tmp/bin.sql
C:\> mysql --user=root --execute "source /tmp/bin.sql"
```

The latter command also can be used to reliably read any SQL file that may contain binary data.

2.4 Installing MySQL on OS X

For a list of OS X versions that the MySQL server supports, see https://www.mysql.com/support/supportedplatforms/database.html.

MySQL for OS X is available in a number of different forms:

• Native Package Installer, which uses the native OS X installer (DMG) to walk you through the installation of MySQL. For more information, see Section 2.4.2, “Installing MySQL on OS X Using Native Packages”. You can use the package installer with OS X. The user you use to perform the installation must have administrator privileges.

• Compressed TAR archive, which uses a file packaged using the Unix `tar` and `gzip` commands. To use this method, you will need to open a Terminal window. You do not need administrator privileges using this method, as you can install the MySQL server anywhere using this method. For more information on using this method, you can use the generic instructions for using a tarball, Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

In addition to the core installation, the Package Installer also includes Section 2.4.3, “Installing a MySQL Launch Daemon” and Section 2.4.4, “Installing and Using the MySQL Preference Pane”, both of which simplify the management of your installation.

For additional information on using MySQL on OS X, see Section 2.4.1, “General Notes on Installing MySQL on OS X”.

2.4.1 General Notes on Installing MySQL on OS X

You should keep the following issues and notes in mind:

• As of MySQL server 5.5.45, the DMG bundles a launchd daemon instead of the deprecated startup item. Startup items do not function as of OS X 10.10 (Yosemite), so using launchd is preferred. The available MySQL preference pane under OS X System Preferences was also updated to use launchd.
• You may need (or want) to create a specific `mysql` user to own the MySQL directory and data. You can do this through the Directory Utility, and the `mysql` user should already exist. For use in single user mode, an entry for `_mysql` (note the underscore prefix) should already exist within the system `/etc/passwd` file.

• Because the MySQL package installer installs the MySQL contents into a version and platform specific directory, you can use this to upgrade and migrate your database between versions. You will need to either copy the `data` directory from the old version to the new version, or alternatively specify an alternative `datadir` value to set location of the data directory. By default, the MySQL directories are installed under `/usr/local/`.

• You might want to add aliases to your shell’s resource file to make it easier to access commonly used programs such as `mysql` and `mysqladmin` from the command line. The syntax for `bash` is:

  ```
  alias mysql=/usr/local/mysql/bin/mysql
  alias mysqladmin=/usr/local/mysql/bin/mysqladmin
  ```

  For `tcsh`, use:

  ```
  alias mysql /usr/local/mysql/bin/mysql
  alias mysqladmin /usr/local/mysql/bin/mysqladmin
  ```

  Even better, add `/usr/local/mysql/bin` to your `PATH` environment variable. You can do this by modifying the appropriate startup file for your shell. For more information, see Section 4.2.1, “Invoking MySQL Programs”.

• After you have copied over the MySQL database files from the previous installation and have successfully started the new server, you should consider removing the old installation files to save disk space. Additionally, you should also remove older versions of the Package Receipt directories located in `/Library/Receipts/mysql-VERSION.pkg`.

• Prior to OS X 10.7, MySQL server was bundled with OS X Server.

### 2.4.2 Installing MySQL on OS X Using Native Packages

The package is located inside a disk image (.dmg) file that you first need to mount by double-clicking its icon in the Finder. It should then mount the image and display its contents.

**Note**

Before proceeding with the installation, be sure to stop all running MySQL server instances by using either the MySQL Manager Application (on OS X Server), the preference pane, or `mysqladmin shutdown` on the command line.

When installing from the package version, you can also install the MySQL preference pane, which will enable you to control the startup and execution of your MySQL server from System Preferences. For more information, see Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

When installing using the package installer, the files are installed into a directory within `/usr/local` matching the name of the installation version and platform. For example, the installer file `mysql-5.5.62-osx10.9-x86_64.dmg` installs MySQL into `/usr/local/mysql-5.5.62-osx10.9-x86_64/`. The following table shows the layout of the installation directory.

**Table 2.11 MySQL Installation Layout on OS X**

<table>
<thead>
<tr>
<th>Directory</th>
<th>Contents of Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bin, scripts</code></td>
<td><code>mysqld</code> server, client and utility programs</td>
</tr>
</tbody>
</table>
During the package installer process, a symbolic link from `/usr/local/mysql` to the version/platform specific directory created during installation will be created automatically.

1. Download and open the MySQL package installer, which is provided on a disk image (.dmg) that includes the main MySQL installation package file. Double-click the disk image to open it.

   ![Figure 2.25 MySQL Package Installer: DMG Contents](image)

   **Figure 2.25 MySQL Package Installer: DMG Contents**

2. Double-click the MySQL installer package. It will be named according to the version of MySQL you have downloaded. For example, if you have downloaded MySQL server 5.5.62, double-click `mysql-5.5.62-osx-10.9-x86_64.pkg`.

3. You will be presented with the opening installer dialog. Click **Continue** to begin installation.
4. If you have downloaded the community version of MySQL, you will be shown a copy of the relevant GNU General Public License. Click **Continue** and then **Agree** to continue.
5. From the Installation Type page you can either click Install to execute the installation wizard using all defaults, click Customize to alter which components to install (MySQL server, Preference Pane, Launchd Support -- all enabled by default).

Note

Although the Change Install Location option is visible, the installation location cannot be changed.

Figure 2.27 MySQL Package Installer: Installation Type
6. Click **Install** to begin the installation process.
7. Once the installation has been completed successfully, you will be shown an **Install Succeeded** message with a short summary. Now, **Close** the wizard and begin using the MySQL server.

**Figure 2.29 MySQL Package Installer: Summary**

MySQL server is now installed, but it is not loaded (started) by default. Use either launchctl from the command line, or start MySQL by clicking "Start" using the MySQL preference pane. For additional information, see Section 2.4.3, “Installing a MySQL Launch Daemon”, and Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

### 2.4.3 Installing a MySQL Launch Daemon

OS X uses launch daemons to automatically start, stop, and manage processes and applications such as MySQL.

**Note**

Before MySQL 5.5.45, the OS X builds installed startup items instead of launchd daemons. However, startup items do not function as of OS X 10.10 (Yosemite). The OS X builds now install launchd daemons.

By default, the installation package (DMG) on OS X installs a launchd file named `/Library/LaunchDaemons/com.oracle.oss.mysql.mysqld.plist` that contains a plist definition similar to:

```xml
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE plist PUBLIC "-//Apple Computer//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList-1.0.dtd">
```
Installing a MySQL Launch Daemon

```xml
<plist version="1.0">
  <dict>
    <key>Label</key>             <string>com.oracle.oss.mysql.mysqld</string>
    <key>ProcessType</key>       <string>Interactive</string>
    <key>Disabled</key>          <false/>
    <key>RunAtLoad</key>         <true/>
    <key>KeepAlive</key>         <true/>
    <key>SessionCreate</key>     <true/>
    <key>LaunchOnlyOnce</key>    <false/>
    <key>UserName</key>          <string>_mysql</string>
    <key>GroupName</key>         <string>_mysql</string>
    <key>ExitTimeOut</key>       <integer>600</integer>
    <key>Program</key>           <string>/usr/local/mysql/bin/mysqld</string>
    <key>ProgramArguments</key>
      <array>
        <string>/usr/local/mysql/bin/mysqld</string>
        <string>--user=_mysql</string>
        <string>--basedir=/usr/local/mysql</string>
        <string>--datadir=/usr/local/mysql/data</string>
        <string>--plugin-dir=/usr/local/mysql/lib/plugin</string>
        <string>--log-error=/usr/local/mysql/data/mysqld.local.err</string>
        <string>--pid-file=/usr/local/mysql/data/mysqld.local.pid</string>
        <string>--port=3306</string>
      </array>
    <key>WorkingDirectory</key>  <string>/usr/local/mysql</string>
  </dict>
</plist>

Note

Some users report that adding a plist DOCTYPE declaration causes the launchd operation to fail, despite it passing the lint check. We suspect it's a copy-n-paste error. The md5 checksum of a file containing the above snippet is 60d7963a0bb2994b69b8b9c123db09df.

To enable the launchd service, you can either:

- Click Start MySQL Server from the MySQL preference pane.
Figure 2.30 MySQL Preference Pane: Location
• Or, manually load the launchd file.

```
shell> cd /Library/LaunchDaemons
shell> sudo launchctl load -F com.oracle.oss.mysql.mysqld.plist
```

**Note**
When upgrading MySQL server, the launchd installation process will remove the old startup items that were installed with MySQL server 5.5.44 and below.

### 2.4.4 Installing and Using the MySQL Preference Pane

The MySQL Installation Package includes a MySQL preference pane that enables you to start, stop, and control automated startup during boot of your MySQL installation.

This preference pane is installed by default, and is listed under your system’s *System Preferences* window.
To install the MySQL Preference Pane:

1. Download and open the MySQL package installer, which is provided on a disk image (.dmg) that includes the main MySQL installation package.

**Note**

Before MySQL 5.5.45, OS X packages included the deprecated startup items instead of launchd daemons, and the preference pane managed that instead of launchd.
2. Go through the process of installing the MySQL server, as described in the documentation at Section 2.4.2, “Installing MySQL on OS X Using Native Packages”.
3. Click **Customize** at the **Installation Type** step. The “Preference Pane” option is listed there and enabled by default.

**Figure 2.34 MySQL Installer on OS X: Customize**

4. Complete the MySQL server installation process.

**Note**

The MySQL preference pane only starts and stops MySQL installation installed from the MySQL package installation that have been installed in the default location.

Once the MySQL preference pane has been installed, you can control your MySQL server instance using the preference pane. To use the preference pane, open the **System Preferences...** from the Apple menu. Select the MySQL preference pane by clicking the MySQL icon within the preference panes list.
Figure 2.35 MySQL Preference Pane: Location
The MySQL Preference Pane shows the current status of the MySQL server, showing **stopped** (in red) if the server is not running and **running** (in green) if the server has already been started. The preference pane also shows the current setting for whether the MySQL server has been set to start automatically.

- **To start the MySQL server using the preference pane:**
  
  Click **Start MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to start the MySQL server.

- **To stop the MySQL server using the preference pane:**
  
  Click **Stop MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to stop the MySQL server.

- **To automatically start the MySQL server when the system boots:**
  
  Check the check box next to **Automatically Start MySQL Server on Startup**.

- **To disable automatic MySQL server startup when the system boots:**
  
  Uncheck the check box next to **Automatically Start MySQL Server on Startup**.

You can close the **System Preferences...** window once you have completed your settings.

### 2.5 Installing MySQL on Linux

Linux supports a number of different solutions for installing MySQL. The recommended method is to use one of the distributions from Oracle. If you choose this method, there are several options available:

- Installing from a generic binary package in **.tar.gz** format. For details, see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".
Installing MySQL on Linux Using RPM Packages

- Extracting and compiling MySQL from a source distribution. For details, see Section 2.9, “Installing MySQL from Source”.

- Installing using a precompiled RPM package. For details, see Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

- Installing using a precompiled Debian package. For details, see Section 2.5.2, “Installing MySQL on Linux Using Debian Packages”.

- Deploying MySQL Server with Docker. For details, see Section 2.5.3, “Deploying MySQL on Linux with Docker”.

- Installing using Oracle's Unbreakable Linux Network (ULN). For details, see Section 2.6, “Installing MySQL Using Unbreakable Linux Network (ULN)”.

As an alternative, you can use the native package manager within your Linux distribution to automatically download and install MySQL for you. Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some versions behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository. For more information on using the native package installers, see Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”.

2.5.1 Installing MySQL on Linux Using RPM Packages

Note

For many Linux installations, you will want to set up MySQL to be started automatically when your machine starts. Many of the native package installations perform this operation for you, but for source, binary and RPM solutions you may need to set this up separately. The required script, `mysql.server`, can be found in the `support-files` directory under the MySQL installation directory or in a MySQL source tree. You can install it as `/etc/init.d/mysql` for automatic MySQL startup and shutdown. See Section 4.3.3, “mysql.server — MySQL Server Startup Script”.

2.5.1 Installing MySQL on Linux Using RPM Packages

Note

To install or upgrade to MySQL 5.5.31, be sure to read the special instructions at the end of this section.

The recommended way to install MySQL on RPM-based Linux distributions is by using the RPM packages. The RPMs that we provide to the community should work on all versions of Linux that support RPM packages and use `glibc` 2.3. To obtain RPM packages, see Section 2.1.2, “How to Get MySQL”.

For non-RPM Linux distributions, you can install MySQL using a `.tar.gz` package. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

Installations created from our Linux RPM distributions result in files under the system directories shown in the following table.

Table 2.12 MySQL Installation Layout for Linux RPM Packages

<table>
<thead>
<tr>
<th>Directory</th>
<th>Contents of Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>/usr/bin</td>
<td>Client programs and scripts</td>
</tr>
</tbody>
</table>
Installing MySQL on Linux Using RPM Packages

<table>
<thead>
<tr>
<th>Directory</th>
<th>Contents of Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>/usr/sbin</td>
<td>The mysqld server</td>
</tr>
<tr>
<td>/var/lib/mysql</td>
<td>Log files, databases</td>
</tr>
<tr>
<td>/var/lib/mysql-files</td>
<td>Value of secure_file_priv</td>
</tr>
<tr>
<td>/usr/share/info</td>
<td>MySQL manual in Info format</td>
</tr>
<tr>
<td>/usr/share/man</td>
<td>Unix manual pages</td>
</tr>
<tr>
<td>/usr/include/mysql</td>
<td>Include (header) files</td>
</tr>
<tr>
<td>/usr/lib/mysql</td>
<td>Libraries</td>
</tr>
<tr>
<td>/usr/share/mysql</td>
<td>Miscellaneous support files, including error messages,</td>
</tr>
<tr>
<td></td>
<td>character set files, sample configuration files, SQL for</td>
</tr>
<tr>
<td></td>
<td>database installation</td>
</tr>
<tr>
<td>/usr/share/sql-bench</td>
<td>Benchmarks</td>
</tr>
</tbody>
</table>

**Note**

RPM distributions of MySQL are also provided by other vendors. Be aware that they may differ from those built by Oracle in features, capabilities, and conventions (including communication setup), and that the instructions in this manual do not necessarily apply to installing them. The vendor's instructions should be consulted instead. Because of these differences, RPM packages built by Oracle check whether such RPMs built by other vendors are installed. If so, the RPM does not install and produces a message explaining this.

Conflicts can arise when an RPM from another vendor is already installed, such as when a vendor's conventions about which files belong with the server and which belong with the client library differ from the breakdown used for Oracle packages. In such cases, attempts to install an Oracle RPM with `rpm -i` may result in messages that files in the RPM to be installed conflict with files from an installed package (denoted `mysql-libs` in the following paragraphs).

Each MySQL release provides a MySQL-shared-compat package that is meant to replace `mysql-libs` and provides a replacement-compatible client library for older MySQL series. MySQL-shared-compat is set up to make `mysql-libs` obsolete, but `rpm` explicitly refuses to replace obsoleted packages when invoked with `-i` (unlike `-U`), which is why installation with `rpm -i` produces a conflict.

MySQL-shared-compat can safely be installed alongside `mysql-libs` because libraries are installed to different locations. Therefore, it is possible to install MySQL-shared-compat first, then manually remove `mysql-libs` before continuing with the installation. After `mysql-libs` is removed, the dynamic linker stops looking for the client library in the location where `mysql-libs` puts it, and the library provided by the MySQL-shared-compat package takes over.

Another alternative is to install packages using `yum`. In a directory containing all RPM packages for a MySQL release, `yum install MySQL*rpm` installs them in the correct order and removes `mysql-libs` in one step without conflicts.

In most cases, you need install only the MySQL-server and MySQL-client packages to get a functional standard MySQL installation. The other packages are not required for a standard installation.

**RPMs for NDB Cluster.** Standard MySQL server RPMs built by MySQL do not provide support for the NDBCLUSTER storage engine.
Important
When upgrading an NDB Cluster RPM installation, you must upgrade all installed RPMs, including the Server and Client RPMs.

For more information about installing NDB Cluster from RPMs, see Section 18.2, “NDB Cluster Installation”.

For upgrades, if your installation was originally produced by installing multiple RPM packages, it is best to upgrade all the installed packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.

If the data directory exists at RPM installation time, the installation process does not modify existing data. This has the effect, for example, that accounts in the grant tables are not initialized to the default set of accounts.

If you get a dependency failure when trying to install MySQL packages (for example, error: removing these packages would break dependencies: libmysqlclient.so.10 is needed by ...), you should also install the MySQL-shared-compat package, which includes the shared libraries for older releases for backward compatibility.

The following list shows the available RPM packages. The names shown here use a suffix of .glibc23.i386.rpm, but particular packages can have different suffixes, described later. If you plan to install multiple RPM packages, you may wish to download the RPM Bundle tar file instead, which contains multiple RPM packages so that you need not download them separately.

• MySQL-server-VERSION.glibc23.i386.rpm
  The MySQL server. You need this unless you only want to connect to a MySQL server running on another machine.

• MySQL-client-VERSION.glibc23.i386.rpm
  The standard MySQL client programs. You probably always want to install this package.

• MySQL-devel-VERSION.glibc23.i386.rpm
  The libraries and include files needed to compile other MySQL clients, such as the Perl MySQL module. Install this RPM if you intend to compile C API applications.

• MySQL-shared-VERSION.glibc23.i386.rpm
  The shared libraries (libmysqlclient.so*) that certain languages and applications need to dynamically load and use MySQL. It contains single-threaded and thread-safe libraries. Install this RPM if you intend to compile or run C API applications that depend on the shared client library. Prior to MySQL 5.5.6, if you install this package, do not install the MySQL-shared-compat package.

• MySQL-shared-compat-VERSION.glibc23.i386.rpm
  The shared libraries for older releases. It contains single-threaded and thread-safe libraries. Install this package if you have applications installed that are dynamically linked against older versions of MySQL but you want to upgrade to the current version without breaking the library dependencies. Before MySQL 5.5.6, MySQL-shared-compat also includes the libraries for the current release, so if you install it, you should not also install MySQL-shared. As of 5.5.6, MySQL-shared-compat does not include the current library version, so there is no conflict.

As of MySQL 5.5.23, the MySQL-shared-compat RPM package enables users of Red Hat-provided mysql-*/5.1 RPM packages to migrate to Oracle-provided MySQL-*/5.5 packages.
shared-compat replaces the Red Hat mysql-libs package by replacing libmysqlclient.so files of the latter package, thus satisfying dependencies of other packages on mysql-libs. This change affects only users of Red Hat (or Red Hat-compatible) RPM packages. Nothing is different for users of Oracle RPM packages.

- **MySQL-embedded-VERSION.glibc23.i386.rpm**
  
  The embedded MySQL server library.

- **MySQL-test-VERSION.glibc23.i386.rpm**
  
  The MySQL test suite.

- **MySQL-VERSION.src.rpm**
  
  The source code for all of the previous packages. It can also be used to rebuild the RPMs on other architectures (for example, SPARC).

In RPM package names, the suffix (following the VERSION value) has the following syntax:

```
.PLATFORM.CPU.rpm
```

The PLATFORM and CPU values indicate the type of system for which the package is built. PLATFORM indicates the platform and CPU indicates the processor type or family.

All packages are dynamically linked against glibc 2.3. The PLATFORM value indicates whether the package is platform independent or intended for a specific platform, as shown in the following table.

**Table 2.13 MySQL Linux RPM Package Platforms**

<table>
<thead>
<tr>
<th>PLATFORM Value</th>
<th>Intended Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>glibc23</td>
<td>Platform independent, should run on any Linux distribution that supports glibc 2.3</td>
</tr>
<tr>
<td>rhel4,rhel5</td>
<td>Red Hat Enterprise Linux 4 or 5</td>
</tr>
<tr>
<td>el6</td>
<td>Enterprise Linux 6</td>
</tr>
<tr>
<td>sles10,sles11</td>
<td>SuSE Linux Enterprise Server 10 or 11</td>
</tr>
</tbody>
</table>

In MySQL 5.5, only glibc23 packages are available currently.

The CPU value indicates the processor type or family for which the package is built, as shown in the following table.

**Table 2.14 MySQL Linux RPM Package CPU Identifiers**

<table>
<thead>
<tr>
<th>CPU Value</th>
<th>Intended Processor Type or Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>i386,i586,i686</td>
<td>Pentium processor or better, 32 bit</td>
</tr>
<tr>
<td>x86_64</td>
<td>64-bit x86 processor</td>
</tr>
<tr>
<td>ia64</td>
<td>Itanium (IA-64) processor</td>
</tr>
</tbody>
</table>

To see all files in an RPM package (for example, a MySQL-server RPM), run a command like this (modify the platform and CPU identifiers appropriately for your system):

```
shell> rpm -ql MySQL-server-VERSION.glibc23.i386.rpm
```

To perform a standard minimal installation, install the server and client RPMs:

```
shell> rpm -i MySQL-server-VERSION.glibc23.i386.rpm
```
Installing MySQL on Linux Using RPM Packages

To install MySQL on Linux using RPM packages, you can use the following command:

```shell
rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

To install only the client programs, install just the client RPM:

```shell
rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

RPM provides a feature to verify the integrity and authenticity of packages before installing them. To learn more about this feature, see Section 2.1.3, “Verifying Package Integrity Using MD5 Checksums or GnuPG”.

The server RPM places data under the `/var/lib/mysql` directory. The RPM also creates a login account for a user named `mysql` (if one does not exist) to use for running the MySQL server, and creates the appropriate entries in `/etc/init.d/` to start the server automatically at boot time. (This means that if you have performed a previous installation and have made changes to its startup script, you may want to make a copy of the script so that you can reinstall it after you install a newer RPM.) See Section 2.10.5, “Starting and Stopping MySQL Automatically”, for more information on how MySQL can be started automatically at system startup.

In MySQL 5.5.5 and later, during a new installation using RPM packages, the server boot scripts are installed, but the MySQL server is not started at the end of the installation, since the status of the server during an unattended installation is not known.

In MySQL 5.5.5 and later, during an upgrade installation using RPM packages, if the MySQL server is running when the upgrade occurs, the MySQL server is stopped, the upgrade occurs, and the MySQL server is restarted. If the MySQL server is not already running when the RPM upgrade occurs, the MySQL server is not started at the end of the installation.

If something goes wrong, you can find more information in the binary installation section. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

**Note**

The accounts created in the MySQL grant tables for an RPM installation initially have no passwords. After starting the server, you should assign passwords to them using the instructions in Section 2.10, “Postinstallation Setup and Testing”.

An RPM installation creates a user named `mysql` and a group named `mysql` on the system using the `useradd`, `groupadd`, and `usermod` commands. Those commands require appropriate administrative privileges, which is required for locally managed users and groups (as listed in the `/etc/passwd` and `/etc/group` files) by the RPM installation process being run by `root`.

If you log in as the `mysql` user, you may find that MySQL displays “Invalid (old?) table or database name” errors that mention `.mysqlgui`, `lost+found`, `.mysqlgui`, `.bash_history`, `.fonts.cache-1`, `.lesshst`, `.mysql_history`, `.profile`, `.viminfo`, and similar files created by MySQL or operating system utilities. You can safely ignore these error messages or remove the files or directories that cause them if you do not need them.

For nonlocal user management (LDAP, NIS, and so forth), the administrative tools may require additional authentication (such as a password), and will fail if the installing user does not provide this authentication. Even if they fail, the RPM installation will not abort but succeed, and this is intentional. If they failed, some of the intended transfer of ownership may be missing, and it is recommended that the system administrator then manually ensures some appropriate user and group exists and manually transfers ownership following the actions in the RPM spec file.

In MySQL 5.5.31, the RPM spec file has been updated, which has the following consequences:

- For a non-upgrade installation (no existing MySQL version installed), it possible to install MySQL using `yum`. 

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151
For upgrades, it is necessary to clean up any earlier MySQL installations. In effect, the update is performed by removing the old installations and installing the new one.

Additional details follow.

For a non-upgrade installation of MySQL 5.5.31, it is possible to install using `yum`:

```
shell> yum install MySQL-server-NEWVERSION.glibc23.i386.rpm
```

For upgrades to MySQL 5.5.31, the upgrade is performed by removing the old installation and installing the new one. To do this, use the following procedure:

1. Remove the existing 5.5.\textit{X} installation. \textit{OLDVERSION} is the version to remove.

```
shell> rpm -e MySQL-server-OLDVERSION.glibc23.i386.rpm
```

Repeat this step for all installed MySQL RPMs.

2. Install the new version. \textit{NEWVERSION} is the version to install.

```
shell> rpm -ivh MySQL-server-NEWVERSION.glibc23.i386.rpm
```

Alternatively, the removal and installation can be done using `yum`:

```
shell> yum remove MySQL-server-OLDVERSION.glibc23.i386.rpm
shell> yum install MySQL-server-NEWVERSION.glibc23.i386.rpm
```

For some Linux distributions, it might be necessary to increase the limit on number of file descriptors available to \texttt{mysqld}. See Section B.4.2.18, “File Not Found and Similar Errors”

### 2.5.2 Installing MySQL on Linux Using Debian Packages

Oracle provides Debian packages for installation on Debian or Debian-like Linux systems. To obtain a package, see Section 2.1.2, “How to Get MySQL”.

**Note**

Debian distributions of MySQL are also provided by other vendors. Be aware that they may differ from those built by us in features, capabilities, and conventions (including communication setup), and that the instructions in this manual do not necessarily apply to installing them. The vendor's instructions should be consulted instead.

Debian package files have names in \texttt{mysql-MVER-DVER-CPU.deb} format. \textit{MVER} is the MySQL version and \textit{DVER} is the Debian version. The \textit{CPU} value indicates the processor type or family for which the package is built, as shown in the following table.

<table>
<thead>
<tr>
<th>\textit{CPU} Value</th>
<th>Intended Processor Type or Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>i686</td>
<td>Pentium processor or better, 32 bit</td>
</tr>
<tr>
<td>x86_64</td>
<td>64-bit x86 processor</td>
</tr>
</tbody>
</table>

After downloading a Debian package, use the following command to install it;

```
shell> dpkg -i mysql-MVER-DVER-CPU.deb
```

The Debian package installs files in the \texttt{/opt/mysql/server-5.5} directory.
You may also need to install the **libaio** library if it is not already present on your system:

```shell
sudo apt-get install libaio1
```

### 2.5.3 Deploying MySQL on Linux with Docker

The Docker deployment framework supports easy installation and configuration of MySQL Server. This section explains how to use a MySQL Server Docker image.

You need to have Docker installed on your system before you can use a MySQL Server Docker image. See [Install Docker](#) for instructions.

**Important**

You need to either run `docker` commands with `sudo`, or create a `docker` user group, and then add it to any users who want to run `docker` commands. See details [here](#). Because Docker containers are always run with root privileges, you should understand the [Docker daemon attack surface](#) and properly mitigate the related risks.

The instructions for using the MySQL Docker container are divided into two sections.

#### 2.5.3.1 Basic Steps for MySQL Server Deployment with Docker

**Warning**

The MySQL Docker images maintained by the MySQL team are built specifically for Linux platforms. Other platforms are not supported, and users using these MySQL Docker images on them are doing so at their own risk.

- **Downloading a MySQL Server Docker Image**
- **Starting a MySQL Server Instance**
- **Connecting to MySQL Server from within the Container**
- **Container Shell Access**
- **Stopping and Deleting a MySQL Container**
- **More Topics on Deploying MySQL Server with Docker**

##### Downloading a MySQL Server Docker Image

Downloading the server image in a separate step is not strictly necessary; however, performing this step before you create your Docker container ensures your local image is up to date. To download the MySQL Community Server image, run this command:

```bash
docker pull mysql/mysql-server:tag
```

The `tag` is the label for the image version you want to pull (for example, 5.5, 5.6, 5.7, 8.0, or `latest`). If `:tag` is omitted, the `latest` label is used, and the image for the latest GA version of MySQL Community Server is downloaded. Refer to the list of tags for available versions on the [mysql/mysql-server page](#) in the Docker Hub.

You can list downloaded Docker images with this command:

```bash
shell> docker images
```

<table>
<thead>
<tr>
<th>REPOSITORY</th>
<th>TAG</th>
<th>IMAGE ID</th>
<th>CREATED</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>mysql/mysql-server</td>
<td>latest</td>
<td>3157d7f55f8d</td>
<td>4 weeks ago</td>
<td>241MB</td>
</tr>
</tbody>
</table>
Deploying MySQL on Linux with Docker

Starting a MySQL Server Instance

Start a new Docker container for the MySQL Server with this command:

```bash
docker run --name=mysql1 -d mysql/mysql-server:tag
```

The `--name` option, for supplying a custom name for your server container (mysql1 in the example), is optional; if no container name is supplied, a random one is generated. If the Docker image of the specified name and tag has not been downloaded by an earlier `docker pull` or `docker run` command, the image is now downloaded. After download completes, initialization for the container begins, and the container appears in the list of running containers when you run the `docker ps` command; for example:

```bash
shell> docker ps
CONTAINER ID   IMAGE                COMMAND                  CREATED             STATUS                              PORTS                NAMES
a24888f0d6f4   mysql/mysql-server   "/entrypoint.sh my..."   14 seconds ago      Up 13 seconds (health: starting)    3306/tcp, 33060/tcp  mysql1
```

The container initialization might take some time. When the server is ready for use, the `STATUS` of the container in the output of the `docker ps` command changes from `(health: starting)` to `(healthy)`.

The `-d` option used in the `docker run` command above makes the container run in the background. Use this command to monitor the output from the container:

```bash
docker logs mysql1
```

Once initialization is finished, the command's output is going to contain the random password generated for the root user; check the password with, for example, this command:

```bash
shell> docker logs mysql1 2>&1 | grep GENERATED
GENERATED ROOT PASSWORD: Axegh3kAJyDLarUbeMc&EShOs
```

Connecting to MySQL Server from within the Container

Once the server is ready, you can run the `mysql` client within the MySQL Server container you just started, and connect it to the MySQL Server. Use the `docker exec -it` command to start a `mysql` client inside the Docker container you have started, like the following:

```bash
docker exec -it mysql1 mysql -uroot -p
```

When asked, enter the generated root password (see the last step in Starting a MySQL Server Instance above on how to find the password). After you have connected a `mysql` client to the server, you should reset the server root password by issuing this statement:

```bash
mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'newpassword';
```

Substitute `newpassword` with the password of your choice. Once the password is reset, the server is ready for use.

Container Shell Access

To have shell access to your MySQL Server container, use the `docker exec -it` command to start a bash shell inside the container:

```bash
shell> docker exec -it mysql1 bash
bash-4.2#
```

You can then run Linux commands inside the container. For example, to view contents in the server’s data directory inside the container, use this command:

```bash
bash-4.2# ls /var/lib/mysql
auto.cnf  ca.pem  client-key.pem  ib_logfile0  ibdata1  mysql  mysql.sock.lock  private_key.pem
ca-key.pem  client-cert.pem  ib_buffer_pool  ib_logfile1  ibtmp1  mysql.sock  performance_schema  public_key.pem
```
Deploying MySQL on Linux with Docker

Stopping and Deleting a MySQL Container

To stop the MySQL Server container we have created, use this command:

```
docker stop mysql1
```

docker stop sends a SIGTERM signal to the mysqld process, so that the server is shut down gracefully.

Also notice that when the main process of a container (mysqld in the case of a MySQL Server container) is stopped, the Docker container stops automatically.

To start the MySQL Server container again:

```
docker start mysql1
```

To stop and start again the MySQL Server container with a single command:

```
docker restart mysql1
```

To delete the MySQL container, stop it first, and then use the docker rm command:

```
docker stop mysql1
docker rm mysql1
```

If you want the Docker volume for the server's data directory to be deleted at the same time, add the -v option to the docker rm command.

More Topics on Deploying MySQL Server with Docker

For more topics on deploying MySQL Server with Docker like server configuration, persisting data and configuration, server error log, and container environment variables, see Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”.

2.5.3.2 More Topics on Deploying MySQL Server with Docker

- The Optimized MySQL Installation for Docker
- Configuring the MySQL Server
- Persisting Data and Configuration Changes
- Running Additional Initialization Scripts
- Connect to MySQL from an Application in Another Docker Container
- Server Error Log
- Docker Environment Variables

The Optimized MySQL Installation for Docker

Docker images for MySQL are optimized for code size, which means they only include crucial components that are expected to be relevant for the majority of users who run MySQL instances in Docker containers. A MySQL Docker installation is different from a common, non-Docker installation in the following aspects:

- Included binaries are limited to:
  - /usr/bin/my_print_defaults
  - /usr/bin/mysql
Deploying MySQL on Linux with Docker

- /usr/bin/mysql_config
- /usr/bin/mysql_install_db
- /usr/bin/mysql_tzinfo_to_sql
- /usr/bin/mysql_upgrade
- /usr/bin/mysqladmin
- /usr/bin/mysqlcheck
- /usr/bin/mysqldump
- /usr/sbin/mysqld
- All binaries are stripped; they contain no debug information.

Configuring the MySQL Server

When you start the MySQL Docker container, you can pass configuration options to the server through the `docker run` command; for example, for the MySQL Server:

```
docker run --name mysql1 -d mysql/mysql-server --character-set-server=utf8mb4 --collation-server=utf8mb4_col
```

The command starts your MySQL Server with `utf8mb4` as the default character set and `utf8mb4_col` as the default collation for your databases.

Another way to configure the MySQL Server is to prepare a configuration file and mount it at the location of the server configuration file inside the container. See Persisting Data and Configuration Changes for details.

Persisting Data and Configuration Changes

Docker containers are in principle ephemeral, and any data or configuration are expected to be lost if the container is deleted or corrupted (see discussions here). Docker volumes, however, provides a mechanism to persist data created inside a Docker container. At its initialization, the MySQL Server container creates a Docker volume for the server data directory. The JSON output for running the `docker inspect` command on the container has a `Mount` key, whose value provides information on the data directory volume:

```
shell> docker inspect mysql1
```

```
"Mounts": [
  {
    "Type": "volume",
    "Name": "4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e845d27652",
    "Source": "/var/lib/docker/volumes/4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e845d27652/_data",
    "Destination": "/var/lib/mysql",
    "Driver": "/var/lib/mysql",
    "Mode": ":",
    "RW": true,
    "Propagation": ""
  }
],
```

The output shows that the source folder `/var/lib/docker/volumes/4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e845d27652/_data`,
Deploying MySQL on Linux with Docker

in which data is persisted on the host, has been mounted at `/var/lib/mysql`, the server data directory inside the container.

Another way to preserve data is to bind-mount a host directory using the `--mount` option when creating the container. The same technique can be used to persist the configuration of the server. The following command creates a MySQL Server container and bind-mounts both the data directory and the server configuration file:

```
docker run --name=mysql1  
  --mount type=bind,src=/path-on-host-machine/my.cnf,dst=/etc/my.cnf  
  --mount type=bind,src=/path-on-host-machine/datadir,dst=/var/lib/mysql  
  -d mysql/mysql-server:tag
```

The command mounts `path-on-host-machine/my.cnf` at `/etc/my.cnf` (the server configuration file inside the container), and `path-on-host-machine/datadir` at `/var/lib/mysql` (the data directory inside the container). The following conditions must be met for the bind-mounting to work:

- The configuration file `path-on-host-machine/my.cnf` must already exist, and it must contain the specification for starting the server using the user `mysql`:

  ```
  [mysqld]
  user=mysql
  ```

  You can also include other server configuration options in the file.

- The data directory `path-on-host-machine/datadir` must already exist. For server initialization to happen, the directory must be empty. You can also mount a directory prepopulated with data and start the server with it; however, you must make sure you start the Docker container with the same configuration as the server that created the data, and any host files or directories required are mounted when starting the container.

### Running Additional Initialization Scripts

If there are any `.sh` or `.sql` scripts you want to run on the database immediately after it has been created, you can put them into a host directory and then mount the directory at `/docker-entrypoint-initdb.d/` inside the container. For example, for a MySQL Server container:

```
docker run --name=mysql1  
  --mount type=bind,src=/path-on-host-machine/scripts/,dst=/docker-entrypoint-initdb.d/  
  -d mysql/mysql-server:tag
```

### Connect to MySQL from an Application in Another Docker Container

By setting up a Docker network, you can allow multiple Docker containers to communicate with each other, so that a client application in another Docker container can access the MySQL Server in the server container. First, create a Docker network:

```
docker network create my-custom-net
```

Then, when you are creating and starting the server and the client containers, use the `--network` option to put them on network you created. For example:

```
docker run --name=mysql1 --network=my-custom-net -d mysql/mysql-server

docker run --name=myapp1 --network=my-custom-net -d myapp
```

The `myapp1` container can then connect to the `mysql1` container with the `mysql1` hostname and vice versa, as Docker automatically sets up a DNS for the given container names. In the following example, we run the `mysql` client from inside the `myapp1` container to connect to host `mysql1` in its own container:

```
docker exec -it myapp1 mysql --host=mysql1 --user=myuser --password
```
For other networking techniques for containers, see the Docker container networking section in the Docker Documentation.

Server Error Log

When the MySQL Server is first started with your server container, a server error log is NOT generated if either of the following conditions is true:

- A server configuration file from the host has been mounted, but the file does not contain the system variable `log_error` (see Persisting Data and Configuration Changes on bind-mounting a server configuration file).

- A server configuration file from the host has not been mounted, but the Docker environment variable `MYSQL_LOG_CONSOLE` is `true` (the variable's default state for MySQL 5.5 server containers is `false`). The MySQL Server's error log is then redirected to `stderr`, so that the error log goes into the Docker container's log and is viewable using the `docker logs mysqld-container` command.

To make MySQL Server generate an error log when either of the two conditions is true, use the `--log-error` option to configure the server to generate the error log at a specific location inside the container. To persist the error log, mount a host file at the location of the error log inside the container as explained in Persisting Data and Configuration Changes. However, you must make sure your MySQL Server inside its container has write access to the mounted host file.

Docker Environment Variables

When you create a MySQL Server container, you can configure the MySQL instance by using the `--env` option (`-e` in short) and specifying one or more of the following environment variables.

Notes

- None of the variables below has any effect if the data directory you mount is not empty, as no server initialization is going to be attempted then (see Persisting Data and Configuration Changes for more details). Any pre-existing contents in the folder, including any old server settings, are not modified during the container startup.

- The boolean variables including `MYSQL_RANDOM_ROOT_PASSWORD`, `MYSQL_ALLOW EMPTY PASSWORD`, and `MYSQL LOG_CONSOLE` are made true by setting them with any strings of nonzero lengths. Therefore, setting them to, for example, “0”, “false”, or “no” does not make them false, but actually makes them true. This is a known issue of the MySQL Server containers.

- `MYSQL_RANDOM_ROOT_PASSWORD`: When this variable is true (which is its default state, unless `MYSQL_ROOT_PASSWORD` or `MYSQL_ALLOW EMPTY PASSWORD` is set to true), a random password for the server's root user is generated when the Docker container is started. The password is printed to `stdout` of the container and can be found by looking at the container’s log (see Starting a MySQL Server Instance).

- `MYSQL_DATABASE`: This variable allows you to specify the name of a database to be created on image startup. If a user name and a password are supplied with `MYSQL_USER` and `MYSQL_PASSWORD`, the user is created and granted superuser access to this database (corresponding to `GRANT ALL`). The specified database is created by a `CREATE DATABASE IF NOT EXIST` statement, so that the variable has no effect if the database already exists.

- `MYSQL_USER, MYSQL_PASSWORD`: These variables are used in conjunction to create a user and set that user's password, and the user is granted superuser permissions for the database specified by the `MYSQL_DATABASE` variable. Both `MYSQL_USER` and `MYSQL_PASSWORD` are required for a user
to be created—if any of the two variables is not set, the other is ignored. If both variables are set but `MYSQL_DATABASE` is not, the user is created without any privileges.

**Note**

There is no need to use this mechanism to create the root superuser, which is created by default with the password set by either one of the mechanisms discussed in the descriptions for `MYSQL_ROOT_PASSWORD` and `MYSQL_RANDOM_ROOT_PASSWORD`, unless `MYSQL_ALLOW_EMPTY_PASSWORD` is true.

- **MYSQL_ROOT_HOST**: By default, MySQL creates the `root'@'localhost` account. This account can only be connected to from inside the container as described in Connecting to MySQL Server from within the Container. To allow root connections from other hosts, set this environment variable. For example, the value `172.17.0.1`, which is the default Docker gateway IP, allows connections from the host machine that runs the container. The option accepts only one entry, but wildcards are allowed (for example, `MYSQL_ROOT_HOST=172.*.*.*` or `MYSQL_ROOT_HOST=%`).

- **MYSQL_LOG_CONSOLE**: When the variable is true (the variable's default state for MySQL 5.5 server containers is `false`), the MySQL Server's error log is redirected to `stderr`, so that the error log goes into the Docker container's log and is viewable using the `docker logs mysqld-container` command.

  **Note**

  The variable has no effect if a server configuration file from the host has been mounted (see Persisting Data and Configuration Changes on bind-mounting a configuration file).

- **MYSQL_ROOT_PASSWORD**: This variable specifies a password that is set for the MySQL root account.

  **Warning**

  Setting the MySQL root user password on the command line is insecure. As an alternative to specifying the password explicitly, you can set the variable with a container file path for a password file, and then mount a file from your host that contains the password at the container file path. This is still not very secure, as the location of the password file is still exposed. It is preferable to use the default settings of `MYSQL_RANDOM_ROOT_PASSWORD=true` being true.

- **MYSQL_ALLOW_EMPTY_PASSWORD**. Set it to true to allow the container to be started with a blank password for the root user.

  **Warning**

  Setting this variable to true is insecure, because it is going to leave your MySQL instance completely unprotected, allowing anyone to gain complete superuser access. It is preferable to use the default settings of `MYSQL_RANDOM_ROOT_PASSWORD=true` being true.

### 2.5.4 Installing MySQL on Linux Using Native Package Managers

Many Linux distributions include a version of the MySQL server, client tools, and development components in their native software repositories and can be installed with the platforms' standard package management systems. This section provides basic instructions for installing MySQL using those package management systems.
Important

Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some way behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository.

Distribution specific instructions are shown below:

- **Red Hat Linux, Fedora, CentOS**

For Red Hat and similar distributions, the MySQL distribution is divided into a number of separate packages, `mysql` for the client tools, `mysql-server` for the server and associated tools, and `mysql-libs` for the libraries. The libraries are required if you want to provide connectivity from different languages and environments such as Perl, Python and others.

To install, use the `yum` command to specify the packages that you want to install. For example:

```
root-shell> yum install mysql mysql-server mysql-libs mysql-server
```

```
Loaded plugins: presto, refresh-packagekit
Setting up Install Process
Resolving Dependencies
---> Running transaction check
----> Package mysql.x86_64 0:5.1.48-2.fc13 set to be updated
----> Package mysql-libs.x86_64 0:5.1.48-2.fc13 set to be updated
----> Package mysql-server.x86_64 0:5.1.48-2.fc13 set to be updated
--> Processing Dependency: perl-DBD-MySQL for package: mysql-server-5.1.48-2.fc13.x86_64
---> Running transaction check
----> Package perl-DBD-MySQL.x86_64 0:4.017-1.fc13 set to be updated
--> Finished Dependency Resolution

Dependencies Resolved
```

```
Package               Arch          Version               Repository      Size
================================================================================
Installing:
  mysql                 x86_64        5.1.48-2.fc13         updates        889 k
  mysql-libs            x86_64        5.1.48-2.fc13         updates        1.2 M
  mysql-server          x86_64        5.1.48-2.fc13         updates        8.1 M
Installing for dependencies:
  perl-DBD-MySQL        x86_64        4.017-1.fc13          updates        136 k
```

```
Transaction Summary
================================================================================
Install       4 Package(s)
Upgrade       0 Package(s)
Total download size: 10 M
Installed size: 30 M
Is this ok [y/N]: y
```

```
Draining delta metadata
Processing delta metadata
Package(s) data still to download: 10 M
(1/4): mysql-5.1.48-2.fc13.x86_64.rpm   889 kB  00:04
(2/4): mysql-libs-5.1.48-2.fc13.x86_64.rpm 1.2 MB  00:06
(3/4): mysql-server-5.1.48-2.fc13.x86_64.rpm   8.1 MB  00:40
(4/4): perl-DBD-MySQL-4.017-1.fc13.x86_64.rpm 136 kB  00:00
```

```
Total                                           201 kB/s | 10 MB    00:52
Running rpm_check_debug
Running Transaction Test
Transaction Test Succeeded
```
Installing MySQL on Linux Using Native Package Managers

Running Transaction

<table>
<thead>
<tr>
<th>Installing</th>
<th>mysql-libs-5.1.48-2.fc13.x86_64</th>
<th>1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installing</td>
<td>mysql-5.1.48-2.fc13.x86_64</td>
<td>2/4</td>
</tr>
<tr>
<td>Installing</td>
<td>perl-DBD-MySQL-4.017-1.fc13.x86_64</td>
<td>3/4</td>
</tr>
<tr>
<td>Installing</td>
<td>mysql-server-5.1.48-2.fc13.x86_64</td>
<td>4/4</td>
</tr>
</tbody>
</table>

Installed:
- mysql.x86_64 0:5.1.48-2.fc13
- mysql-libs.x86_64 0:5.1.48-2.fc13
- mysql-server.x86_64 0:5.1.48-2.fc13

Dependency Installed:
- perl-DBD-MySQL.x86_64 0:4.017-1.fc13

Complete!

MySQL and the MySQL server should now be installed. A sample configuration file is installed into `/etc/my.cnf`. An init script, to start and stop the server, will have been installed into `/etc/init.d/mysqld`. To start the MySQL server use `service`:

```
root-shell> service mysqld start
```

To enable the server to be started and stopped automatically during boot, use `chkconfig`:

```
root-shell> chkconfig --levels 235 mysqld on
```

Which enables the MySQL server to be started (and stopped) automatically at the specified the run levels.

The database tables will have been automatically created for you, if they do not already exist. You should, however, run `mysql_secure_installation` to set the root passwords on your server.

- **Debian, Ubuntu, Kubuntu**

  On Debian and related distributions, there are two packages, `mysql-client` and `mysql-server`, for the client and server components respectively. You should specify an explicit version, for example `mysql-client-5.1`, to ensure that you install the version of MySQL that you want.

  To download and install, including any dependencies, use the `apt-get` command, specifying the packages that you want to install.

```
root-shell> apt-get install mysql-client-5.1 mysql-server-5.1
```

A sample installation of the MySQL packages might look like this (some sections trimmed for clarity):

```
root-shell> apt-get install mysql-client-5.1 mysql-server-5.1
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  linux-headers-2.6.28-11 linux-headers-2.6.28-11-generic
Use 'apt-get autoremove' to remove them.
The following extra packages will be installed:
  libdbd-mysql-perl libdbi-perl libhtml-template-perl
  libmysqlclient15off libmysqlclient16 libnet-daemon-perl libplrpc-perl mailx
  mysql-common postfix
Suggested packages:
  dbishell libippc-sharedcache-perl tinyca procmail postfix-mysql postfix-pgsql
  postfix-ldap postfix-pcre sasl2-bin resolvconf postfix-cdb
The following NEW packages will be installed
```

Note
Before installing, make sure that you update your `apt-get` index files to ensure you are downloading the latest available version.
Installing MySQL on Linux Using Native Package Managers

Note

The `apt-get` command will install a number of packages, including the MySQL server, in order to provide the typical tools and application environment. This can mean that you install a large number of packages in addition to the main MySQL package.

During installation, the initial database will be created, and you will be prompted for the MySQL root password (and confirmation). A configuration file will have been created in `/etc/mysql/my.cnf`. An init script will have been created in `/etc/init.d/mysql`.

The server will already be started. You can manually start and stop the server using:

```
root-shell> service mysql [start|stop]
```

The service will automatically be added to the 2, 3 and 4 run levels, with stop scripts in the single, shutdown and restart levels.
Gentoo Linux

As a source-based distribution, installing MySQL on Gentoo involves downloading the source, patching the Gentoo specifics, and then compiling the MySQL server and installing it. This process is handled automatically by the `emerge` command.

The MySQL server and client tools are provided within a single package, `dev-db/mysql`. You can obtain a list of the versions available to install by looking at the portage directory for the package:

```
root-shell> ls /usr/portage/dev-db/mysql/mysql-5.5*
mysql-5.5.46.ebuild
mysql-5.5.47.ebuild
```

To install a specific MySQL version, you must specify the entire atom. For example:

```
root-shell> emerge =dev-db/mysql-5.5.46
```

After installation, you should initialize the data directory and set the password for the MySQL root user (see Section 2.10.1, “Initializing the Data Directory”). Alternatively, use the configuration interface to perform those tasks:

```
root-shell> emerge --config =dev-db/mysql-5.5.46
```

During installation, a sample configuration file is created for you in `/etc/mysql/my.cnf`, and an init script is created in `/etc/init.d/mysql`.

To enable MySQL to start automatically at the normal (default) run levels, use this command:

```
root-shell> rc-update add mysql default
```

2.6 Installing MySQL Using Unbreakable Linux Network (ULN)

Linux supports a number of different solutions for installing MySQL, covered in Section 2.5, “Installing MySQL on Linux”. One of the methods, covered in this section, is installing from Oracle's Unbreakable Linux Network (ULN). You can find information about Oracle Linux and ULN under http://linux.oracle.com/.

To use ULN, you need to obtain a ULN login and register the machine used for installation with ULN. This is described in detail in the ULN FAQ. The page also describes how to install and update packages. The MySQL packages are in the “MySQL for Oracle Linux 6” channel for your system architecture on ULN.

Note

At the time of this writing, ULN provides MySQL 5.5 for Oracle Linux 6.

Once MySQL has been installed using ULN, you can find information on starting and stopping the server, and more, in this section, particularly under Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

If you're updating an existing MySQL installation to an installation using ULN, the recommended procedure is to export your data using `mysqldump`, remove the existing installation, install MySQL from ULN, and load the exported data into your freshly installed MySQL.

If the existing MySQL installation you're upgrading from is from a previous release series (prior to MySQL 5.5), make sure to read the section on upgrading MySQL, Section 2.11, “Upgrading MySQL”.

2.7 Installing MySQL on Solaris
Note

MySQL 5.5 supports Solaris 10 (Update 11 and later), and Solaris 11 (Update 3 and later).

MySQL on Solaris is available in a number of different formats.

- For information on installing using the native Solaris PKG format, see Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”.
- To use a standard `tar` binary installation, use the notes provided in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”. Check the notes and hints at the end of this section for Solaris specific notes that you may need before or after installation.

To obtain a binary MySQL distribution for Solaris in tarball or PKG format, https://dev.mysql.com/downloads/mysql/5.5.html.

Additional notes to be aware of when installing and using MySQL on Solaris:

- If you want to use MySQL with the `mysql` user and group, use the `groupadd` and `useradd` commands:

  ```
  groupadd mysql
  useradd -g mysql -s /bin/false mysql
  ```

- If you install MySQL using a binary tarball distribution on Solaris, because the Solaris `tar` cannot handle long file names, use GNU `tar (gtar)` to unpack the distribution. If you do not have GNU `tar` on your system, install it with the following command:

  ```
  pkg install archiver/gnu-tar
  ```

- You should mount any file systems on which you intend to store InnoDB files with the `forcedirectio` option. (By default mounting is done without this option.) Failing to do so will cause a significant drop in performance when using the InnoDB storage engine on this platform.

- If you would like MySQL to start automatically, you can copy `support-files/mysql.server` to `/etc/init.d` and create a symbolic link to it named `/etc/rc3.d/S99mysql.server`.

- If too many processes try to connect very rapidly to `mysqld`, you should see this error in the MySQL log:

  ```
  Error in accept: Protocol error
  ```

  You might try starting the server with the `--back_log=50` option as a workaround for this.

- To configure the generation of core files on Solaris you should use the `coreadm` command. Because of the security implications of generating a core on a `setuid()` application, by default, Solaris does not support core files on `setuid()` programs. However, you can modify this behavior using `coreadm`. If you enable `setuid()` core files for the current user, they will be generated using the mode 600 and owned by the superuser.

### 2.7.1 Installing MySQL on Solaris Using a Solaris PKG

You can install MySQL on Solaris using a binary package using the native Solaris PKG format instead of the binary tarball distribution.

To use this package, download the corresponding `mysql-VERSION-solaris10-PLATFORM.pkg.gz` file, then uncompress it. For example:

```
shell> gunzip mysql-5.5.62-solaris10-x86_64.pkg.gz
```
Installing MySQL on FreeBSD

To install a new package, use `pkgadd` and follow the onscreen prompts. You must have root privileges to perform this operation:

```
shell> pkgadd -d mysql-5.5.62-solaris10-x86_64.pkg
```

The following packages are available:

```
1  mysql  MySQL Community Server (GPL)
     (i86pc) 5.5.62
```

Select package(s) you wish to process (or 'all' to process all packages). (default: all) [?,??,q]:

The PKG installer installs all of the files and tools needed, and then initializes your database if one does not exist. To complete the installation, you should set the root password for MySQL as provided in the instructions at the end of the installation. Alternatively, you can run the `mysql_secure_installation` script that comes with the installation.

By default, the PKG package installs MySQL under the root path `/opt/mysql`. You can change only the installation root path when using `pkgadd`, which can be used to install MySQL in a different Solaris zone. If you need to install in a specific directory, use a binary `tar` file distribution.

The `pkg` installer copies a suitable startup script for MySQL into `/etc/init.d/mysql`. To enable MySQL to startup and shutdown automatically, you should create a link between this file and the init script directories. For example, to ensure safe startup and shutdown of MySQL you could use the following commands to add the right links:

```
shell> ln /etc/init.d/mysql /etc/rc3.d/S91mysql
shell> ln /etc/init.d/mysql /etc/rc0.d/K02mysql
```

To remove MySQL, the installed package name is `mysql`. You can use this in combination with the `pkgrm` command to remove the installation.

To upgrade when using the Solaris package file format, you must remove the existing installation before installing the updated package. Removal of the package does not delete the existing database information, only the server, binaries and support files. The typical upgrade sequence is therefore:

```
shell> mysqladmin shutdown
shell> pkgrm mysql
shell> pkgadd -d mysql-5.5.62-solaris10-x86_64.pkg
shell> mysql_safe &
shell> mysql_upgrade
```

You should check the notes in Section 2.11, “Upgrading MySQL” before performing any upgrade.

### 2.8 Installing MySQL on FreeBSD

This section provides information about installing MySQL on variants of FreeBSD Unix.

You can install MySQL on FreeBSD by using the binary distribution provided by Oracle. For more information, see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

The easiest (and preferred) way to install MySQL is to use the `mysql-server` and `mysql-client` ports available at [http://www.freebsd.org/](http://www.freebsd.org/). Using these ports gives you the following benefits:

- A working MySQL with all optimizations enabled that are known to work on your version of FreeBSD.
- Automatic configuration and build.
- Startup scripts installed in `/usr/local/etc/rc.d`.
- The ability to use `pkg_info -L` to see which files are installed.
Installing MySQL from Source

• The ability to use `pkg_delete` to remove MySQL if you no longer want it on your machine.

The MySQL build process requires GNU make (`gmake`) to work. If GNU `make` is not available, you must install it first before compiling MySQL.

To install using the ports system:

```bash
# cd /usr/ports/databases/mysql55-server
# make
...  
# cd /usr/ports/databases/mysql55-client
# make
...
```

The standard port installation places the server into `/usr/local/libexec/mysqld`, with the startup script for the MySQL server placed in `/usr/local/etc/rc.d/mysql-server`.

Some additional notes on the BSD implementation:

• To remove MySQL after installation using the ports system:

```bash
# cd /usr/ports/databases/mysql55-server
# make deinstall
...  
# cd /usr/ports/databases/mysql55-client
# make deinstall
...
```

• If you get problems with the current date in MySQL, setting the `TZ` variable should help. See Section 4.9, "Environment Variables".

2.9 Installing MySQL from Source

Building MySQL from the source code enables you to customize build parameters, compiler optimizations, and installation location. For a list of systems on which MySQL is known to run, see https://www.mysql.com/support/supportedplatforms/database.html.

Before you proceed with an installation from source, check whether Oracle produces a precompiled binary distribution for your platform and whether it works for you. We put a great deal of effort into ensuring that our binaries are built with the best possible options for optimal performance. Instructions for installing binary distributions are available in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

**Warning**

Building MySQL with nonstandard options may lead to reduced functionality, performance, or security.

**Note**

This section describes how to build MySQL from source using `CMake`. Before MySQL 5.5, source builds used the GNU autotools on Unix-like systems. Source builds on Windows used `CMake`, but the process was different from that described here. For source-building instructions for older versions of MySQL, see the MySQL 5.1 Reference Manual. If you are familiar with autotools but not `CMake`, you might find these transition instructions helpful: Autotools to CMake Transition Guide

2.9.1 Source Installation Methods

There are two methods for installing MySQL from source:
• Use a standard MySQL source distribution. To obtain a standard distribution, see Section 2.1.2, “How to Get MySQL”. For instructions on building from a standard distribution, see Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”.

Standard distributions are available as compressed tar files, Zip archives, or RPM packages. Distribution files have names of the form mysql-VERSION.tar.gz, mysql-VERSION.zip, or mysql-VERSION.rpm, where VERSION is a number like 5.5.62. File names for source distributions can be distinguished from those for precompiled binary distributions in that source distribution names are generic and include no platform name, whereas binary distribution names include a platform name indicating the type of system for which the distribution is intended (for example, pc-linux-i686 or winx64).

• Use a MySQL development tree. For information on building from one of the development trees, see Section 2.9.5, “Installing MySQL Using a Development Source Tree”.

2.9.2 Source Installation Prerequisites

Installation of MySQL from source requires several development tools. Some of these tools are needed no matter whether you use a standard source distribution or a development source tree. Other tool requirements depend on which installation method you use.

To install MySQL from source, the following system requirements must be satisfied, regardless of installation method:

• CMake, which is used as the build framework on all platforms. CMake can be downloaded from http://www.cmake.org.

• A good make program. Although some platforms come with their own make implementations, it is highly recommended that you use GNU make 3.75 or higher. It may already be available on your system as gmake. GNU make is available from http://www.gnu.org/software/make/.

• A working ANSI C++ compiler. GCC 4.2.1 or later, Sun Studio 12 or later, Visual Studio 2008 or later, and many current vendor-supplied compilers are known to work.

For NDB Cluster 7.2 on Linux and similar platforms, GCC 4 (4.2.1 or later) or GCC 5 is required to compile from source; GCC 6 and later versions of GCC are not supported.

• An SSL library is required for support of encrypted connections, entropy for random number generation, and other encryption-related operations. To specify the library explicitly, use the WITH_SSL option when you invoke CMake. For additional information, see Section 2.9.6, “Configuring SSL Library Support”.

• The ncurses library.

• Sufficient free memory. If you encounter problems such as “internal compiler error” when compiling large source files, it may be that you have too little memory. If compiling on a virtual machine, try increasing the memory allocation.

• Perl is needed if you intend to run test scripts. Most Unix-like systems include Perl. On Windows, you can use a version such as ActiveState Perl.

To install MySQL from a standard source distribution, one of the following tools is required to unpack the distribution file:

• For a .tar.gz compressed tar file: GNU gunzip to uncompress the distribution and a reasonable tar to unpack it. If your tar program supports the z option, it can both uncompress and unpack the file.

GNU tar is known to work. The standard tar provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU tar, or if

167
available, use a preinstalled version of GNU tar. Usually this is available as gnutar, gtar, or as tar within a GNU or Free Software directory, such as /usr/sfw/bin or /usr/local/bin. GNU tar is available from http://www.gnu.org/software/tar/.

- For a .zip Zip archive: WinZip or another tool that can read .zip files.
- For an .rpm RPM package: The rpmbuild program used to build the distribution unpacks it.

To install MySQL from a development source tree, the following additional tools are required:

- The Git revision control system is required to obtain the development source code. The GitHub Help provides instructions for downloading and installing Git on different platforms. MySQL officially joined GitHub in September, 2014. For more information about MySQL’s move to GitHub, refer to the announcement on the MySQL Release Engineering blog: MySQL on GitHub
- bison 2.1 or higher, available from http://www.gnu.org/software/bison/. (Version 1 is no longer supported.) Use the latest version of bison where possible; if you experience problems, upgrade to a later version, rather than revert to an earlier one.

bison is available from http://www.gnu.org/software/bison/. bison for Windows can be downloaded from http://gnuwin32.sourceforge.net/packages/bison.htm. Download the package labeled “Complete package, excluding sources”. On Windows, the default location for bison is the C:\Program Files\GnuWin32 directory. Some utilities may fail to find bison because of the space in the directory name. Also, Visual Studio may simply hang if there are spaces in the path. You can resolve these problems by installing into a directory that does not contain a space (for example C:\GnuWin32).

- On Solaris Express, m4 must be installed in addition to bison. m4 is available from http://www.gnu.org/software/m4/.

Note
If you have to install any programs, modify your PATH environment variable to include any directories in which the programs are located. See Section 4.2.6, “Setting Environment Variables”.

If you run into problems and need to file a bug report, please use the instructions in Section 1.6, “How to Report Bugs or Problems”.

2.9.3 MySQL Layout for Source Installation

By default, when you install MySQL after compiling it from source, the installation step installs files under /usr/local/mysql. The component locations under the installation directory are the same as for binary distributions. See Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”, and Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”. To configure installation locations different from the defaults, use the options described at Section 2.9.7, “MySQL Source-Configuration Options”.

2.9.4 Installing MySQL Using a Standard Source Distribution

To install MySQL from a standard source distribution:

1. Verify that your system satisfies the tool requirements listed at Section 2.9.2, “Source Installation Prerequisites”.
2. Obtain a distribution file using the instructions in Section 2.1.2, “How to Get MySQL”.
3. Configure, build, and install the distribution using the instructions in this section.
Installing MySQL Using a Standard Source Distribution

4. Perform postinstallation procedures using the instructions in Section 2.10, “Postinstallation Setup and Testing”.

MySQL uses CMake as the build framework on all platforms. The instructions given here should enable you to produce a working installation. For additional information on using CMake to build MySQL, see How to Build MySQL Server with CMake.

If you start from a source RPM, use the following command to make a binary RPM that you can install. If you do not have rpmbuild, use rpm instead.

```
shell> rpmbuild --rebuild --clean MySQL-VERSION.src.rpm
```

The result is one or more binary RPM packages that you install as indicated in Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

The sequence for installation from a compressed tar file or Zip archive source distribution is similar to the process for installing from a generic binary distribution (see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”), except that it is used on all platforms and includes steps to configure and compile the distribution. For example, with a compressed tar file source distribution on Unix, the basic installation command sequence looks like this:

```
# Preconfiguration setup
shell> groupadd mysql
shell> useradd -- -g mysql -s /bin/false mysql
# Beginning of source-build specific instructions
shell> tar zxvf mysql-VERSION.tar.gz
shell> cd mysql-VERSION
shell> mkdir bld
shell> cd bld
shell> cmake ..
shell> make
# End of source-build specific instructions
# Postinstallation setup
shell> cd /usr/local/mysql
shell> chown -R mysql .
shell> chgrp -R mysql .
shell> scripts/mysql_install_db --user=mysql
shell> chown -R root .
shell> chown -R mysql data
# Next command is optional
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> bin/mysqld_safe --user=mysql &
# Next command is optional
shell> cp support-files/mysql.server /etc/init.d/mysql.server
```

A more detailed version of the source-build specific instructions is shown following.

---

**Note**

The procedure shown here does not set up any passwords for MySQL accounts. After following the procedure, proceed to Section 2.10, “Postinstallation Setup and Testing”, for postinstallation setup and testing.

- Perform Preconfiguration Setup
- Obtain and Unpack the Distribution
- Configure the Distribution
- Build the Distribution
- Install the Distribution
Perform Preconfiguration Setup

On Unix, set up the `mysql` user and group that will be used to run and execute the MySQL server and own the database directory. For details, see Create a `mysql` User and Group. Then perform the following steps as the `mysql` user, except as noted.

Obtain and Unpack the Distribution

Pick the directory under which you want to unpack the distribution and change location into it.

Obtain a distribution file using the instructions in Section 2.1.2, “How to Get MySQL”.

Unpack the distribution into the current directory:

- To unpack a compressed `tar` file, `tar` can uncompress and unpack the distribution if it has `z` option support:
  ```shell
taxzvf mysql-VERSION.tar.gz
```

If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it:

```shell
gunzip < mysql-VERSION.tar.gz | tar xvf -
```

Alternatively, `CMake` can uncompress and unpack the distribution:

```shell
cmake -E tar zxvf mysql-VERSION.tar.gz
```

- To unpack a Zip archive, use `WinZip` or another tool that can read `.zip` files.

Unpacking the distribution file creates a directory named `mysql-VERSION`.

Configure the Distribution

Change location into the top-level directory of the unpacked distribution:

```shell
cd mysql-VERSION
```

Build outside of the source tree to keep the tree clean. If the top-level source directory is named `mysql-src` under your current working directory, you can build in a directory named `bld` at the same level. Create the directory and go there:

```shell
mkdir bld
cd bld
```

Configure the build directory. The minimum configuration command includes no options to override configuration defaults:

```shell
cmake ../mysql-src
```

The build directory needs not be outside the source tree. For example, you can build in a directory named `bld` under the top-level source tree. To do this, starting with `mysql-src` as your current working directory, create the directory `bld` and then go there:

```shell
mkdir bld
cd bld
```

Configure the build directory. The minimum configuration command includes no options to override configuration defaults:
If you have multiple source trees at the same level (for example, to build multiple versions of MySQL), the second strategy can be advantageous. The first strategy places all build directories at the same level, which requires that you choose a unique name for each. With the second strategy, you can use the same name for the build directory within each source tree. The following instructions assume this second strategy.

On Windows, specify the development environment. For example, the following commands configure MySQL for 32-bit or 64-bit builds, respectively:

```
shell> cmake .. -G "Visual Studio 9 2008"
shell> cmake .. -G "Visual Studio 9 2008 Win64"
```

On macOS, to use the Xcode IDE:

```
shell> cmake .. -G Xcode
```

When you run `cmake`, you might want to add options to the command line. Here are some examples:

- `-DBUILD_CONFIG=mysql_release`: Configure the source with the same build options used by Oracle to produce binary distributions for official MySQL releases.
- `-DCMAKE_INSTALL_PREFIX=dir_name`: Configure the distribution for installation under a particular location.
- `-DCPACK_MONOLITHIC_INSTALL=1`: Cause `make package` to generate a single installation file rather than multiple files.
- `-DWITH_DEBUG=1`: Build the distribution with debugging support.

For a more extensive list of options, see Section 2.9.7, “MySQL Source-Configuration Options”.

To list the configuration options, use one of the following commands:

```
shell> cmake .. -L  # overview
shell> cmake .. -LH  # overview with help text
shell> cmake .. -LAH  # all params with help text
shell> ccmake ..  # interactive display
```

If CMake fails, you might need to reconfigure by running it again with different options. If you do reconfigure, take note of the following:

- If CMake is run after it has previously been run, it may use information that was gathered during its previous invocation. This information is stored in CMakeCache.txt. When CMake starts, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.
- Each time you run CMake, you must run make again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old object files or configuration information from being used, run these commands in the build directory on Unix before re-running CMake:

```
shell> make clean
shell> rm CMakeCache.txt
```

Or, on Windows:

```
shell> devenv MySQL.sln /clean
shell> del CMakeCache.txt
```
Installing MySQL Using a Standard Source Distribution

Before asking on the MySQL Community Slack, check the files in the CMakeFiles directory for useful information about the failure. To file a bug report, please use the instructions in Section 1.6, “How to Report Bugs or Problems”.

Build the Distribution

On Unix:

shell> make
shell> make VERBOSE=1

The second command sets VERBOSE to show the commands for each compiled source.

Use gmake instead on systems where you are using GNU make and it has been installed as gmake.

On Windows:

shell> devenv MySQL.sln /build RelWithDebInfo

If you have gotten to the compilation stage, but the distribution does not build, see Section 2.9.8, “Dealing with Problems Compiling MySQL”, for help. If that does not solve the problem, please enter it into our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If you have installed the latest versions of the required tools, and they crash trying to process our configuration files, please report that also. However, if you get a command not found error or a similar problem for required tools, do not report it. Instead, make sure that all the required tools are installed and that your PATH variable is set correctly so that your shell can find them.

Install the Distribution

On Unix:

shell> make install

This installs the files under the configured installation directory (by default, /usr/local/mysql). You might need to run the command as root.

To install in a specific directory, add a DESTDIR parameter to the command line:

shell> make install DESTDIR="/opt/mysql"

Alternatively, generate installation package files that you can install where you like:

shell> make package

This operation produces one or more .tar.gz files that can be installed like generic binary distribution packages. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”. If you run CMake with -DCPACK_MONOLITHIC_INSTALL=1, the operation produces a single file. Otherwise, it produces multiple files.

On Windows, generate the data directory, then create a .zip archive installation package:

shell> devenv MySQL.sln /build RelWithDebInfo /project initial_database
shell> devenv MySQL.sln /build RelWithDebInfo /project package

You can install the resulting .zip archive where you like. See Section 2.3.6, “Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive”.

Perform Postinstallation Setup

The remainder of the installation process involves setting up the configuration file, creating the core databases, and starting the MySQL server. For instructions, see Section 2.10, “Postinstallation Setup and Testing”.
2.9.5 Installing MySQL Using a Development Source Tree

This section describes how to install MySQL from the latest development source code, which is hosted on GitHub. To obtain the MySQL Server source code from this repository hosting service, you can set up a local MySQL Git repository.

On GitHub, MySQL Server and other MySQL projects are found on the MySQL page. The MySQL Server project is a single repository that contains branches for several MySQL series.

MySQL officially joined GitHub in September, 2014. For more information about MySQL's move to GitHub, refer to the announcement on the MySQL Release Engineering blog: MySQL on GitHub

- Prerequisites for Installing from Development Source
- Setting Up a MySQL Git Repository

Prerequisites for Installing from Development Source

To install MySQL from a development source tree, your system must satisfy the tool requirements listed at Section 2.9.2, “Source Installation Prerequisites”.

Setting Up a MySQL Git Repository

To set up a MySQL Git repository on your machine, use this procedure:

1. Clone the MySQL Git repository to your machine. The following command clones the MySQL Git repository to a directory named `mysql-server`. The initial download will take some time to complete, depending on the speed of your connection.

   ```bash
   ~$ git clone https://github.com/mysql/mysql-server.git
   Cloning into 'mysql-server'...
   remote: Counting objects: 1035465, done.
   remote: Total 1035465 (delta 0), reused 0 (delta 0)
   Receiving objects: 100% (1035465/1035465), 437.48 MiB | 5.10 MiB/s, done.
   Resolving deltas: 100% (855607/855607), done.
   Checking connectivity... done.
   Checking out files: 100% (21902/21902), done.
   ```

2. When the clone operation completes, the contents of your local MySQL Git repository appear similar to the following:

   ```bash
   ~/mysql-server$ ls
   BUILD            COPYING             libmysqld    regex          tests
   BUILD-CMAKE      dbug                libservices  scripts        unittest
   client           Docs                man          sql            VERSION
   cmake            extra               mysql-test   sql-bench      vio
   CMakeLists.txt   include             mysys        sql-common     zlib
   cmd-line-utils   INSTALL-SOURCE      plugin       storage        zlib
   configure.cmake  INSTALL-WIN-SOURCE  README       support-files
   configure.mysql  libmysql            README       support-files
   ```

3. Use the `git branch -r` command to view the remote tracking branches for the MySQL repository.

   ```bash
   ~/mysql-server$ git branch -r
   ```
4. To view the branches that are checked out in your local repository, issue the `git branch` command. When you cloned the MySQL Git repository, the MySQL 5.7 branch was checked out automatically. The asterisk identifies the 5.7 branch as the active branch.

```
~/mysql-server$ git branch
* 5.7
```

5. To check out a different MySQL branch, run the `git checkout` command, specifying the branch name. For example, to check out the MySQL 5.5 branch:

```
~/mysql-server$ git checkout 5.5
Branch 5.5 set up to track remote branch 5.5 from origin.
Switched to a new branch '5.5'
```

6. Run `git branch` again to verify that the MySQL 5.5 branch is present. MySQL 5.5, which is the last branch you checked out, is marked by an asterisk indicating that it is the active branch.

```
~/mysql-server$ git branch
* 5.5
  5.7
```

The `git checkout` command is also used to switch branches. For example, to make MySQL 5.7 the active branch again, you would run `git checkout 5.7`.

7. To obtain changes made after your initial setup of the MySQL Git repository, switch to the branch you want to update and issue the `git pull` command:

```
~/mysql-server$ git checkout 5.5
~/mysql-server$ git pull
```

To examine the commit history, use the `git log` option:

```
~/mysql-server$ git log
```

You can also browse commit history and source code on the GitHub MySQL site.

If you see changes or code that you have a question about, ask on the MySQL Community Slack. For information about contributing a patch, see Contributing to MySQL Server.

8. After you have cloned the MySQL Git repository and have checked out the branch you want to build, you can build MySQL Server from the source code. Instructions are provided in Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”, except that you skip the part about obtaining and unpacking the distribution.

Be careful about installing a build from a distribution source tree on a production machine. The installation command may overwrite your live release installation. If you already have MySQL installed and do not want to overwrite it, run `CMake` with values for the `CMAKE_INSTALL_PREFIX`, `MYSQL_TCP_PORT`, and `MYSQL_UNIX_ADDR` options different from those used by your production server. For additional information about preventing multiple servers from interfering with each other, see Section 5.7, “Running Multiple MySQL Instances on One Machine”.

Play hard with your new installation. For example, try to make new features crash. Start by running `make test`. See Section 24.1.2, “The MySQL Test Suite”.
2.9.6 Configuring SSL Library Support

An SSL library is required for support of encrypted connections, entropy for random number generation, and other encryption-related operations. Your system must support either OpenSSL or yaSSL:

- MySQL Enterprise Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL.

If you compile MySQL from a source distribution, CMake configures the distribution to use yaSSL by default. To compile using OpenSSL instead, use this procedure:

1. Ensure that OpenSSL 1.0.1 or higher is installed on your system. If it is necessary to obtain OpenSSL, visit http://www.openssl.org.

2. The `WITH_SSL` CMake option determines which SSL library to use for compiling MySQL (see Section 2.9.7, “MySQL Source-Configuration Options”). The default is `-DWITH_SSL=bundled`, which uses yaSSL. To use OpenSSL, add the `-DWITH_SSL=system` option to the CMake command you normally use to configure the MySQL source distribution. For example:

   ```
   cmake . -DWITH_SSL=system
   ```

   That command configures the distribution to use the installed OpenSSL library.

3. Compile and install the distribution.

To check whether a `mysqld` server supports encrypted connections, examine the value of the `have_ssl` system variable:

```
mysql> SHOW VARIABLES LIKE 'have_ssl';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>have_ssl</td>
<td>YES</td>
</tr>
</tbody>
</table>

If the value is `YES`, the server supports encrypted connections. If the value is `DISABLED`, the server is capable of supporting encrypted connections but was not started with the appropriate `--ssl-xxx` options to enable encrypted connections to be used; see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

2.9.7 MySQL Source-Configuration Options

The CMake program provides a great deal of control over how you configure a MySQL source distribution. Typically, you do this using options on the CMake command line. For information about options supported by CMake, run either of these commands in the top-level source directory:

```
ccmake .
```

You can also affect CMake using certain environment variables. See Section 4.9, “Environment Variables”.

For boolean options, the value may be specified as 1 or `ON` to enable the option, or as 0 or `OFF` to disable the option.

Many options configure compile-time defaults that can be overridden at server startup. For example, the `CMAKE_INSTALL_PREFIX`, `MYSQL_TCP_PORT`, and `MYSQL_UNIX_ADDR` options that configure the default installation base directory location, TCP/IP port number, and Unix socket file can be changed at server
startup with the \texttt{--basedir}, \texttt{--port}, and \texttt{--socket} options for \texttt{mysqld}. Where applicable, configuration option descriptions indicate the corresponding \texttt{mysqld} startup option.

The following sections provide more information about \texttt{CMake} options.

- \texttt{CMake Option Reference}
- \texttt{General Options}
- \texttt{Installation Layout Options}
- \texttt{Storage Engine Options}
- \texttt{Feature Options}
- \texttt{Compiler Flags}
- \texttt{CMake Options for Compiling NDB Cluster}

\textbf{CMake Option Reference}

The following table shows the available \texttt{CMake} options. In the \texttt{Default} column, \texttt{PREFIX} stands for the value of the \texttt{CMAKE_INSTALL_PREFIX} option, which specifies the installation base directory. This value is used as the parent location for several of the installation subdirectories.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|}
\hline
\textbf{Formats} & \textbf{Description} & \textbf{Default} & \textbf{Introduced}\textbf{Removed} \\
\hline
\texttt{BUILD\_CONFIG} & Use same build options as official releases & & 5.5.7 \\
\hline
\texttt{CMAKE\_BUILD\_TYPE} & Type of build to produce & \texttt{RelWithDebInfo} & 5.5.7 \\
\hline
\texttt{CMAKE\_CXX\_FLAGS} & Flags for C++ Compiler & & 5.5.7 \\
\hline
\texttt{CMAKE\_C\_FLAGS} & Flags for C Compiler & & 5.5.7 \\
\hline
\texttt{CMAKE\_INSTALL\_PREFIX} & Installation base directory & /usr/local/mysql & 5.5.8 \\
\hline
\texttt{COMPILATION\_COMMENT} & Comment about compilation environment & & 5.5.7 \\
\hline
\texttt{CPACK\_MONOLITHIC\_INSTALL} & Whether package build produces single file & \texttt{OFF} & 5.5.7 \\
\hline
\texttt{DEFAULT\_CHARSET} & The default server character set & \texttt{latin1} & 5.5.7 \\
\hline
\texttt{DEFAULT\_COLLATION} & The default server collation & \texttt{latin1\_swedish} & 5.5.7 \\
\hline
\texttt{ENABLE\_LOCAL\_INFILE} & Whether to enable LOCAL for LOAD DATA & \texttt{OFF} & 5.5.7 \\
\hline
\texttt{ENABLE\_PROFILING} & Whether to enable query profiling code & \texttt{ON} & 5.5.7 \\
\hline
\texttt{ENABLE\_DEBUG\_SYNC} & Whether to enable Debug Sync support & \texttt{ON} & 5.5.7 5.5.55 \\
\hline
\texttt{ENABLE\_DOWNLOADS} & Whether to download optional files & \texttt{OFF} & 5.5.7 \\
\hline
\texttt{ENABLE\_DTRACE} & Whether to include DTrace support & & 5.5.7 \\
\hline
\end{tabular}
\caption{MySQL Source-Configuration Option Reference (CMake)}
\end{table}
<table>
<thead>
<tr>
<th>Formats</th>
<th>Description</th>
<th>Default</th>
<th>Introduced</th>
<th>Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENABLE_GCOV</td>
<td>Whether to include gcov support</td>
<td></td>
<td>5.5.14</td>
<td></td>
</tr>
<tr>
<td>IGNORE_AIO_CHECK</td>
<td>With -DBUILD_CONFIG=mysql_release, ignore libaio check</td>
<td>OFF</td>
<td>5.5.9</td>
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<tr>
<td>INSTALL_BINDIR</td>
<td>User executables directory</td>
<td>PREFIX/bin</td>
<td>5.5.7</td>
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<tr>
<td>INSTALL_DOCDIR</td>
<td>Documentation directory</td>
<td>PREFIX/docs</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_DOCREADMEDIR</td>
<td>README file directory</td>
<td>PREFIX</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_INCLUDEDIR</td>
<td>Header file directory</td>
<td>PREFIX/include</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_INFODIR</td>
<td>Info file directory</td>
<td>PREFIX/docs</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_LAYOUT</td>
<td>Select predefined installation layout</td>
<td>STANDALONE</td>
<td>5.5.7</td>
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<tr>
<td>INSTALL_LIBDIR</td>
<td>Library file directory</td>
<td>PREFIX/lib</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_MANDIR</td>
<td>Manual page directory</td>
<td>PREFIX/man</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_MYSQLSHAREDIR</td>
<td>Shared data directory</td>
<td>PREFIX/share</td>
<td>5.5.7</td>
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</tr>
<tr>
<td>INSTALL_MYSQLTESTDIR</td>
<td>mysql-test directory</td>
<td>PREFIX/mysql-test</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_PLUGINDIR</td>
<td>Plugin directory</td>
<td>PREFIX/lib/plugin</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>INSTALL_SBINDIR</td>
<td>Server executable directory</td>
<td>PREFIX/bin</td>
<td>5.5.7</td>
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<td>INSTALL_SCRIPTDIR</td>
<td>Scripts directory</td>
<td>PREFIX/scripts</td>
<td>5.5.7</td>
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<td>INSTALL_SECURE_FILE_PRIVDIR</td>
<td>secure_file_priv default value for libmysqld</td>
<td>platform specific</td>
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<td>INSTALL_SECURE_FILE_PRIVDIR</td>
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<td>platform specific</td>
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<td>INSTALL_SHAREDIR</td>
<td>aclocal/mysql.m4 installation directory</td>
<td>PREFIX/share</td>
<td>5.5.7</td>
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<td>INSTALL_SQLBENCHDIR</td>
<td>sql-bench directory</td>
<td>PREFIX</td>
<td>5.5.7</td>
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<tr>
<td>INSTALL_SUPPORTFILESDIR</td>
<td>Extra support files directory</td>
<td>PREFIX/support-files</td>
<td>5.5.7</td>
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<td>MEMCACHED_HOME</td>
<td>Path to memcached</td>
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<td>MYSQL_DATADIR</td>
<td>Data directory</td>
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<td>MYSQL_MAINTAINER_MODE</td>
<td>Whether to enable MySQL maintainer-specific development environment</td>
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<td>MYSQL_PROJECT_NAME</td>
<td>Windows/OS X project name</td>
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<td>MYSQL_TCP_PORT</td>
<td>TCP/IP port number</td>
<td>3306</td>
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<td>MYSQL_UNIX_ADDR</td>
<td>Unix socket file</td>
<td>/tmp/mysql.sock</td>
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<td>ODBC_INCLUDES</td>
<td>ODBC includes directory</td>
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<tr>
<td>ODBC_LIB_DIR</td>
<td>ODBC library directory</td>
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<td>Formats</td>
<td>Description</td>
<td>Default</td>
<td>Introduced</td>
<td>Removed</td>
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<td>-------------</td>
<td>---------</td>
<td>------------</td>
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<tr>
<td>REPRODUCIBLE_BUILD</td>
<td>Take extra care to create a build result independent of build location and time</td>
<td></td>
<td>5.5.57</td>
<td></td>
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<tr>
<td>SYSCONFDIR</td>
<td>Option file directory</td>
<td></td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>TMPDIR</td>
<td>tmpdir default value</td>
<td></td>
<td>5.5.36</td>
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</tr>
<tr>
<td>WITHOUT_xxx_STORAGE_ENGINE</td>
<td>Exclude storage engine xxx from build</td>
<td></td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>WITH_ASAN</td>
<td>Enable AddressSanitizer</td>
<td>OFF</td>
<td>5.5.35</td>
<td></td>
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<tr>
<td>WITH_BUNDLED_LIBEVENT</td>
<td>Use bundled libevent when building ndbmemcache</td>
<td>ON</td>
<td>5.5.16-ndb-7.2.2</td>
<td></td>
</tr>
<tr>
<td>WITH_BUNDLED_MEMCACHED</td>
<td>Use bundled memcached when building ndbmemcache</td>
<td>ON</td>
<td>5.5.16-ndb-7.2.2</td>
<td></td>
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<tr>
<td>WITH_CLASSPATH</td>
<td>Classpath to use when building MySQL Cluster Connector for Java. Default is an empty string.</td>
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<tr>
<td>WITH_DEBUG</td>
<td>Whether to include debugging support</td>
<td>OFF</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>WITH_EMBEDDED_SERVER</td>
<td>Whether to build embedded server</td>
<td>OFF</td>
<td>5.5.7</td>
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<tr>
<td>WITH_EMBEDDED_SHARED_LIB</td>
<td>Whether to build a shared embedded server library</td>
<td>OFF</td>
<td>5.5.37</td>
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<tr>
<td>WITH_ERROR_INSERT</td>
<td>Enable error injection in the NDB storage engine. Should not be used for building binaries intended for production.</td>
<td>OFF</td>
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<td></td>
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<tr>
<td>WITH_EXTRA_CHARSET</td>
<td>Which extra character sets to include</td>
<td>all</td>
<td>5.5.7</td>
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<tr>
<td>WITH_LIBEDIT</td>
<td>Use bundled libedit library</td>
<td>ON</td>
<td>5.5.7</td>
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<tr>
<td>WITH_LIBWRAP</td>
<td>Whether to include libwrap (TCP wrappers) support</td>
<td>OFF</td>
<td>5.5.7</td>
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</tr>
<tr>
<td>WITH_NDBCLUSTER</td>
<td>Build the NDB storage engine; alias for WITH_NDBCLUSTER_STORAGE_ENGINE</td>
<td>ON</td>
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<tr>
<td>WITH_NDBCLUSTER_STORAGE_ENGINE</td>
<td>Build the NDB storage engine</td>
<td>ON</td>
<td></td>
<td></td>
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<tr>
<td>WITH_NDBMTD</td>
<td>Build multithreaded data node.</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WITH_NDB_BINLOG</td>
<td>Enable binary logging by default by mysqld.</td>
<td>ON</td>
<td></td>
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<tr>
<td>WITH_NDB_DEBUG</td>
<td>Produce a debug build for testing or troubleshooting.</td>
<td>OFF</td>
<td></td>
<td></td>
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<tr>
<td>WITH_NDB_JAVA</td>
<td>Enable building of Java and ClusterJ support. Enabled by</td>
<td>ON</td>
<td>5.5.27-ndb-7.2.9</td>
<td></td>
</tr>
</tbody>
</table>
MySQL Source-Configuration Options

<table>
<thead>
<tr>
<th>Formats</th>
<th>Description</th>
<th>Default</th>
<th>Introduced</th>
<th>Removed</th>
</tr>
</thead>
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<tr>
<td>default</td>
<td>default. Supported in MySQL Cluster only.</td>
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<tr>
<td>WITH_NDB_PORT</td>
<td>Default port used by a management server built with this option. If this option was not used to build it, the management server's default port is 1186.</td>
<td>[none]</td>
<td></td>
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<tr>
<td>WITH_NDB_TEST</td>
<td>Include NDB API test programs.</td>
<td>OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WITH_READLINE</td>
<td>Use bundled readline library</td>
<td>OFF</td>
<td>5.5.7</td>
<td></td>
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<tr>
<td>WITH_SSL</td>
<td>Type of SSL support</td>
<td>bundled</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>WITH_UNIT_TESTS</td>
<td>Compile MySQL with unit tests</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WITH_UNIXODBC</td>
<td>Enable unixODBC support</td>
<td>OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WITH_VALGRIND</td>
<td>Whether to compile in Valgrind header files</td>
<td>OFF</td>
<td>5.5.6</td>
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<tr>
<td>WITH_ZLIB</td>
<td>Type of zlib support</td>
<td>bundled</td>
<td>5.5.7</td>
<td></td>
</tr>
<tr>
<td>WITH_xxx_STORAGE_ENGINE</td>
<td>Compile storage engine xxx statically into server</td>
<td></td>
<td>5.5.7</td>
<td></td>
</tr>
</tbody>
</table>

General Options

- `-DBUILD_CONFIG=mysql_release`

This option configures a source distribution with the same build options used by Oracle to produce binary distributions for official MySQL releases.

- `-DCMAKE_BUILD_TYPE=type`

The type of build to produce:

- `RelWithDebInfo`: Enable optimizations and generate debugging information. This is the default MySQL build type.

- `Debug`: Disable optimizations and generate debugging information. This build type is also used if the `WITH_DEBUG` option is enabled. That is, `-DWITH_DEBUG=1` has the same effect as `-DCMAKE_BUILD_TYPE=Debug`.

- `-DCPACK_MONOLITHIC_INSTALL=bool`

This option affects whether the `make package` operation produces multiple installation package files or a single file. If disabled, the operation produces multiple installation package files, which may be useful if you want to install only a subset of a full MySQL installation. If enabled, it produces a single file for installing everything.

Installation Layout Options

The `CMAKE_INSTALL_PREFIX` option indicates the base installation directory. Other options with names of the form `INSTALL_xxx` that indicate component locations are interpreted relative to the prefix and their values are relative pathnames. Their values should not include the prefix.
MySQL Source-Configuration Options

- **-DCMAKE_INSTALL_PREFIX=dir_name**
  The installation base directory.
  This value can be set at server startup with the **--basedir** option.
- **-DINSTALL_BINDIR=dir_name**
  Where to install user programs.
- **-DINSTALL_DOCDIR=dir_name**
  Where to install documentation.
- **-DINSTALL_DOCREADMEDIR=dir_name**
  Where to install README files.
- **-DINSTALL_INCLUDEDIR=dir_name**
  Where to install header files.
- **-DINSTALL_INFODIR=dir_name**
  Where to install Info files.
- **-DINSTALL_LAYOUT=name**
  Select a predefined installation layout:
  - **STANDALONE**: Same layout as used for .tar.gz and .zip packages. This is the default.
  - **RPM**: Layout similar to RPM packages.
  - **SVR4**: Solaris package layout.
  - **DEB**: DEB package layout (experimental).
  You can select a predefined layout but modify individual component installation locations by specifying other options. For example:

  `cmake . -DINSTALL_LAYOUT=SVR4 -DMYSQL_DATADIR=/var/mysql/data`

- **-DINSTALL_LIBDIR=dir_name**
  Where to install library files.
- **-DINSTALL_MANDIR=dir_name**
  Where to install manual pages.
- **-DINSTALL_MYSQLSHAREDIR=dir_name**
  Where to install shared data files.
- **-DINSTALL_MYSQLTESTDIR=dir_name**
  Where to install the mysql-test directory. As of MySQL 5.5.32, to suppress installation of this directory, explicitly set the option to the empty value (**-DINSTALL_MYSQLTESTDIR=**).
MySQL Source-Configuration Options

- **-DINSTALL_PLUGINDIR=dir_name**
  
  The location of the plugin directory.
  
  This value can be set at server startup with the **--plugin_dir** option.

- **-DINSTALL_SBINDIR=dir_name**
  
  Where to install the *mysqld* server.

- **-DINSTALL_SCRIPTDIR=dir_name**
  
  Where to install *mysql_install_db*.

- **-DINSTALL_SECURE_FILE_PRIVDIR=dir_name**
  
  The default value for the *secure_file_priv* system variable. The default value is platform specific and depends on the value of the INSTALL_LAYOUT CMake option; see the description of the *secure_file_priv* system variable in Section 5.1.7, “Server System Variables”.
  
  This option was added in MySQL 5.5.53. To set the value for the *libmysqld* embedded server, use INSTALL_SECURE_FILE_PRIV_EMBEDDEDIR.

- **-DINSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR=dir_name**
  
  The default value for the *secure_file_priv* system variable, for the *libmysqld* embedded server. This option was added in MySQL 5.5.53.

- **-DINSTALL_SHAREDIR=dir_name**
  
  Where to install *aclocal/mysql.m4*.

- **-DINSTALL_SQLBENCHDIR=dir_name**
  
  Where to install the *sql-bench* directory. To suppress installation of this directory, explicitly set the option to the empty value (**-DINSTALL_SQLBENCHDIR=**).

- **-DINSTALL_SUPPORTFILES=dir_name**
  
  Where to install extra support files.

- **-DMYSQL_DATADIR=dir_name**
  
  The location of the MySQL data directory.
  
  This value can be set at server startup with the **--datadir** option.

- **-DODBC_INCLUDES=dir_name**
  
  The location of the ODBC includes directory, and may be used while configuring Connector/ODBC.

- **-DODBC_LIB_DIR=dir_name**
  
  The location of the ODBC library directory, and may be used while configuring Connector/ODBC.
MySQL Source-Configuration Options

-DSYSCONFDIR=dir_name

The default my.cnf option file directory.

This location cannot be set at server startup, but you can start the server with a given option file using the --defaults-file=file_name option, where file_name is the full path name to the file.

-DTMPDIR=dir_name

The default location to use for the tmpdir system variable. If unspecified, the value defaults to P_tmpdir in <stdio.h>. This option was added in MySQL 5.6.16.

Storage Engine Options

Storage engines are built as plugins. You can build a plugin as a static module (compiled into the server) or a dynamic module (built as a dynamic library that must be installed into the server using the INSTALL PLUGIN statement or the --plugin-load option before it can be used). Some plugins might not support static or dynamic building.

The InnoDB, MyISAM, MERGE, MEMORY, and CSV engines are mandatory (always compiled into the server) and need not be installed explicitly.

To compile a storage engine statically into the server, use -DWITH_engine_STORAGE_ENGINE=1. Some permissible engine values are ARCHIVE, BLACKHOLE, EXAMPLE, FEDERATED, NDBCLUSTER (NDB), PARTITION (partitioning support), and PERFSchema (Performance Schema). Examples:

-DWITH_ARCHIVE_STORAGE_ENGINE=1
-DWITH_BLACKHOLE_STORAGE_ENGINE=1
-DWITH_PERFSHEMA_STORAGE_ENGINE=1

Note

WITH_NDBCLUSTER_STORAGE_ENGINE is supported only when building NDB Cluster using the NDB Cluster sources. It cannot be used to enable clustering support in other MySQL source trees or distributions. In MySQL NDB Cluster 7.2 source distributions, it is enabled by default. See Section 18.2.1.4, “Building NDB Cluster from Source on Linux”, and Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”, for more information.

To exclude a storage engine from the build, use -DWITHOUT_engine_STORAGE_ENGINE=1. Examples:

-DWITHOUT_EXAMPLE_STORAGE_ENGINE=1
-DWITHOUT_FEDERATED_STORAGE_ENGINE=1
-DWITHOUT_PARTITION_STORAGE_ENGINE=1

If neither -DWITH_engine_STORAGE_ENGINE nor -DWITHOUT_engine_STORAGE_ENGINE are specified for a given storage engine, the engine is built as a shared module, or excluded if it cannot be built as a shared module.

Feature Options

-DCOMPILATION_COMMENT=string

A descriptive comment about the compilation environment.

-DDEFAULT_CHARSET=charset_name

The server character set. By default, MySQL uses the latin1 (cp1252 West European) character set.
**charset_name** may be one of *binary, armsci8, ascii, big5, cp1250, cp1251, cp1256, cp1257, cp850, cp852, cp866, cp932, dec8, eucjpms, euckr, gb2312, gbk, geostd8, greek, hebrew, hp8, keybcs2, koi8r, koi8u, latin1, latin2, latin5, latin7, macce, macroman, sjis, swe7, tis620, ucs2, ujis, utf8, utf8mb4, utf16, utf32*. The permissible character sets are listed in the `cmake/character_sets.cmake` file as the value of `CHARSETS_AVAILABLE`.

This value can be set at server startup with the `--character_set_server` option.

- `-DDEFAULT_COLLATION=collation_name`

  The server collation. By default, MySQL uses `latin1_swedish_ci`. Use the `SHOW COLLATION` statement to determine which collations are available for each character set.

This value can be set at server startup with the `--collation_server` option.

- `-DENABLE_DEBUG_SYNC=bool`

  **Note**
  
  As of MySQL 5.5.55, `ENABLE_DEBUG_SYNC` is removed and enabling `WITH_DEBUG` enables Debug Sync.

  Whether to compile the Debug Sync facility into the server. This facility is used for testing and debugging. This option is enabled by default, but has no effect unless MySQL is configured with debugging enabled. If debugging is enabled and you want to disable Debug Sync, use `-DENABLE_DEBUG_SYNC=0`.

  When compiled in, Debug Sync is disabled by default at runtime. To enable it, start `mysql` with the `--debug-sync-timeout=N` option, where `N` is a timeout value greater than 0. (The default value is 0, which disables Debug Sync.) `N` becomes the default timeout for individual synchronization points.

  For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- `-DENABLE_DOWNLOADS=bool`

  Whether to download optional files. For example, with this option enabled, `CMake` downloads the Google Test distribution that is used by the test suite to run unit tests.

- `-DENABLE_DTRACE=bool`

  Whether to include support for DTrace probes. For information about DTrace, see Section 5.8, “Tracing `mysqld` Using DTrace”

- `-DENABLE_GCOV=bool`

  Whether to include gcov support (Linux only).

- `-DENABLED_LOCAL_INFILE=bool`

  This option controls the compiled-in default `LOCAL` capability for the MySQL client library. Clients that make no explicit arrangements therefore have `LOCAL` capability disabled or enabled according to the `ENABLED_LOCAL_INFILE` setting specified at MySQL build time.

  By default, the client library in MySQL binary distributions is compiled with `ENABLED_LOCAL_INFILE` enabled. If you compile MySQL from source, configure it with `ENABLED_LOCAL_INFILE` disabled or
enabled based on whether clients that make no explicit arrangements should have `LOCAL` capability disabled or enabled, respectively.

`ENABLED_LOCAL_INFILE` controls the default for client-side `LOCAL` capability. For the server, the `local_infile` system variable controls server-side `LOCAL` capability. To explicitly cause the server to refuse or permit `LOAD DATA LOCAL` statements (regardless of how client programs and libraries are configured at build time or runtime), start `mysqld` with `local_infile` disabled or enabled, respectively. `local_infile` can also be set at runtime. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

- **-DENABLED_PROFILING=bool**

  Whether to enable query profiling code (for the `SHOW PROFILE` and `SHOW PROFILES` statements).

- **-DIGNORE_AIO_CHECK=bool**

  If the `-DBUILD_CONFIG=mysql_release` option is given on Linux, the `libaio` library must be linked in by default. If you do not have `libaio` or do not want to install it, you can suppress the check for it by specifying `-DIGNORE_AIO_CHECK=1`.

- **-DMYSQL_MAINTAINER_MODE=bool**

  Whether to enable a MySQL maintainer-specific development environment. If enabled, this option causes compiler warnings to become errors.

- **-DMYSQL_PROJECT_NAME=name**

  For Windows or macOS, the project name to incorporate into the project file name. This option was added in MySQL 5.5.21.

- **-DMYSQL_TCP_PORT=port_num**

  The port number on which the server listens for TCP/IP connections. The default is 3306. This value can be set at server startup with the `--port` option.

- **-DMYSQL_UNIX_ADDR=file_name**

  The Unix socket file path on which the server listens for socket connections. This must be an absolute path name. The default is `/tmp/mysql.sock`. This value can be set at server startup with the `--socket` option.

- **-DREPRODUCIBLE_BUILD=bool**

  For builds on Linux systems, this option controls whether to take extra care to create a build result independent of build location and time. This option was added in MySQL 5.5.55.

- **-DWITH_ASAN=bool**

  Whether to enable AddressSanitizer, for compilers that support it. The default is off. This option was added in MySQL 5.5.35.

- **-DWITH_DEBUG=bool**

  Whether to include debugging support.
MySQL Source-Configuration Options

Configuring MySQL with debugging support enables you to use the \(--debug="d,parser_debug"\) option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

As of MySQL 5.5.55, enabling WITH_DEBUG also enables Debug Sync. For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- \(-DWITH_EMBEDDED_SERVER=bool\)
  Whether to build the libmysqld embedded server library.

- \(-DWITH_EMBEDDED_SHARED_LIBRARY=bool\)
  Whether to build a shared libmysqld embedded server library. This option was added in MySQL 5.5.37.

- \(-DWITH_EXTRA_CHARSETS=name\)
  Which extra character sets to include:
  - all: All character sets. This is the default.
  - complex: Complex character sets.
  - none: No extra character sets.

- \(-DWITH_LIBEDIT=bool\)
  Whether to use the libedit library bundled with the distribution.

- \(-DWITH_LIBWRAP=bool\)
  Whether to include libwrap (TCP wrappers) support.

- \(-DWITH_READLINE=bool\)
  Whether to use the readline library bundled with the distribution.

- \(-DWITH_SSL=ssl_type\)
  For support of encrypted connections, entropy for random number generation, and other encryption-related operations, MySQL must be built using an SSL library. This option specifies which SSL library to use:
  - no: No SSL support. This is the default before MySQL 5.5.56. As of 5.5.56, this is no longer a permitted value and the default is bundled.
  - yes: Use the system OpenSSL library if present, else the library bundled with the distribution.
  - bundled: Use the SSL library bundled with the distribution. This is the default as of MySQL 5.5.56.
  - system: Use the system OpenSSL library.
  For additional information about configuring the SSL library, see Section 2.9.6, “Configuring SSL Library Support”.

- \(-DWITH_UNIT_TESTS={ON|OFF}\)
If enabled, compile MySQL with unit tests. The default is ON unless the server is not being compiled.

- `--WITH_UNIXODBC=1`

    Enables unixODBC support, for Connector/ODBC.

- `--WITH_VALGRIND=bool`

    Whether to compile in the Valgrind header files, which exposes the Valgrind API to MySQL code. The default is OFF.

    To generate a Valgrind-aware debug build, `--WITH_VALGRIND=1` normally is combined with `--WITH_DEBUG=1`. See Building Debug Configurations.

- `--WITH_ZLIB=zlib_type`

    Some features require that the server be built with compression library support, such as the `COMPRESS()` and `UNCOMPRESS()` functions, and compression of the client/server protocol. The `WITH_ZLIB` indicates the source of `zlib` support:

    - `bundled`: Use the `zlib` library bundled with the distribution. This is the default.
    - `system`: Use the system `zlib` library.

### Compiler Flags

- `--DCMAKE_C_FLAGS="flags"`

    Flags for the C Compiler.

- `--DCMAKE_CXX_FLAGS="flags"`

    Flags for the C++ Compiler.

To specify your own C and C++ compiler flags, for flags that do not affect optimization, use the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options.

When providing your own compiler flags, you might want to specify `CMAKE_BUILD_TYPE` as well.

For example, to create a 32-bit release build on a 64-bit Linux machine, do this:

```bash
mkdir bld
cd bld
cmake .. -DCMAKE_C_FLAGS=-m32 \  -DCMAKE_CXX_FLAGS=-m32 \  -DCMAKE_BUILD_TYPE=RelWithDebInfo
```

If you set flags that affect optimization (`-Onumber`), you must set the `CMAKE_C_FLAGS_build_type` and/or `CMAKE_CXX_FLAGS_build_type` options, where `build_type` corresponds to the `CMAKE_BUILD_TYPE` value. To specify a different optimization for the default build type (RelWithDebInfo) set the `CMAKE_C_FLAGS_RELWITHDEBINFO` and `CMAKE_CXX_FLAGS_RELWITHDEBINFO` options. For example, to compile on Linux with `-O3` and with debug symbols, do this:

```bash
cmake .. -DCMAKE_C_FLAGS_RELWITHDEBINFO="-O3 -g" \  -DCMAKE_CXX_FLAGS_RELWITHDEBINFO="-O3 -g"
```
CMake Options for Compiling NDB Cluster

The following options are for use when building MySQL NDB Cluster 7.2 or later. These options are supported only with the MySQL NDB Cluster 7.2 and later NDB Cluster sources; they are not supported when using sources from the MySQL 5.5 Server tree.

- **-DMEMCACHED_HOME=*dir_name***

  Perform the build using the memcached (version 1.6 or later) installed in the system directory indicated by *dir_name*. Files from this installation that are used in the build include the memcached binary, header files, and libraries, as well as the `memcached_utilities` library and the header file `engine_testapp.h`.

  You must leave this option unset when building `ndbmemcache` using the bundled memcached sources (WITH_BUNDLED_MEMCACHED option); in other words, the bundled sources are used by default).

  This option was added in MySQL NDB Cluster 7.2.2.

  While additional CMake options—such as for SASL authorization and for providing dtrace support—are available for use when compiling memcached from external sources, these options are currently not enabled for the memcached sources bundled with NDB Cluster.

- **-DWITH_BUNDLED_LIBEVENT=*ON|OFF***

  Use the libevent included in the NDB Cluster sources when building NDB Cluster with ndbmemcached support (MySQL NDB Cluster 7.2.2 and later). Enabled by default. OFF causes the system's libevent to be used instead.

- **-DWITH_BUNDLED_MEMCACHED=*ON|OFF***

  Build the memcached sources included in the NDB Cluster source tree (MySQL NDB Cluster 7.2.3 and later), then use the resulting memcached server when building the ndbmemcache engine. In this case, `make install` places the `memcached` binary in the installation bin directory, and the ndbmemcache engine shared library file `ndb_engine.so` in the installation lib directory.

  This option is ON by default.

- **-DWITH_CLASSPATH=*path***

  Sets the classpath for building NDB Cluster Connector for Java. The default is empty. In MySQL NDB Cluster 7.2.9 and later, this option is ignored if -DWITH_NDB_JAVA=OFF is used.

- **-DWITH_ERROR_INSERT=*ON|OFF***

  Enables error injection in the NDB kernel. For testing only; not intended for use in building production binaries. The default is OFF.

- **-DWITH_NDBCLUSTER_STORAGE_ENGINE=*ON|OFF***

  Build and link in support for the NDB (NDBCLUSTER) storage engine in `mysqld`. The default is ON.

- **-DWITH_NDBCLUSTER=*ON|OFF***

  This is an alias for WITH_NDBCLUSTER_STORAGE_ENGINE.

- **-DWITH_NDBMTD=*ON|OFF***

  Build the multithreaded data node executable `ndbmtd`. The default is ON.
Dealing with Problems Compiling MySQL

- **DWITH_NDB_BINLOG={ON|OFF}**
  Enable binary logging by default in the `mysqld` built using this option. ON by default.

- **DWITH_NDB_DEBUG={ON|OFF}**
  Enable building the debug versions of the NDB Cluster binaries. OFF by default.

- **DWITH_NDB_JAVA={ON|OFF}**
  Enable building NDB Cluster with Java support, including `ClusterJ`.
  This option was added in MySQL NDB Cluster 7.2.9, and is ON by default. If you do not wish to compile NDB Cluster with Java support, you must disable it explicitly by specifying `-DWITH_NDB_JAVA=OFF` when running `CMake`. Otherwise, if Java cannot be found, configuration of the build fails.

- **DWITH_NDB_PORT=port**
  Causes the NDB Cluster management server (`ndb_mgmd`) that is built to use this port by default. If this option is unset, the resulting management server tries to use port 1186 by default.

- **DWITH_NDB_TEST={ON|OFF}**
  If enabled, include a set of NDB API test programs. The default is OFF.

### 2.9.8 Dealing with Problems Compiling MySQL

The solution to many problems involves reconfiguring. If you do reconfigure, take note of the following:

- If `CMake` is run after it has previously been run, it may use information that was gathered during its previous invocation. This information is stored in `CMakeCache.txt`. When `CMake` starts, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.

- Each time you run `CMake`, you must run `make` again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old object files or configuration information from being used, run the following commands before re-running `CMake`:

On Unix:
```shell
shell> make clean
shell> rm CMakeCache.txt
```

On Windows:
```shell
shell> devenv MySQL.sln /clean
shell> del CMakeCache.txt
```

If you build outside of the source tree, remove and recreate your build directory before re-running `CMake`. For instructions on building outside of the source tree, see How to Build MySQL Server with CMake.

On some systems, warnings may occur due to differences in system include files. The following list describes other problems that have been found to occur most often when compiling MySQL:

- To define which C and C++ compilers to use, you can define the `CC` and `CXX` environment variables. For example:
  ```shell
  shell> CC=gcc
  ```
To specify your own C and C++ compiler flags, use the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options. See Compiler Flags.

To see what flags you might need to specify, invoke `mysql_config` with the `--cflags` option.

- To see what commands are executed during the compile stage, after using CMake to configure MySQL, run `make VERBOSE=1` rather than just `make`.

- If compilation fails, check whether the `MYSQL_MAINTAINER_MODE` option is enabled. This mode causes compiler warnings to become errors, so disabling it may enable compilation to proceed.

- If your compile fails with errors such as any of the following, you must upgrade your version of `make` to GNU `make`:

```make
make: Fatal error in reader: Makefile, line 18:
Badly formed macro assignment
```

Or:

```make
make: file `Makefile' line 18: Must be a separator (:)
```

Or:

```make
pthread.h: No such file or directory
```

Solaris and FreeBSD are known to have troublesome `make` programs.

GNU `make` 3.75 is known to work.

- The `sql_yacc.cc` file is generated from `sql_yacc.yy`. Normally, the build process does not need to create `sql_yacc.cc` because MySQL comes with a pregenerated copy. However, if you do need to re-create it, you might encounter this error:

```make
"sql_yacc.yy", line xxx fatal: default action causes potential...
```

This is a sign that your version of `yacc` is deficient. You probably need to install a recent version of `bison` (the GNU version of `yacc`) and use that instead.

Versions of `bison` older than 1.75 may report this error:

```make
sql_yacc.yy:#####: fatal error: maximum table size (32767) exceeded
```

The maximum table size is not actually exceeded; the error is caused by bugs in older versions of `bison`.

For information about acquiring or updating tools, see the system requirements in Section 2.9, “Installing MySQL from Source”.

### 2.9.9 MySQL Configuration and Third-Party Tools

Third-party tools that need to determine the MySQL version from the MySQL source can read the `VERSION` file in the top-level source directory. The file lists the pieces of the version separately. For example, if the version is MySQL 5.7.4-m14, the file looks like this:

```ini
MYSQL_VERSION_MAJOR=5
MYSQL_VERSION_MINOR=7
```
If the source is not for a General Availability (GA) release, the `MYSQL_VERSION_EXTRA` value will be nonempty. For the example, the value corresponds to Milestone 14.

To construct a five-digit number from the version components, use this formula:

\[
\text{MYSQL_VERSION_MAJOR} \times 10000 + \text{MYSQL_VERSION_MINOR} \times 100 + \text{MYSQL_VERSION_PATCH}
\]

# 2.10 Postinstallation Setup and Testing

This section discusses tasks that you should perform after installing MySQL:

- If necessary, initialize the data directory and create the MySQL grant tables. For some MySQL installation methods, data directory initialization may be done for you automatically:
  - Installation on Windows
  - Installation on Linux using a server RPM distribution.
  - Installation using the native packaging system on many platforms, including Debian Linux, Ubuntu Linux, Gentoo Linux, and others.
  - Installation on macOS using a DMG distribution.

For other platforms and installation types, you must initialize the data directory manually. These include installation from generic binary and source distributions on Unix and Unix-like systems, and installation from a ZIP Archive package on Windows. For instructions, see Section 2.10.1, “Initializing the Data Directory”.

- For instructions, see Section 2.10.2, “Starting the Server”, and Section 2.10.3, “Testing the Server”.

- Assign passwords to any initial accounts in the grant tables, if that was not already done during data directory initialization. Passwords prevent unauthorized access to the MySQL server. You may also wish to restrict access to test databases. For instructions, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

- Optionally, arrange for the server to start and stop automatically when your system starts and stops. For instructions, see Section 2.10.5, “Starting and Stopping MySQL Automatically”.

- Optionally, populate time zone tables to enable recognition of named time zones. For instructions, see Section 5.1.12, “MySQL Server Time Zone Support”.

When you are ready to create additional user accounts, you can find information on the MySQL access control system and account management in Section 6.2, “Access Control and Account Management”.

## 2.10.1 Initializing the Data Directory

After MySQL is installed, the data directory must be initialized, including the tables in the `mysql` system database:

- For some MySQL installation methods, data directory initialization is automatic, as described in Section 2.10, “Postinstallation Setup and Testing”.

- For other installation methods, you must initialize the data directory manually. These include installation from generic binary and source distributions on Unix and Unix-like systems, and installation from a ZIP Archive package on Windows.
Initializing the Data Directory

This section describes how to initialize the data directory manually for MySQL installation methods for which data directory initialization is not automatic. For some suggested commands that enable testing whether the server is accessible and working properly, see Section 2.10.3, “Testing the Server”.

In the examples shown here, the server is intended to run under the user ID of the mysql login account. This assumes that such an account exists. Either create the account if it does not exist (see Create a mysql User and Group), or substitute the name of a different existing login account that you plan to use for running the server.

1. Change location to the top-level directory of your MySQL installation, represented here by `BASEDIR`:
   ```
   cd BASEDIR
   ```
   `BASEDIR` is likely to be something like `/usr/local/mysql` or `/usr/local`. The following steps assume that you have changed location to this directory.
   
   You will find several files and subdirectories in the `BASEDIR` directory. The most important for installation purposes are the `bin` and `scripts` subdirectories, which contain the server as well as client and utility programs.

2. If necessary, ensure that the distribution contents are accessible to `mysql`. If you installed the distribution as `mysql`, no further action is required. If you installed the distribution as `root`, its contents will be owned by `root`. Change its ownership to `mysql` by executing the following commands as `root` in the installation directory. The first command changes the owner attribute of the files to the `mysql` user. The second changes the group attribute to the `mysql` group.
   ```
   chown -R mysql .
   chgrp -R mysql .
   ```

3. If necessary, initialize the data directory, including the `mysql` database containing the initial MySQL grant tables that determine how users are permitted to connect to the server.
   
   Typically, data directory initialization need be done only the first time you install MySQL. For upgrades to an existing installation, you should run `mysql_upgrade` instead (see Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”). However, the command that initializes the data directory does not overwrite any existing privilege tables, so it should be safe to run in any circumstances. Use the server to initialize the data directory; for example:
   ```
   scripts/mysql_install_db --user=mysql
   ```
   It is important to make sure that the database directories and files are owned by the `mysql` login account so that the server has read and write access to them when you run it later. To ensure this if you run `mysql_install_db` as `root`, include the `--user` option as shown. Otherwise, you should execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

   The `mysql_install_db` command creates the server’s data directory. Under the data directory, it creates directories for the `mysql` database that holds the grant tables and the `test` database that you can use to test MySQL. The program also creates privilege table entries for the initial account or accounts. `test_`. For a complete listing and description of the grant tables, see Section 6.2, “Access Control and Account Management”.

   It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not identify the correct locations for the installation directory or data directory. For example (enter the command on a single line):
   ```
   scripts/mysql_install_db --user=mysql
   --basedir=/opt/mysql/mysql
   ```
Initializing the Data Directory

If you do not want to have the test database, you can remove it after starting the server, using the instructions in Section 2.10.4, “Securing the Initial MySQL Accounts”.

If you have trouble with mysql_install_db at this point, see Section 2.10.1.1, “Problems Running mysql_install_db”.

4. After initializing the data directory, you can establish the final installation ownership settings. To leave the installation owned by mysql, no action is required here. Otherwise, most of the MySQL installation can be owned by root if you like. The exception is that the data directory must be owned by mysql. To accomplish this, run the following commands as root in the installation directory. For some distribution types, the data directory might be named var rather than data; adjust the second command accordingly.

    chown -R root .
    chown -R mysql data

If the plugin directory (the directory named by the plugin_dir system variable) is writable by the server, it may be possible for a user to write executable code to a file in the directory using SELECT ... INTO DUMPFILE. This can be prevented by making the plugin directory read only to the server or by setting the secure_file_priv system variable at server startup to a directory where SELECT writes can be performed safely.

5. In the absence of any option files, the server starts with its default settings. (See Section 5.1.2, “Server Configuration Defaults”.) If you installed MySQL using a source distribution, you may want to optionally copy one of the provided configuration files from the support-files directory into your /etc directory. There are different sample configuration files for different use cases, server types, and CPU and RAM configurations. To use one of these standard files, copy it to /etc/my.cnf, or /etc/mysql/my.cnf and edit and check the configuration before starting your MySQL server for the first time.

You can also create my.cnf yourself and place into it the options the server should use at startup. (See Section 4.2.2.2, “Using Option Files”.) For example, you can use an option file to set the secure_file_priv system variable.

If you do not copy one of the standard configuration files or create your own, the MySQL server starts with its default settings.

6. To arrange for MySQL to start automatically at system boot time, see Section 2.10.5, “Starting and Stopping MySQL Automatically”.

Data directory initialization creates time zone tables in the mysql database but does not populate them. To do so, use the instructions in Section 5.1.12, “MySQL Server Time Zone Support”.

**2.10.1.1 Problems Running mysql_install_db**

The purpose of the mysql_install_db program is to initialize the data directory, including the tables in the mysql system database. It does not overwrite existing MySQL privilege tables, and it does not affect any other data.

To re-create your privilege tables, first stop the mysqld server if it is running. Then rename the mysql directory under the data directory to save it, and run mysql_install_db. Suppose that your current directory is the MySQL installation directory and that mysql_install_db is located in the bin directory and the data directory is named data. To rename the mysql database and re-run mysql_install_db, use these commands.

    mv data/mysql data/mysql.old
Initializing the Data Directory

When you run `mysql_install_db`, you might encounter the following problems:

- **mysql_install_db fails to install the grant tables**

  You may find that `mysql_install_db` fails to install the grant tables and terminates after displaying the following messages:

  ```
  Starting mysqld daemon with databases from XXXXXX
  mysqld ended
  ```

  In this case, you should examine the error log file very carefully. The log should be located in the directory `XXXXXX` named by the error message and should indicate why `mysqld` did not start. If you do not understand what happened, include the log when you post a bug report. See Section 1.6, “How to Report Bugs or Problems”.

- **There is a mysqld process running**

  This indicates that the server is running, in which case the grant tables have probably been created already. If so, there is no need to run `mysql_install_db` at all because it needs to be run only once, when you first install MySQL.

- **Installing a second mysqld server does not work when one server is running**

  This can happen when you have an existing MySQL installation, but want to put a new installation in a different location. For example, you might have a production installation, but you want to create a second installation for testing purposes. Generally the problem that occurs when you try to run a second server is that it tries to use a network interface that is in use by the first server. In this case, you should see one of the following error messages:

    - Can't start server: Bind on TCP/IP port:
    - Address already in use
    - Can't start server: Bind on unix socket...

  For instructions on setting up multiple servers, see Section 5.7, “Running Multiple MySQL Instances on One Machine”.

- **You do not have write access to the /tmp directory**

  If you do not have write access to create temporary files or a Unix socket file in the default location (the `/tmp` directory) or the `TMPDIR` environment variable, if it has been set, an error occurs when you run `mysql_install_db` or the `mysqld` server.

  You can specify different locations for the temporary directory and Unix socket file by executing these commands prior to starting `mysql_install_db` or `mysqld`, where `some_tmp_dir` is the full path name to some directory for which you have write permission:

  ```
  TMPDIR=/some_tmp_dir/
  MYSQL_UNIX_PORT=/some_tmp_dir/mysql.sock
  export TMPDIR MYSQL_UNIX_PORT
  ```

  Then you should be able to run `mysql_install_db` and start the server with these commands:

  ```
  scripts/mysql_install_db --user=mysql
  bin/mysqld_safe --user=mysql &
  ```

  If `mysql_install_db` is located in the `scripts` directory, modify the first command to `scripts/mysql_install_db`.

193
See Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”, and Section 4.9, “Environment Variables”.

There are some alternatives to running the `mysql_install_db` program provided in the MySQL distribution:

- If you want the initial privileges to differ from the standard defaults, use account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to change the privileges after the grant tables have been set up. In other words, run `mysql_install_db`, and then use `mysql -u root mysql` to connect to the server as the MySQL root user so that you can issue the necessary statements. (See Section 13.7.1, “Account Management Statements”.)

To install MySQL on several machines with the same privileges, put the `CREATE USER`, `GRANT`, and `REVOKE` statements in a file and execute the file as a script using `mysql` after running `mysql_install_db`. For example:

```bash
cache/mysql_install_db --user=mysql
bin/mysql -u root < your_script_file
```

This enables you to avoid issuing the statements manually on each machine.

- It is possible to re-create the grant tables completely after they have previously been created. You might want to do this if you are just learning how to use `CREATE USER`, `GRANT`, and `REVOKE` and have made so many modifications after running `mysql_install_db` that you want to wipe out the tables and start over.

To re-create the grant tables, stop the server if it is running and remove the `mysql` database directory. Then run `mysql_install_db` again.

### 2.10.2 Starting the Server

This section describes how to start the server on Unix and Unix-like systems. (For Windows, see Section 2.3.6.4, “Starting the Server for the First Time”.) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 2.10.3, “Testing the Server”.

Start the MySQL server like this:

```
shell> bin/mysqld_safe --user=mysql &
```

It is important that the MySQL server be run using an unprivileged (non-root) login account. To ensure this if you run `mysqld_safe` as `root`, include the `--user` option as shown. Otherwise, execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

For further instructions for running MySQL as an unprivileged user, see Section 6.1.5, “How to Run MySQL as a Normal User”.

If the command fails immediately and prints `mysqld ended`, look for information in the error log (which by default is the `host_name.err` file in the data directory).

If the server is unable to access the data directory it starts or read the grant tables in the `mysql` database, it writes a message to its error log. Such problems can occur if you neglected to create the grant tables by initializing the data directory before proceeding to this step, or if you ran the command that initializes the data directory without the `--user` option. Remove the `data` directory and run the command with the `--user` option.

If you have other problems starting the server, see Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”. For more information about `mysqld_safe`, see Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”.
You can set up new accounts using the `bin/mysql_setpermission` script if you install the DBI and DBD::mysql Perl modules. See Section 4.6.13, "mysql_setpermission — Interactively Set Permissions in Grant Tables". For Perl module installation instructions, see Section 2.13, “Perl Installation Notes”.

If you would like to use `mysqlaccess` and have the MySQL distribution in some nonstandard location, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the `bin/mysqlaccess` script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, a Broken pipe error will occur when you run `mysqlaccess`.

### 2.10.2.1 Troubleshooting Problems Starting the MySQL Server

This section provides troubleshooting suggestions for problems starting the server. For additional suggestions for Windows systems, see Section 2.3.7, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

If you have problems starting the server, here are some things to try:

- Check the error log to see why the server does not start.
- Specify any special options needed by the storage engines you are using.
- Make sure that the server knows where to find the data directory.
- Make sure that the server can access the data directory. The ownership and permissions of the data directory and its contents must be set such that the server can read and modify them.
- Verify that the network interfaces the server wants to use are available.

Some storage engines have options that control their behavior. You can create a `my.cnf` file and specify startup options for the engines that you plan to use. If you are going to use storage engines that support transactional tables (InnoDB, NDB), be sure that you have them configured the way you want before starting the server:

If you are using InnoDB tables, see Section 14.11, “InnoDB Configuration”.

Storage engines will use default option values if you specify none, but it is recommended that you review the available options and specify explicit values for those for which the defaults are not appropriate for your installation.

When the `mysqld` server starts, it changes location to the data directory. This is where it expects to find databases and where it expects to write log files. The server also writes the pid (process ID) file in the data directory.

The data directory location is hardwired in when the server is compiled. This is where the server looks for the data directory by default. If the data directory is located somewhere else on your system, the server will not work properly. You can determine what the default path settings are by invoking `mysqld` with the `--verbose` and `--help` options.

If the default locations do not match the MySQL installation layout on your system, you can override them by specifying options to `mysqld` or `mysqld_safe` on the command line or in an option file.

To specify the location of the data directory explicitly, use the `--datadir` option. However, normally you can tell `mysqld` the location of the base directory under which MySQL is installed and it looks for the data directory there. You can do this with the `--basedir` option.
To check the effect of specifying path options, invoke `mysqld` with those options followed by the `--verbose` and `--help` options. For example, if you change location to the directory where `mysqld` is installed and then run the following command, it shows the effect of starting the server with a base directory of `/usr/local`:

```
shell> ./mysqld --basedir=/usr/local --verbose --help
```

You can specify other options such as `--datadir` as well, but `--verbose` and `--help` must be the last options.

Once you determine the path settings you want, start the server without `--verbose` and `--help`.

If `mysqld` is currently running, you can find out what path settings it is using by executing this command:

```
shell> mysqladmin variables
```

Or:

```
shell> mysqladmin -h host_name variables
```

`host_name` is the name of the MySQL server host.

If you get `Errcode 13` (which means `Permission denied`) when starting `mysqld`, this means that the privileges of the data directory or its contents do not permit server access. In this case, you change the permissions for the involved files and directories so that the server has the right to use them. You can also start the server as `root`, but this raises security issues and should be avoided.

Change location to the data directory and check the ownership of the data directory and its contents to make sure the server has access. For example, if the data directory is `/usr/local/mysql/var`, use this command:

```
shell> ls -la /usr/local/mysql/var
```

If the data directory or its files or subdirectories are not owned by the login account that you use for running the server, change their ownership to that account. If the account is named `mysql`, use these commands:

```
shell> chown -R mysql /usr/local/mysql/var
shell> chgrp -R mysql /usr/local/mysql/var
```

Even with correct ownership, MySQL might fail to start up if there is other security software running on your system that manages application access to various parts of the file system. In this case, reconfigure that software to enable `mysqld` to access the directories it uses during normal operation.

If the server fails to start up correctly, check the error log. Log files are located in the data directory (typically `C:\Program Files\MySQL\MySQL Server 5.5\data` on Windows, `/usr/local/mysql/data` for a Unix/Linux binary distribution, and `/usr/local/var` for a Unix/Linux source distribution). Look in the data directory for files with names of the form `host_name.err` and `host_name.log`, where `host_name` is the name of your server host. Then examine the last few lines of these files. You can use `tail` to display them:

```
shell> tail host_name.err
shell> tail host_name.log
```

The error log should contain information that indicates why the server could not start.

If either of the following errors occur, it means that some other program (perhaps another `mysqld` server) is using the TCP/IP port or Unix socket file that `mysqld` is trying to use:

```
Can't start server: Bind on TCP/IP port: Address already in use
Can't start server: Bind on unix socket...
```
Testing the Server

Use `ps` to determine whether you have another `mysqld` server running. If so, shut down the server before starting `mysqld` again. (If another server is running, and you really want to run multiple servers, you can find information about how to do so in Section 5.7, “Running Multiple MySQL Instances on One Machine”.)

If no other server is running, try to execute the command `telnet your_host_name tcp_ip_port_number`. (The default MySQL port number is 3306.) Then press Enter a couple of times. If you do not get an error message like `Connection refused`, some other program is using the TCP/IP port that `mysqld` is trying to use. You will need to track down what program this is and disable it, or else tell `mysqld` to listen to a different port with the `--port` option. In this case, you will also need to specify the port number for client programs when connecting to the server using TCP/IP.

Another reason the port might be inaccessible is that you have a firewall running that blocks connections to it. If so, modify the firewall settings to permit access to the port.

If the server starts but you cannot connect to it, you should make sure that you have an entry in `/etc/hosts` that looks like this:

```
127.0.0.1       localhost
```

If you cannot get `mysqld` to start, you can try to make a trace file to find the problem by using the `--debug` option. See Section 24.5.3, “The DBUG Package”.

2.10.3 Testing the Server

After the data directory is initialized and you have started the server, perform some simple tests to make sure that it works satisfactorily. This section assumes that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your shell (command interpreter) to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 4.2.6, “Setting Environment Variables”.

Use `mysqladmin` to verify that the server is running. The following commands provide simple tests to check whether the server is up and responding to connections:

```
shell> bin/mysqladmin version
shell> bin/mysqladmin variables
```

If you cannot connect to the server, specify a `-u root` option to connect as `root`. If you have assigned a password for the `root` account already, you'll also need to specify `-p` on the command line and enter the password when prompted. For example:

```
shell> bin/mysqladmin -u root -p version
Enter password: (enter root password here)
```

The output from `mysqladmin version` varies slightly depending on your platform and version of MySQL, but should be similar to that shown here:

```
shell> bin/mysqladmin version
mysqladmin  Ver 14.12 Distrib 5.5.62, for pc-linux-gnu on i686
...  
Server version 5.5.62
Protocol version 10
Connection Localhost via UNIX socket
UNIX socket /var/lib/mysql/mysql.sock
Uptime: 14 days 5 hours 5 min 21 sec
```
Testing the Server

To see what else you can do with mysqladmin, invoke it with the --help option.

Verify that you can shut down the server (include a -p option if the root account has a password already):

shell> bin/mysqladmin -u root shutdown

Verify that you can start the server again. Do this by using mysqld_safe or by invoking mysqld directly. For example:

shell> bin/mysqld_safe --user=mysql &

If mysqld_safe fails, see Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”.

Run some simple tests to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use mysqlshow to see what databases exist:

shell> bin/mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| test               |
+--------------------+

The list of installed databases may vary, but always includes at least mysql and information_schema.

If you specify a database name, mysqlshow displays a list of the tables within the database:

shell> bin/mysqlshow mysql
Database: mysql
+---------------------------+
|          Tables           |
+---------------------------+
| columns_priv              |
| db                        |
| event                     |
| func                      |
| general_log               |
| help_category             |
| help_keyword              |
| help_relation             |
| help_topic                |
| host                      |
| ndb_binlog_index          |
| plugin                    |
| proc                      |
| procs_priv                |
| proxies_priv              |
| servers                   |
| slow_log                  |
| tables_priv               |
| time_zone                 |
| time_zone_leap_second     |
| time_zone_name            |
| time_zone_transition      |
| time_zone_transition_type |
| user                      |
+---------------------------+
Securing the Initial MySQL Accounts

Use the `mysql` program to select information from a table in the `mysql` database:

```shell
bin/mysql -e "SELECT User, Host, plugin FROM mysql.user" mysql
```

<table>
<thead>
<tr>
<th>User</th>
<th>Host</th>
<th>plugin</th>
</tr>
</thead>
<tbody>
<tr>
<td>root</td>
<td>localhost</td>
<td>mysql_native_password</td>
</tr>
</tbody>
</table>

At this point, your server is running and you can access it. To tighten security if you have not yet assigned passwords to the initial account or accounts, follow the instructions in Section 2.10.4, “Securing the Initial MySQL Accounts”.

For more information about `mysql`, `mysqladmin`, and `mysqlshow`, see Section 4.5.1, “mysql — The MySQL Command-Line Client”, Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”, and Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”.

### 2.10.4 Securing the Initial MySQL Accounts

The MySQL installation process involves initializing the data directory, including the grant tables in the `mysql` system database that define MySQL accounts. For details, see Section 2.10.1, “Initializing the Data Directory”.

This section describes how to assign passwords to the initial accounts created during the MySQL installation procedure, if you have not already done so.

The `mysql.user` grant table defines the initial MySQL user accounts and their access privileges:

- Some accounts have the user name `root`. These are superuser accounts that have all privileges and can do anything. If these `root` accounts have empty passwords, anyone can connect to the MySQL server as `root without a password` and be granted all privileges.

  - On Windows, `root` accounts are created that permit connections from the local host only. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, or the IPv6 address `::1`. If the user selects the **Enable root access from remote machines** option during installation, the Windows installer creates another `root` account that permits connections from any host.

  - On Unix, each `root` account permits connections from the local host. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, the IPv6 address `::1`, or the actual host name or IP address.

  An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with `skip_name_resolve` enabled, so the `127.0.0.1` account is useful in that case. The `::1` account is used for IPv6 connections.

- If accounts for anonymous users were created, these have an empty user name. The anonymous accounts have no password, so anyone can use them to connect to the MySQL server.

  - On Windows, there is one anonymous account that permits connections from the local host. Connections can be made by specifying a host name of `localhost`.

  - On Unix, each anonymous account permits connections from the local host. Connections can be made by specifying a host name of `localhost` for one of the accounts, or the actual host name or IP address for the other.

  The `'root'@'localhost'` account also has a row in the `mysql.proxies_priv` table that enables granting the `PROXY` privilege for `'@'`, that is, for all users and all hosts. This enables `root` to set...
Securing the Initial MySQL Accounts

up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 6.2.11, “Proxy Users”.

To display which accounts exist in the `mysql.user` system table and check whether their passwords are empty, use the following statement:

```
mysql> SELECT User, Host, Password FROM mysql.user;
```

<table>
<thead>
<tr>
<th>User</th>
<th>Host</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>root</td>
<td>localhost</td>
<td></td>
</tr>
<tr>
<td>root</td>
<td>myhost.example.com</td>
<td></td>
</tr>
<tr>
<td>root</td>
<td>127.0.0.1</td>
<td></td>
</tr>
<tr>
<td>root</td>
<td>::1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localhost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>myhost.example.com</td>
<td></td>
</tr>
</tbody>
</table>

This output indicates that there are several `root` and anonymous-user accounts, none of which have passwords. The output might differ on your system, but the presence of accounts with empty passwords means that your MySQL installation is unprotected until you do something about it:

- Assign a password to each MySQL `root` account that does not have one.
- To prevent clients from connecting as anonymous users without a password, either assign a password to each anonymous account or remove the accounts.

In addition, the `mysql.db` table contains rows that permit all accounts to access the `test` database and other databases with names that start with `test_`. This is true even for accounts that otherwise have no special privileges such as the default anonymous accounts. This is convenient for testing but inadvisable on production servers. Administrators who want database access restricted only to accounts that have permissions granted explicitly for that purpose should remove these `mysql.db` table rows.

The following instructions describe how to set up passwords for the initial MySQL accounts, first for the `root` accounts, then for the anonymous accounts. The instructions also cover how to remove anonymous accounts, should you prefer not to permit anonymous access at all, and describe how to remove permissive access to test databases. Replace `new_password` in the examples with the password that you want to use. Replace `host_name` with the name of the server host. You can determine this name from the output of the preceding `SELECT` statement. For the output shown, `host_name` is `myhost.example.com`.

You need not remove anonymous entries in the `mysql.proxies_priv` table, which are used to support proxy users. See Section 6.2.11, “Proxy Users”.

Note
For additional information about setting passwords, see Section 6.2.9, “Assigning Account Passwords”. If you forget your `root` password after setting it, see Section B.4.3.2, “How to Reset the Root Password”.

To set up additional accounts, see Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”.

You might want to defer setting the passwords until later, to avoid the need to specify them while you perform additional setup or testing. However, be sure to set them before using your installation for production purposes.

Note
On Windows, you can also perform the process described in this section using the Configuration Wizard (see Section 2.3.5.11, “The Security Options Dialog”). On
Securing the Initial MySQL Accounts

all platforms, the MySQL distribution includes `mysql_secure_installation`, a command-line utility that automates much of the process of securing a MySQL installation. MySQL Workbench is available on all platforms, and also offers the ability to manage user accounts (see Chapter 26, *MySQL Workbench*).

- Assigning root Account Passwords
- Assigning Anonymous Account Passwords
- Removing Anonymous Accounts
- Securing Test Databases

**Assigning root Account Passwords**

A root account password can be set several ways. The following discussion demonstrates three methods:

- Use the `SET PASSWORD` statement
- Use the `UPDATE` statement
- Use the `mysqladmin` command-line client program

To assign passwords using `SET PASSWORD`, connect to the server as root and issue a `SET PASSWORD` statement for each root account listed in the `mysql.user` system table.

For Windows, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'::1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'host_name' = PASSWORD('new_password');
```

The last statement is unnecessary if the `mysql.user` table has no root account with a host value of %.

For Unix, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'::1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'host_name' = PASSWORD('new_password');
```

You can also use a single statement that assigns a password to all root accounts by using `UPDATE` to modify the `mysql.user` table directly. This method works on any platform:

```
shell> mysql -u root
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    WHERE User = 'root';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

To assign passwords to the root accounts using `mysqladmin`, execute the following commands:

```
shell> mysqladmin -u root password "new_password"
shell> mysqladmin -u root -h host_name password "new_password"
```

Those commands apply both to Windows and to Unix. The double quotation marks around the password are not always necessary, but you should use them if the password contains spaces or other characters that are special to your command interpreter.
Securing the Initial MySQL Accounts

The `mysqladmin` method of setting the `root` account passwords does not work for the 'root'@'127.0.0.1' or 'root'@'::1' account. Use the `SET PASSWORD` method shown earlier.

After the `root` passwords have been set, you must supply the appropriate password whenever you connect as `root` to the server. For example, to shut down the server with `mysqladmin`, use this command:

```
shell> mysqladmin -u root -p shutdown
Enter password: (enter root password here)
```

The `mysql` commands in the following instructions include a `-p` option based on the assumption that you have assigned the `root` account passwords using the preceding instructions and must specify that password when connecting to the server.

**Assigning Anonymous Account Passwords**

To assign passwords to the anonymous accounts, connect to the server as `root`, then use either `SET PASSWORD` or `UPDATE`.

To use `SET PASSWORD` on Windows, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
```

To use `SET PASSWORD` on Unix, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR ''@'host_name' = PASSWORD('new_password');
```

To set the anonymous-user account passwords with a single `UPDATE` statement, do this (on any platform):

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    -> WHERE User = '';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

**Removing Anonymous Accounts**

If you prefer to remove any anonymous accounts rather than assigning them passwords, do so as follows on Windows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
```

On Unix, remove the anonymous accounts like this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
mysql> DROP USER ''@'host_name';
```

**Securing Test Databases**

By default, the `mysql.db` table contains rows that permit access by any user to the `test` database and other databases with names that start with `test_`. (These rows have an empty `User` column value, which
for access-checking purposes matches any user name.) This means that such databases can be used even by accounts that otherwise possess no privileges. If you want to remove any-user access to test databases, do so as follows:

```shell
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DELETE FROM mysql.db WHERE Db LIKE 'test%';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the privilege change remains unnoticed by the server until you restart it.

With the preceding change, only users who have global database privileges or privileges granted explicitly for the `test` database can use it. However, if you prefer that the database not exist at all, drop it:

```shell
mysql> DROP DATABASE test;
```

### 2.10.5 Starting and Stopping MySQL Automatically

This section discusses methods for starting and stopping the MySQL server.

Generally, you start the `mysqld` server in one of these ways:

- Invoke `mysqld` directly. This works on any platform.

- On Windows, you can set up a MySQL service that runs automatically when Windows starts. See Section 2.3.6.7, “Starting MySQL as a Windows Service”.

- On Unix and Unix-like systems, you can invoke `mysqld_safe`, which tries to determine the proper options for `mysqld` and then runs it with those options. See Section 4.3.2, "mysqld_safe — MySQL Server Startup Script".

- On systems that use System V-style run directories (that is, `/etc/init.d` and run-level specific directories), invoke `mysql.server`. This script is used primarily at system startup and shutdown. It usually is installed under the name `mysql`. The `mysql.server` script starts the server by invoking `mysqld_safe`. See Section 4.3.3, "mysql.server — MySQL Server Startup Script".

- On macOS, install a launchd daemon to enable automatic MySQL startup at system startup. The daemon starts the server by invoking `mysqld_safe`. For details, see Section 2.4.3, “Installing a MySQL Launch Daemon”. A MySQL Preference Pane also provides control for starting and stopping MySQL through the System Preferences. See Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

- On Solaris, use the service management framework (SMF) system to initiate and control MySQL startup.

The `mysqld_safe` and `mysql.server` scripts, Solaris SMF, and the macOS Startup Item (or MySQL Preference Pane) can be used to start the server manually, or automatically at system startup time. `mysql.server` and the Startup Item also can be used to stop the server.

The following table shows which option groups the server and startup scripts read from option files.

<table>
<thead>
<tr>
<th>Script</th>
<th>Option Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>mysqld</code></td>
<td><code>[mysqld], [server], [mysqld-major_version]</code></td>
</tr>
<tr>
<td><code>mysqld_safe</code></td>
<td><code>[mysqld], [server], [mysqld_safe]</code></td>
</tr>
<tr>
<td><code>mysql.server</code></td>
<td><code>[mysqld], [mysql.server], [server]</code></td>
</tr>
</tbody>
</table>
Upgrading MySQL

[mysqld-major_version] means that groups with names like [mysqld-5.1] and [mysqld-5.5] are read by servers having versions 5.1.x, 5.5.x, and so forth. This feature can be used to specify options that can be read only by servers within a given release series.

For backward compatibility, mysql.server also reads the [mysql_server] group and mysqld_safe also reads the [safe_mysqld] group. However, you should update your option files to use the [mysql.server] and [mysqld_safe] groups instead.

For more information on MySQL configuration files and their structure and contents, see Section 4.2.2.2, “Using Option Files”.

2.11 Upgrading MySQL

This section describes the steps to upgrade a MySQL installation.

Upgrading is a common procedure, as you pick up bug fixes within the same MySQL release series or significant features between major MySQL releases. You perform this procedure first on some test systems to make sure everything works smoothly, and then on the production systems.

Note

In the following discussion, MySQL commands that must be run using a MySQL account with administrative privileges include \texttt{-u root} on the command line to specify the MySQL root user. Commands that require a password for root also include a \texttt{-p} option. Because \texttt{-p} is followed by no option value, such commands prompt for the password. Type the password when prompted and press Enter.

SQL statements can be executed using the \texttt{mysql} command-line client (connect as root to ensure that you have the necessary privileges).

2.11.1 Before You Begin

Review the information in this section before upgrading. Perform any recommended actions.

- Protect your data by creating a backup. The backup should include the \texttt{mysql} system database, which contains the MySQL system tables. See Section 7.2, “Database Backup Methods”.

- Review Section 2.11.2, “Upgrade Paths” to ensure that your intended upgrade path is supported.

- Review Section 2.11.3, “Changes in MySQL 5.5” for changes that you should be aware of before upgrading. Some changes may require action.

- Review Section 1.4, “What Is New in MySQL 5.5” for deprecated and removed features. An upgrade may require changes with respect to those features if you use any of them.

- Review the Release Notes for information about fixes, changes, and new features.

- If you use replication, review Section 17.4.3, “Upgrading a Replication Setup”.

- Upgrade procedures vary by platform and how the initial installation was performed. Use the procedure that applies to your current MySQL installation:
  - For binary and package-based installations on non-Windows platforms, refer to Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”.
  - For installations on Windows, refer to Section 2.11.5, “Upgrading MySQL on Windows”.
• If your MySQL installation contains a large amount of data that might take a long time to convert after an in-place upgrade, it may be useful to create a test instance for assessing the conversions that are required and the work involved to perform them. To create a test instance, make a copy of your MySQL instance that contains the `mysql` database and other databases without the data. Run the upgrade procedure on the test instance to assess the work involved to perform the actual data conversion.

• Rebuilding and reinstalling MySQL language interfaces is recommended when you install or upgrade to a new release of MySQL. This applies to MySQL interfaces such as PHP `mysql` extensions and the Perl `DBD::mysql` module.

### 2.11.2 Upgrade Paths

• Upgrade is only supported between General Availability (GA) releases.

• Upgrade from MySQL 5.1 to 5.5 is supported. Upgrading to the latest release is recommended before upgrading to the next version. For example, upgrade to the latest MySQL 5.1 release before upgrading to MySQL 5.5.

• Upgrade that skips versions is not supported. For example, upgrading directly from MySQL 5.0 to 5.5 is not supported.

• Upgrade within a release series is supported. For example, upgrading from MySQL 5.5.x to 5.5.y is supported. Skipping a release is also supported. For example, upgrading from MySQL 5.5.x to 5.5.z is supported.

### 2.11.3 Changes in MySQL 5.5

Before upgrading to MySQL 5.5, review the changes described in this section to identify those that apply to your current MySQL installation and applications. Perform any recommended actions.

Changes marked as **Incompatible change** are incompatibilities with earlier versions of MySQL, and may require your attention before upgrading. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases. If an upgrade issue applicable to your installation involves an incompatibility, follow the instructions given in the description. Sometimes this involves dumping and reloading tables, or use of a statement such as `CHECK TABLE` or `REPAIR TABLE`.

For dump and reload instructions, see Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”. Any procedure that involves `REPAIR TABLE` with the `USE_FRM` option must be done before upgrading. Use of this statement with a version of MySQL different from the one used to create the table (that is, using it after upgrading) may damage the table. See Section 13.7.2.5, “REPAIR TABLE Statement”.

• Configuration Changes

• Server Changes

• InnoDB Changes

• SQL Changes

### Configuration Changes

• **Incompatible change**: The `InnoDB Plugin` is included in MySQL 5.5 releases. It becomes the built-in version of `InnoDB` in MySQL Server, replacing the version previously included as the built-in `InnoDB` engine. `InnoDB Plugin` is also available in MySQL 5.1 as of 5.1.38, but it is an optional storage engine that must be enabled explicitly using two server options:

```
[mysqld]
```
Changes in MySQL 5.5

<table>
<thead>
<tr>
<th>ignore-builtin-innodb</th>
</tr>
</thead>
<tbody>
<tr>
<td>plugin-load=innodb=ha_innodb_plugin.so</td>
</tr>
</tbody>
</table>

If you were using InnoDB Plugin in MySQL 5.1 by means of those options, you must remove them after an upgrade to 5.5 or the server will fail to start.

In addition, in InnoDB Plugin, the innodb_file_io_threads system variable has been removed and replaced with innodb_read_io_threads and innodb_write_io_threads. If you upgrade from MySQL 5.1 to MySQL 5.5 and previously explicitly set innodb_file_io_threads at server startup, you must change your configuration. Either remove any reference to innodb_file_io_threads or replace it with references to innodb_read_io_threads and innodb_write_io_threads.

**Incompatible change:** In MySQL 5.5, the server includes a plugin services interface that complements the plugin API. The services interface enables server functionality to be exposed as a “service” that plugins can access through a function-call interface. The libmysqlservices library provides access to the available services and dynamic plugins now must be linked against this library (use the --lmysqlservices flag). For an example showing how to configure for CMake, see Section 24.3, “MySQL Services for Plugins”.

**Server Changes**

- **On Linux systems,** the libaio library may be needed. Install it first, if it is not already present on your system.

- As of MySQL 5.5.32, for new installations, the url columns in the mysql database help tables are now created as type TEXT to accommodate longer URLs. For upgrades, mysql_upgrade does not update the columns. Modify them manually using these statements:

  ```
  ALTER TABLE mysql.help_category MODIFY url TEXT NOT NULL;
  ALTER TABLE mysql.help_topic MODIFY url TEXT NOT NULL;
  ```

**Incompatible change:** As of MySQL 5.5.3, due to work done for Bug #989, FLUSH TABLES is not permitted when there is an active LOCK TABLES ... READ. To provide a workaround for this restriction, FLUSH TABLES has a new variant, FLUSH TABLES tbl_list WITH READ LOCK, that enables tables to be flushed and locked in a single operation. As a result of this change, applications that previously used this statement sequence to lock and flush tables will fail:

  ```
  LOCK TABLES tbl_list READ;
  FLUSH TABLES tbl_list;
  ```

Such applications should now use this statement instead:

  ```
  FLUSH TABLES tbl_list WITH READ LOCK;
  ```

**Incompatible change:** As of MySQL 5.5.7, the server requires that a new grant table, proxies_priv, be present in the mysql database. If you are upgrading to 5.5.7 from a previous MySQL release rather than performing a new installation, the server will find that this table is missing and exit during startup with the following message:

  ```
  Table 'mysql.proxies_priv' doesn't exist
  ```

To create the proxies_priv table, start the server with the --skip-grant-tables option to cause it to skip the normal grant table checks, then run mysql_upgrade. For example:

  ```
  mysqld --skip-grant-tables &
  mysql_upgrade
  ```

Then stop the server and restart it normally.
You can specify other options on the `mysqld` command line if necessary. Alternatively, if your installation is configured so that the server normally reads options from an option file, use the `--defaults-file` option to specify the file (enter each command on a single line):

```bash
mysqld --defaults-file=/usr/local/mysql/etc/my.cnf
mysqld --skip-grant-tables &
mysqld_upgrade
```

With the `--skip-grant-tables` option, the server does no password or privilege checking, so any client can connect and effectively have all privileges. For additional security, enable the `skip_networking` system variable as well to prevent remote clients from connecting.

**Note**

This problem is fixed in MySQL 5.5.8: the server treats a missing `proxies_priv` table as equivalent to an empty table. However, after starting the server, you should still run `mysql_upgrade` to create the table.

**Incompatible change:** As of MySQL 5.5.7, InnoDB always uses the fast truncation technique, equivalent to `DROP TABLE` and `CREATE TABLE`. It no longer performs a row-by-row delete for tables with parent-child foreign key relationships. `TRUNCATE TABLE` returns an error for such tables. Modify your SQL to issue `DELETE FROM table_name` for such tables instead.

**Incompatible change:** Prior to MySQL 5.5.7, if you flushed the logs using `FLUSH LOGS` or `mysqladmin flush-logs` and `mysqld` was writing the error log to a file (for example, if it was started with the `--log-error` option), it renames the current log file with the suffix `-old`, then created a new empty log file. This had the problem that a second log-flushing operation thus caused the original error log file to be lost unless you saved it under a different name. For example, you could use the following commands to save the file:

```bash
mysqladmin flush-logs
mv host_name.err-old backup-directory
```

To avoid the preceding file-loss problem, no renaming occurs as of MySQL 5.5.7; the server merely closes and reopens the log file. To rename the file, you can do so manually before flushing. Then flushing the logs reopens a new file with the original file name. For example, you can rename the file and create a new one using the following commands:

```bash
mv host_name.err host_name.err-old
mysqladmin flush-logs
mv host_name.err-old backup-directory
```

**Incompatible change:** As of MySQL 5.5.6, handling of `CREATE TABLE IF NOT EXISTS ... SELECT` statements has been changed for the case that the destination table already exists:

- Previously, for `CREATE TABLE IF NOT EXISTS ... SELECT`, MySQL produced a warning that the table exists, but inserted the rows and wrote the statement to the binary log anyway. By contrast, `CREATE TABLE ... SELECT (without IF NOT EXISTS)` failed with an error, but MySQL inserted no rows and did not write the statement to the binary log.

- MySQL now handles both statements the same way when the destination table exists, in that neither statement inserts rows or is written to the binary log. The difference between them is that MySQL produces a warning when `IF NOT EXISTS` is present and an error when it is not.

This change in handling of `IF NOT EXISTS` results in an incompatibility for statement-based replication from a MySQL 5.1 master with the original behavior and a MySQL 5.5 slave with the new behavior. Suppose that `CREATE TABLE IF NOT EXISTS ... SELECT` is executed on the master and the
Changes in MySQL 5.5

destination table exists. The result is that rows are inserted on the master but not on the slave. (Row-
based replication does not have this problem.)

To address this issue, statement-based binary logging for `CREATE TABLE IF NOT EXISTS ... SELECT` is changed in MySQL 5.1 as of 5.1.51:

• If the destination table does not exist, there is no change: The statement is logged as is.

• If the destination table does exist, the statement is logged as the equivalent pair of `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements. (If the `SELECT` in the original statement is preceded by `IGNORE` or `REPLACE`, the `INSERT` becomes `INSERT IGNORE` or `REPLACE`, respectively.)

This change provides forward compatibility for statement-based replication from MySQL 5.1 to 5.5 because when the destination table exists, the rows will be inserted on both the master and slave. To take advantage of this compatibility measure, the 5.1 server must be at least 5.1.51 and the 5.5 server must be at least 5.5.6.

To upgrade an existing 5.1-to-5.5 replication scenario, upgrade the master first to 5.1.51 or higher. Note that this differs from the usual replication upgrade advice of upgrading the slave first.

A workaround for applications that wish to achieve the original effect (rows inserted regardless of whether the destination table exists) is to use `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements rather than `CREATE TABLE IF NOT EXISTS ... SELECT` statements.

Along with the change just described, the following related change was made: Previously, if an existing view was named as the destination table for `CREATE TABLE IF NOT EXISTS ... SELECT`, rows were inserted into the underlying base table and the statement was written to the binary log. As of MySQL 5.1.51 and 5.5.6, nothing is inserted or logged.

• **Incompatible change:** Prior to MySQL 5.5.6, if the server was started with `character_set_server` set to `utf16`, it crashed during full-text stopword initialization. Now the stopword file is loaded and searched using `latin1` if `character_set_server` is `ucs2`, `utf16`, or `utf32`. If any table was created with `FULLTEXT` indexes while the server character set was `ucs2`, `utf16`, or `utf32`, it should be repaired using this statement:

```sql
REPAIR TABLE tbl_name QUICK;
```

• **Incompatible change:** As of MySQL 5.5.5, all numeric operators and functions on integer, floating-point and `DECIMAL` values throw an “out of range” error (`ER_DATA_OUT_OF_RANGE`) rather than returning an incorrect value or `NULL`, when the result is out of the supported range for the corresponding data type. See Section 11.1.7, “Out-of-Range and Overflow Handling”.

• **Incompatible change:** In very old versions of MySQL (prior to 4.1), the `TIMESTAMP` data type supported a display width, which was silently ignored beginning with MySQL 4.1. This is deprecated in MySQL 5.1, and removed altogether in MySQL 5.5. These changes in behavior can lead to two problem scenarios when trying to use `TIMESTAMP(N)` columns with a MySQL 5.5 or later server:

  • When importing a dump file (for example, one created using `mysqldump`) created in a MySQL 5.0 or earlier server into a server from a newer release series, a `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` causes the import to fail with a syntax error.

    To fix this problem, edit the dump file in a text editor to replace any instances of `TIMESTAMP(N)` with `TIMESTAMP` prior to importing the file. Be sure to use a plain text editor for this, and not a word processor; otherwise, the result is almost certain to be unusable for importing into the MySQL server.

  • When trying replicate any `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` from a master MySQL server that supports the `TIMESTAMP(N)` syntax to a MySQL 5.5.3 or higher
Changes in MySQL 5.5

slaves, the statement causes replication to fail. Similarly, when you try to restore from a binary log written by a server that supports `TIMESTAMP (N)` to a MySQL 5.5.3 or higher server, any `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP (N)` causes the backup to fail. This holds true regardless of the logging format.

It may be possible to fix such issues using a hex editor, by replacing any width arguments used with `TIMESTAMP`, and the parentheses containing them, with space characters (hexadecimal 20). Be sure to use a programmer's binary hex editor and not a regular text editor or word processor for this; otherwise, the result is almost certain to be a corrupted binary log file. To guard against accidental corruption of the binary log, you should always work on a copy of the file rather than the original.

You should try to handle potential issues of these types proactively by updating with `ALTER TABLE` any `TIMESTAMP (N)` columns in your databases so that they use `TIMESTAMP` instead, before performing any upgrades.

• **Incompatible change**: As of MySQL 5.5.3, the Unicode implementation has been extended to provide support for supplementary characters that lie outside the Basic Multilingual Plane (BMP). Noteworthy features:

  • `utf16` and `utf32` character sets have been added. These correspond to the UTF-16 and UTF-32 encodings of the Unicode character set, and they both support supplementary characters.

  • The `utf8mb4` character set has been added. This is similar to `utf8`, but its encoding allows up to four bytes per character to enable support for supplementary characters.

  • The `ucs2` character set is essentially unchanged except for the inclusion of some newer BMP characters.

In most respects, upgrading to MySQL 5.5 should present few problems with regard to Unicode usage, although there are some potential areas of incompatibility. These are the primary areas of concern:

• For the variable-length character data types (`VARCHAR` and the `TEXT` types), the maximum length in characters is less for `utf8mb4` columns than for `utf8` columns.

• For all character data types (`CHAR`, `VARCHAR`, and the `TEXT` types), the maximum number of characters that can be indexed is less for `utf8mb4` columns than for `utf8` columns.

Consequently, if you want to upgrade tables from `utf8` to `utf8mb4` to take advantage of supplementary-character support, it may be necessary to change some column or index definitions.

For additional details about the new Unicode character sets and potential incompatibilities, see Section 10.9, “Unicode Support”, and Section 10.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”.

• **Incompatible change**: As of MySQL 5.5.3, the server includes `dtoa`, a library for conversion between strings and numbers by David M. Gay. In MySQL, this library provides the basis for improved conversion between string or `DECIMAL` values and approximate-value (`FLOAT` or `DOUBLE`) numbers.

Because the conversions produced by this library differ in some cases from previous results, the potential exists for incompatibilities in applications that rely on previous results. For example, applications that depend on a specific exact result from previous conversions might need adjustment to accommodate additional precision.

For additional information about the properties of `dtoa` conversions, see Section 12.2, “Type Conversion in Expression Evaluation”.

209
Changes in MySQL 5.5

• **Incompatible change**: In MySQL 5.5, several changes were made regarding the language and character set of error messages:
  
  • The `--language` option for specifying the directory for the error message file is now deprecated. The new `lc_messages_dir` and `lc_messages` system variables should be used instead, and the server treats `--language` as an alias for `lc_messages_dir`.
  
  • The `language` system variable has been removed and replaced with the new `lc_messages_dir` and `lc_messages` system variables. `lc_messages_dir` has only a global value and is read only. `lc_messages` has global and session values and can be modified at runtime, so the error message language can be changed while the server is running, and individual clients each can have a different error message language by changing their session `lc_messages` value to a different locale name.

  • Error messages previously were constructed in a mix of character sets. This issue is resolved by constructing error messages internally within the server using UTF-8 and returning them to the client in the character set specified by the `character_set_results` system variable. The content of error messages therefore may in some cases differ from the messages returned previously.

  For more information, see Section 10.12, “Setting the Error Message Language”, and Section 10.6, “Error Message Character Set”.

• **Incompatible change**: MySQL 5.5 implements new functions used to calculate row placement for tables partitioned by `KEY` and `LINEAR KEY`. Tables that were created using `KEY` or `LINEAR KEY` partitioning in MySQL 5.1 can be upgraded in MySQL 5.5.31 and later using `ALTER TABLE ... PARTITION BY ALGORITHM=2 [LINEAR] KEY (...)`. (Bug #14521864, Bug #66462)

**InnoDB Changes**

As of MySQL 5.5.62, the zlib library version bundled with MySQL was raised from version 1.2.3 to version 1.2.11.

The `zlib compressBound()` function in zlib 1.2.11 returns a slightly higher estimate of the buffer size required to compress a given length of bytes than it did in zlib version 1.2.3. The `compressBound()` function is called by InnoDB functions that determine the maximum row size permitted when creating compressed InnoDB tables or inserting rows into compressed InnoDB tables. As a result, `CREATE TABLE ... ROW_FORMAT=COMPRESSED` or `INSERT` operations with row sizes very close to the maximum row size that were successful in earlier releases could now fail.

If you have compressed InnoDB tables with large rows, it is recommended that you test compressed table `CREATE TABLE` statements on a MySQL 5.5 test instance prior to upgrading.

**SQL Changes**

• **Incompatible change**: Previously, the parser accepted an `INTO` clause in nested `SELECT` statements, which is invalid because such statements must return their results to the outer context. As of MySQL 5.5.3, this syntax is no longer permitted and statements that use it must be changed.

• **Incompatible change**: In MySQL 5.5.3, several changes were made to alias resolution in multiple-table `DELETE` statements so that it is no longer possible to have inconsistent or ambiguous table aliases.

  • In MySQL 5.1.23, alias declarations outside the `table_references` part of the statement were disallowed for the `USING` variant of multiple-table `DELETE` syntax, to reduce the possibility of ambiguous aliases that could lead to ambiguous statements that have unexpected results such as deleting rows from the wrong table.

  As of MySQL 5.5.3, alias declarations outside `table_references` are disallowed for all multiple-table `DELETE` statements. Alias declarations are permitted only in the `table_references` part.
Incorrect:

```
DELETE FROM t1 AS a2 USING t1 AS a1 INNER JOIN t2 AS a2;
DELETE t1 AS a2 FROM t1 AS a1 INNER JOIN t2 AS a2;
```

Correct:

```
DELETE FROM t1 USING t1 AS a1 INNER JOIN t2 AS a2;
DELETE t1 FROM t1 AS a1 INNER JOIN t2 AS a2;
```

• Previously, for alias references in the list of tables from which to delete rows in a multiple-table delete, the default database is used unless one is specified explicitly. For example, if the default database is `db1`, the following statement does not work because the unqualified alias reference `a2` is interpreted as having a database of `db1`:

```
DELETE a1, a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
WHERE a1.id=a2.id;
```

To correctly match an alias that refers to a table outside the default database, you must explicitly qualify the reference with the name of the proper database:

```
DELETE a1, db2.a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
WHERE a1.id=a2.id;
```

As of MySQL 5.5.3, alias resolution does not require qualification and alias references should not be qualified with the database name. Qualified names are interpreted as referring to tables, not aliases.

Statements containing alias constructs that are no longer permitted must be rewritten.

• Some keywords may be reserved in MySQL 5.5 that were not reserved in MySQL 5.1. See Section 9.3, “Keywords and Reserved Words”. This can cause words previously used as identifiers to become illegal. To fix affected statements, use identifier quoting. See Section 9.2, “Schema Object Names”.

### 2.11.4 Upgrading MySQL Binary or Package-based Installations on Unix/Linux

This section describes how to upgrade MySQL binary and package-based installations on Unix/Linux. In-place and logical upgrade methods are described.

- **In-Place Upgrade**
- **Logical Upgrade**

**Note**

A logical upgrade is recommended when upgrading from a previous version. For example, use this method when upgrading from 5.1 to 5.5.

**In-Place Upgrade**

An in-place upgrade involves shutting down the old MySQL server, replacing the old MySQL binaries or packages with the new ones, restarting MySQL on the existing data directory, and upgrading any remaining parts of the existing installation that require upgrading.

**Note**

If you upgrade an installation originally produced by installing multiple RPM packages, upgrade all the packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.
To perform an in-place upgrade:

1. If you use XA transactions with InnoDB, run XA RECOVER before upgrading to check for uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by issuing an XA COMMIT or XA ROLLBACK statement.

2. If you use InnoDB, configure MySQL to perform a slow shutdown by setting innodb_fast_shutdown to 0. For example:

   ```bash
   mysql -u root -p --execute="SET GLOBAL innodb_fast_shutdown=0"
   ```

   With a slow shutdown, InnoDB performs a full purge and change buffer merge before shutting down, which ensures that data files are fully prepared in case of file format differences between releases.

3. Shut down the old MySQL server. For example:

   ```bash
   mysqladmin -u root -p shutdown
   ```

4. Upgrade the MySQL binary installation or packages. If upgrading a binary installation, unpack the new MySQL binary distribution package. See Obtain and Unpack the Distribution. For package-based installations, install the new packages.

5. Start the MySQL 5.5 server, using the existing data directory. For example:

   ```bash
   mysqld_safe --user=mysql --datadir=/path/to/existing-datadir &
   ```

6. Run mysql_upgrade. For example:

   ```bash
   mysql_upgrade -u root -p
   ```

   `mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the `mysql` system database so that you can take advantage of new privileges or capabilities.

   **Note**

   `mysql_upgrade` does not upgrade the contents of the time zone tables or help tables. For upgrade instructions, see Section 5.1.12, “MySQL Server Time Zone Support”, and Section 5.1.13, “Server-Side Help Support”.

7. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

   ```bash
   mysqladmin -u root -p shutdown
   mysqld_safe --user=mysql --datadir=/path/to/existing-datadir &
   ```

**Logical Upgrade**

A logical upgrade involves exporting SQL from the old MySQL instance using a backup or export utility such as `mysqldump`, installing the new MySQL server, and applying the SQL to your new MySQL instance.

To perform a logical upgrade:

1. Review the information in Section 2.11.1, “Before You Begin”.

2. Export your existing data from the previous MySQL installation:

   ```bash
   mysqldump -u root -p
   ```
Upgrading MySQL on Windows

```shell
--add-drop-table --routines --events
--all-databases --force > data-for-upgrade.sql
```

**Note**
Use the `--routines` and `--events` options with `mysqldump` (as shown above) if your databases include stored programs. The `--all-databases` option includes all databases in the dump, including the `mysql` database that holds the system tables.

3. Shut down the old MySQL server. For example:

```
mysqladmin -u root -p shutdown
```

4. Install MySQL 5.5. For installation instructions, see Chapter 2, *Installing and Upgrading MySQL*.

5. Initialize a new data directory, as described at Section 2.10.1, “Initializing the Data Directory”. For example:

```
scripts/mysql_install_db --user=mysql --datadir=/path/to/5.5-datadir
```

6. Start the MySQL 5.5 server, using the new data directory. For example:

```
mysqld_safe --user=mysql --datadir=/path/to/5.5-datadir &
```

7. Load the previously created dump file into the new MySQL server. For example:

```
mysql -u root -p --force < data-for-upgrade.sql
```

8. Run `mysql_upgrade`. For example:

```
mysql_upgrade -u root -p
```

`mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the `mysql` system database so that you can take advantage of new privileges or capabilities.

**Note**
`mysql_upgrade` does not upgrade the contents of the time zone tables or help tables. For upgrade instructions, see Section 5.1.12, “MySQL Server Time Zone Support”, and Section 5.1.13, “Server-Side Help Support”.

9. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/5.5-datadir &
```

### 2.11.5 Upgrading MySQL on Windows

There are two approaches for upgrading MySQL on Windows:

- **Using MySQL Installer**
- **Using the Windows ZIP archive distribution**

The approach you select depends on how the existing installation was performed. Before proceeding, review Section 2.11, “Upgrading MySQL” for additional information on upgrading MySQL that is not specific to Windows.
Upgrading MySQL on Windows

Note
Whichever approach you choose, always back up your current MySQL installation before performing an upgrade. See Section 7.2, “Database Backup Methods”.

Upgrades between milestone releases (or from a milestone release to a GA release) are not supported. Significant development changes take place in milestone releases and you may encounter compatibility issues or problems starting the server. For instructions on how to perform a logical upgrade with a milestone release, see Logical Upgrade.

Note
MySQL Installer does not support upgrades between Community releases and Commercial releases. If you require this type of upgrade, perform it using the ZIP archive approach.

Upgrading MySQL with MySQL Installer

Performing an upgrade with MySQL Installer is the best approach when the current server installation was performed with it and the upgrade is within the current release series. MySQL Installer does not support upgrades between release series, such as from 5.1 to 5.5, and it does not provide an upgrade indicator to prompt you to upgrade. For instructions on upgrading between release series, see Upgrading MySQL Using the Windows ZIP Distribution.

To perform an upgrade using MySQL Installer:

1. Start MySQL Installer.
2. From the dashboard, click Catalog to download the latest changes to the catalog. The installed server can be upgraded only if the dashboard displays an arrow next to the version number of the server.
3. Click Upgrade. All products that have a newer version now appear in a list.

Note
MySQL Installer deselects the server upgrade option for milestone releases (Pre-Release) in the same release series. In addition, it displays a warning to indicate that the upgrade is not supported, identifies the risks of continuing, and provides a summary of the steps to perform a logical upgrade manually. You can reselect server upgrade and proceed at your own risk.

4. Deselect all but the MySQL server product, unless you intend to upgrade other products at this time, and click Next.
5. Click Execute to start the download. When the download finishes, click Next to begin the upgrade operation.
6. Configure the server.

Note
MySQL Workbench 6.3 is the last Workbench version to fully support MySQL Server 5.5.

Upgrading MySQL Using the Windows ZIP Distribution

To perform an upgrade using the Windows ZIP archive distribution:

1. Download the latest Windows distribution of MySQL from https://dev.mysql.com/downloads/.
2. If the server is running, stop it. If the server is installed as a service, stop the service with the following command from the command prompt:

```
C:\> SC STOP mysql_service_name
```

Alternatively, use `NET STOP mysql_service_name`.

If you are not running the MySQL server as a service, use `mysqladmin` to stop it. For example, before upgrading from MySQL 5.1 to 5.5, use `mysqladmin` from MySQL 5.1 as follows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqladmin" -u root shutdown
```

3. If you are using the MySQL Installation Wizard, start the wizard as described in Section 2.3.4.1, “Using the MySQL Installation Wizard”.

4. If you are upgrading MySQL from a ZIP archive, extract the archive. You may either overwrite your existing MySQL installation (usually located at `C:\mysql`), or install it into a different directory, such as `C:\mysql5`. Overwriting the existing installation is recommended. However, for upgrades (as opposed to installing for the first time), you must remove the data directory from your existing MySQL installation to avoid replacing your current data files. To do so, follow these steps:

   a. Unzip the ZIP archive in some location other than your current MySQL installation
   b. Remove the data directory
   c. Move the data directory from the current MySQL installation to the location of the just-removed data directory
   d. Remove the current MySQL installation
   e. Move the unzipped installation to the location of the just-removed installation

5. Restart the server. For example, use the `SC START mysql_service_name` or `NET START mysql_service_name` command if you run MySQL as a service, or invoke `mysqld` directly otherwise.

6. As Administrator, run `mysql_upgrade` to check your tables, attempt to repair them if necessary, and update your grant tables if they have changed so that you can take advantage of any new capabilities. See Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”.

7. If you encounter errors, see Section 2.3.7, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

### 2.11.6 Upgrade Troubleshooting

- If problems occur, such as that the new `mysqld` server does not start or that you cannot connect without a password, verify that you do not have an old `my.cnf` file from your previous installation. You can check this with the `--print-defaults` option (for example, `mysqld --print-defaults`). If this command displays anything other than the program name, you have an active `my.cnf` file that affects server or client operation.

- If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, you probably have used old header or library files when
compiling your programs. In this case, check the date for your `mysql.h` file and `libmysqlclient.a` library to verify that they are from the new MySQL distribution. If not, recompile your programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.15` to `libmysqlclient.so.16`).

- If you have created a user-defined function (UDF) with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use `DROP FUNCTION` to drop the UDF, and then use `CREATE FUNCTION` to re-create the UDF with a different nonconflicting name. The same is true if the new version of MySQL implements a built-in function with the same name as an existing stored function. See Section 9.2.5, “Function Name Parsing and Resolution”, for the rules describing how the server interprets references to different kinds of functions.

2.11.7 Rebuilding or Repairing Tables or Indexes

This section describes how to rebuild or repair tables or indexes, which may be necessitated by:

- Changes to how MySQL handles data types or character sets. For example, an error in a collation might have been corrected, necessitating a table rebuild to update the indexes for character columns that use the collation.

- Required table repairs or upgrades reported by `CHECK TABLE`, `mysqlcheck`, or `mysql_upgrade`.

Methods for rebuilding a table include:

- **Dump and Reload Method**
- **ALTER TABLE Method**
- **REPAIR TABLE Method**

**Dump and Reload Method**

If you are rebuilding tables because a different version of MySQL will not handle them after a binary (in-place) upgrade or downgrade, you must use the dump-and-reload method. Dump the tables before upgrading or downgrading using your original version of MySQL. Then reload the tables after upgrading or downgrading.

If you use the dump-and-reload method of rebuilding tables only for the purpose of rebuilding indexes, you can perform the dump either before or after upgrading or downgrading. Reloading still must be done afterward.

If you need to rebuild an InnoDB table because a `CHECK TABLE` operation indicates that a table upgrade is required, use `mysqldump` to create a dump file and `mysql` to reload the file. If the `CHECK TABLE` operation indicates that there is a corruption or causes InnoDB to fail, refer to Section 14.23.2, “Forcing InnoDB Recovery” for information about using the `innodb_force_recovery` option to restart InnoDB. To understand the type of problem that `CHECK TABLE` may be encountering, refer to the InnoDB notes in Section 13.7.2.2, "CHECK TABLE Statement".

To rebuild a table by dumping and reloading it, use `mysqldump` to create a dump file and `mysql` to reload the file:

```
mysqldump db_name t1 > dump.sql
mysql db_name < dump.sql
```

To rebuild all the tables in a single database, specify the database name without any following table name:
Copying MySQL Databases to Another Machine

mysqldump db_name > dump.sql
mysql db_name < dump.sql

To rebuild all tables in all databases, use the --all-databases option:

mysqldump --all-databases > dump.sql
mysql < dump.sql

ALTER TABLE Method

To rebuild a table with ALTER TABLE, use a “null” alteration; that is, an ALTER TABLE statement that “changes” the table to use the storage engine that it already has. For example, if t1 is an InnoDB table, use this statement:

ALTER TABLE t1 ENGINE = InnoDB;

If you are not sure which storage engine to specify in the ALTER TABLE statement, use SHOW CREATE TABLE to display the table definition.

REPAIR TABLE Method

The REPAIR TABLE method is only applicable to MyISAM, ARCHIVE, and CSV tables.

You can use REPAIR TABLE if the table checking operation indicates that there is a corruption or that an upgrade is required. For example, to repair a MyISAM table, use this statement:

REPAIR TABLE t1;

mysqlcheck --repair provides command-line access to the REPAIR TABLE statement. This can be a more convenient means of repairing tables because you can use the --databases or --all-databases option to repair all tables in specific databases or all databases, respectively:

mysqlcheck --repair --databases db_name ...
mysqlcheck --repair --all-databases

2.11.8 Copying MySQL Databases to Another Machine

In cases where you need to transfer databases between different architectures, you can use mysqldump to create a file containing SQL statements. You can then transfer the file to the other machine and feed it as input to the mysql client.

Note
You can copy the .frm, .MYI, and .MYD files for MyISAM tables between different architectures that support the same floating-point format. (MySQL takes care of any byte-swapping issues.) See Section 15.3, “The MyISAM Storage Engine”.

Use mysqldump --help to see what options are available.

The easiest (although not the fastest) way to move a database between two machines is to run the following commands on the machine on which the database is located:

mysqladmin -h 'other_hostname' create db_name
mysqldump db_name | mysql -h 'other_hostname' db_name

If you want to copy a database from a remote machine over a slow network, you can use these commands:

mysqladmin create db_name
Downgrading MySQL

You can also store the dump in a file, transfer the file to the target machine, and then load the file into the database there. For example, you can dump a database to a compressed file on the source machine like this:

```
mysqldump --quick db_name | gzip > db_name.gz
```

Transfer the file containing the database contents to the target machine and run these commands there:

```
mysqladmin create db_name
gunzip < db_name.gz | mysql db_name
```

You can also use mysqldump and mysqlimport to transfer the database. For large tables, this is much faster than simply using mysqldump. In the following commands, DUMPDIR represents the full path name of the directory you use to store the output from mysqldump.

First, create the directory for the output files and dump the database:

```
mkdir DUMPDIR
mysqldump --tab=DUMPDIR db_name
```

Then transfer the files in the DUMPDIR directory to some corresponding directory on the target machine and load the files into MySQL there:

```
mysqladmin create db_name  # create database
cat DUMPDIR/*.sql | mysql db_name  # create tables in database
mysqlimport db_name DUMPDIR/*.txt  # load data into tables
```

Do not forget to copy the mysql database because that is where the grant tables are stored. You might have to run commands as the MySQL root user on the new machine until you have the mysql database in place.

After you import the mysql database on the new machine, execute mysqladmin flush-privileges so that the server reloads the grant table information.

2.12 Downgrading MySQL

This section describes the steps to downgrade a MySQL installation.

Downgrading is a less common operation than upgrade. Downgrading is typically performed because of a compatibility or performance issue that occurs on a production system, and was not uncovered during initial upgrade verification on the test systems. As with the upgrade procedure verification on the test systems. As with the upgrade procedure Section 2.11, “Upgrading MySQL”), perform and verify the downgrade procedure on some test systems first, before using it on a production system.

Note

In the following discussion, MySQL commands that must be run using a MySQL account with administrative privileges include -u root on the command line to specify the MySQL root user. Commands that require a password for root also include a -p option. Because -p is followed by no option value, such commands prompt for the password. Type the password when prompted and press Enter.

SQL statements can be executed using the mysql command-line client (connect as root to ensure that you have the necessary privileges).
### 2.12.1 Before You Begin

Review the information in this section before downgrading. Perform any recommended actions.

- Protect your data by taking a backup. The backup should include the `mysql` database, which contains the MySQL system tables. See Section 7.2, “Database Backup Methods”.

- Review Section 2.12.2, “Downgrade Paths” to ensure that your intended downgrade path is supported.

- Review Section 2.12.3, “Downgrade Notes” for items that may require action before downgrading.

**Note**

The downgrade procedures described in the following sections assume you are downgrading with data files created or modified by the newer MySQL version. However, if you did not modify your data after upgrading, downgrading using backups taken before upgrading to the new MySQL version is recommended. Many of the changes described in Section 2.12.3, “Downgrade Notes” that require action are not applicable when downgrading using backups taken before upgrading to the new MySQL version.

- Use of new features, new configuration options, or new configuration option values that are not supported by a previous release may cause downgrade errors or failures. Before downgrading, reverse changes resulting from the use of new features and remove configuration settings that are not supported by the release you are downgrading to.

### 2.12.2 Downgrade Paths

- Downgrade is only supported between General Availability (GA) releases.

- Downgrade from MySQL 5.5 to 5.1 is supported using the *logical downgrade* method.

- Downgrade that skips versions is not supported. For example, downgrading directly from MySQL 5.5 to 5.0 is not supported.

- Downgrade within a release series is supported. For example, downgrading from MySQL 5.5.z to 5.5.y is supported. Skipping a release is also supported. For example, downgrading from MySQL 5.5.z to 5.5.x is supported.

### 2.12.3 Downgrade Notes

Before downgrading from MySQL 5.5, review the information in this section. Some items may require action before downgrading.

**System Tables.** The `mysql.proc.comment` column definition changed between MySQL 5.1 and 5.5. After downgrading from 5.5 to 5.1, this table is seen as corrupt and in need of repair. Running `mysql_upgrade` from the version of MySQL to which you downgraded (as documented in the downgrade procedures) reverts the `mysql.proc.comment` column definition.

- **InnoDB.** MySQL 5.5 uses *InnoDB Plugin* as the built-in version of *InnoDB*. MySQL 5.1 includes *InnoDB Plugin* as of 5.1.38, but as an option that must be enabled explicitly. See the Release Notes for MySQL 5.1.38.

- **InnoDB.** In MySQL 5.5.14, the length limit for index prefix keys is increased from 767 bytes to 3072 bytes, for *InnoDB* tables using `ROW_FORMAT=DYNAMIC` or `ROW_FORMAT=COMPRESSED`. See Section 14.24, “InnoDB Limits” for details. If you downgrade from one of these releases or higher, to
an earlier release with a lower length limit, the index prefix keys could be truncated at 767 bytes or the
downgrade could fail. This issue could only occur if the configuration option `innodb_large_prefix`
was enabled on the server being downgraded.

- **Tables partitioned by [LINEAR] KEY.** MySQL 5.5 implements new functions used to calculate
  row placement for tables partitioned by `KEY` and `LINEAR_KEY`. Tables that were created using `KEY`
or `LINEAR KEY` partitioning in MySQL 5.5 cannot be used by a MySQL 5.1 server. In MySQL 5.5.31
  and later, you can downgrade such tables with `ALTER TABLE ... PARTITION BY ALGORITHM=1 [LINEAR] KEY (...)`
to make them compatible with MySQL 5.1.

### 2.12.4 Downgrading MySQL Binary and Package Installations on Unix/Linux

This section describes how to downgrade MySQL binary and package-based installations on Unix/Linux.
In-place and logical downgrade methods are described.

- **In-Place Downgrade**
- **Logical Downgrade**

#### In-Place Downgrade

In-place downgrade involves shutting down the new MySQL version, replacing the new MySQL binaries or
packages with the old ones, and restarting the old MySQL version on the existing data directory.

In-place downgrade is supported for downgrades between GA releases within the same release series.

To perform an in-place downgrade:

1. Review the information in Section 2.12.1, “Before You Begin”.

2. If you use XA transactions with InnoDB, run `XA RECOVER` before downgrading to check for
   uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by
   issuing a `XA COMMIT` or `XA ROLLBACK` statement.

3. If you use InnoDB, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to 0.
   For example:
   ```
   mysql -u root -p --execute="SET GLOBAL innodb_fast_shutdown=0"
   ```
   With a slow shutdown, InnoDB performs a full purge and change buffer merge before shutting down,
   which ensures that data files are fully prepared in case of file format differences between releases.

4. Shut down the newer MySQL server. For example:
   ```
   mysqladmin -u root -p shutdown
   ```

5. After the slow shutdown, remove the InnoDB redo log files (the `ib_logfile*` files) from the data
directory to avoid downgrade issues related to redo log file format changes that may have occurred
between releases.
   ```
   rm ib_logfile*
   ```

6. Downgrade the MySQL binaries or packages in-place by replacing the newer binaries or packages with
   the older ones.

7. Start the older (downgraded) MySQL server, using the existing data directory. For example:
   ```
   mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
   ```
8. Run `mysql_upgrade`. For example:

```shell
mysql_upgrade -u root -p
```

9. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```shell
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

**Logical Downgrade**

Logical downgrade involves using `mysqldump` to dump all tables from the new MySQL version, and then loading the dump file into the old MySQL version.

Logical downgrades are supported for downgrades between releases within the same release series and for downgrades to the previous release level. Only downgrades between General Availability (GA) releases are supported. Before proceeding, review Section 2.12.1, “Before You Begin”.

To perform a logical downgrade:

1. Review the information in Section 2.12.1, “Before You Begin”.

2. Dump all databases. For example:

```shell
mysqldump -u root -p
    --add-drop-table --routines --events
    --all-databases --force > data-for-downgrade.sql
```

3. Shut down the newer MySQL server. For example:

```shell
mysqladmin -u root -p shutdown
```

4. Initialize an older MySQL instance, with a new data directory. For example:

```shell
scripts/mysql_install_db --user=mysql
```

5. Start the older MySQL server, using the new data directory. For example:

```shell
mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

6. Load the dump file into the older MySQL server. For example:

```shell
mysql -u root -p --force < data-for-upgrade.sql
```

7. Run `mysql_upgrade`. For example:

```shell
mysql_upgrade -u root -p
```

8. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```shell
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

**2.12.5 Downgrading from MySQL Enterprise Edition to MySQL Community Server**

This section describes the steps required to downgrade from MySQL Enterprise Edition to MySQL Community Edition. This can be done at any time, and is required at the expiration of a MySQL Enterprise Edition subscription if you wish to continue using MySQL Server.
When you perform such a downgrade, all commercially licensed components of the MySQL Enterprise Edition subscription must be uninstalled. These components and related considerations are described in the rest of this section.

Note
The issues described in this section are in addition to any that may be encountered as a result of any upgrade or downgrade of the MySQL Server version (such as between MySQL 5.5 and 5.1). Information about upgrading and downgrading between MySQL release series can be found elsewhere in this chapter; see Section 2.11, “Upgrading MySQL”, and Section 2.12, “Downgrading MySQL”.

MySQL Enterprise Database Server.  All commercial versions of MySQL Database Server must be uninstalled.

Commercially licensed extensions.  All commercially licensed MySQL Enterprise Database Server extensions must be uninstalled. This includes the following commercial extensions:

• MySQL External Authentication for Windows: Following uninstallation of this plugin, existing MySQL user accounts must be re-created using local authentication. See Section 6.2, “Access Control and Account Management”, for more information.

• MySQL External Authentication for PAM: Following uninstallation of this plugin, existing MySQL user accounts must be re-created using local authentication. See Section 6.2, “Access Control and Account Management”, for more information.

• MySQL Enterprise Thread Pool: Following uninstallation of this plugin, existing MySQL servers revert to default thread and connection handling.

• MySQL Enterprise Audit: Following uninstallation of this plugin, no logging of user logins or query activity occurs.

• MySQL High Availability: Following uninstallation of this plugin, automated failover is no longer available.

MySQL Enterprise Backup.  MySQL Enterprise Backup must be uninstalled. Uninstalling this application has the effects listed here:

• Automated backup scripts no longer work.

• Existing backup images taken with MySQL Enterprise Backup can no longer be used for recovery.

• Third-party integration with multimedia systems such as NetBackup, Tivoli, and Oracle Secure Backup no longer works.

MySQL Enterprise Monitor, MySQL Query Analyzer, agents.  MySQL Enterprise Monitor, MySQL Query Analyzer, and all server-side agents must be uninstalled. Uninstalling these applications and agents has the following effects:

• Automated SNMP and SMTP alerts no longer work.

• All historical MySQL, OS monitoring, query, and performance metrics as well as all trending data are lost.

• All environment-specific monitoring templates, custom advisors, graphs and scripts are also lost.

2.12.6 Downgrade Troubleshooting
If you downgrade from one release series to another, there may be incompatibilities in table storage formats. In this case, use `mysqldump` to dump your tables before downgrading. After downgrading, reload
the dump file using `mysql` or `mysqlimport` to re-create your tables. For examples, see Section 2.11.8, “Copying MySQL Databases to Another Machine”.

A typical symptom of a downward-incompatible table format change when you downgrade is that you cannot open tables. In that case, use the following procedure:

1. Stop the older MySQL server that you are downgrading to.
2. Restart the newer MySQL server you are downgrading from.
3. Dump any tables that were inaccessible to the older server by using `mysql dump` to create a dump file.
4. Stop the newer MySQL server and restart the older one.
5. Reload the dump file into the older server. Your tables should be accessible.

### 2.13 Perl Installation Notes

The Perl DBI module provides a generic interface for database access. You can write a DBI script that works with many different database engines without change. To use DBI, you must install the DBI module, as well as a DataBase Driver (DBD) module for each type of database server you want to access. For MySQL, this driver is the DBD::mysql module.

Perl, and the DBD::MySQL module for DBI must be installed if you want to run the MySQL benchmark scripts; see Section 8.13.2, “The MySQL Benchmark Suite”. They are also required for the NDB Cluster ndb_size.pl utility; see Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”.

**Note**

Perl support is not included with MySQL distributions. You can obtain the necessary modules from http://search.cpan.org for Unix, or by using the ActiveState ppm program on Windows. The following sections describe how to do this.

The DBI/DBD interface requires Perl 5.6.0, and 5.6.1 or later is preferred. DBI does not work if you have an older version of Perl. You should use DBD::mysql 4.009 or higher. Although earlier versions are available, they do not support the full functionality of MySQL 5.5.

### 2.13.1 Installing Perl on Unix

MySQL Perl support requires that you have installed MySQL client programming support (libraries and header files). Most installation methods install the necessary files. If you install MySQL from RPM files on Linux, be sure to install the developer RPM as well. The client programs are in the client RPM, but client programming support is in the developer RPM.

The files you need for Perl support can be obtained from the CPAN (Comprehensive Perl Archive Network) at http://search.cpan.org.

The easiest way to install Perl modules on Unix is to use the CPAN module. For example:

```
shell> perl -MCBPAN -e shell
cpan> install DBI
cpan> install DBD::mysql
```

The DBD::mysql installation runs a number of tests. These tests attempt to connect to the local MySQL server using the default user name and password. (The default user name is your login name on Unix, and ODBC on Windows. The default password is “no password.”) If you cannot connect to the server with
those values (for example, if your account has a password), the tests fail. You can use `force install DBD::mysql` to ignore the failed tests.

`DBI` requires the `Data::Dumper` module. It may be installed; if not, you should install it before installing `DBI`.

It is also possible to download the module distributions in the form of compressed `tar` archives and build the modules manually. For example, to unpack and build a DBI distribution, use a procedure such as this:

1. Unpack the distribution into the current directory:
   ```shell
   gunzip < DBI-VERSION.tar.gz | tar xvf -
   ```
   This command creates a directory named `DBI-VERSION`.

2. Change location into the top-level directory of the unpacked distribution:
   ```shell
   cd DBI-VERSION
   ```

3. Build the distribution and compile everything:
   ```shell
   perl Makefile.PL
   make
   make test
   make install
   ```
   The `make test` command is important because it verifies that the module is working. Note that when you run that command during the `DBD::mysql` installation to exercise the interface code, the MySQL server must be running or the test fails.

   It is a good idea to rebuild and reinstall the `DBD::mysql` distribution whenever you install a new release of MySQL. This ensures that the latest versions of the MySQL client libraries are installed correctly.

   If you do not have access rights to install Perl modules in the system directory or if you want to install local Perl modules, the following reference may be useful: [http://learn.perl.org/faq/perlfaq8.html#How-do-I-keep-my-own-module-library-directory](http://learn.perl.org/faq/perlfaq8.html#How-do-I-keep-my-own-module-library-directory).

### 2.13.2 Installing ActiveState Perl on Windows

On Windows, you should do the following to install the MySQL `DBD` module with ActiveState Perl:

1. Get ActiveState Perl from [http://www.activestate.com/Products/ActivePerl/](http://www.activestate.com/Products/ActivePerl/) and install it.

2. Open a console window.

3. If necessary, set the `HTTP_proxy` variable. For example, you might try a setting like this:
   ```
   C:\> set HTTP_proxy=my.proxy.com:3128
   ```

4. Start the PPM program:
   ```
   C:\> C:\perl\bin\ppm.pl
   ```

5. If you have not previously done so, install `DBI`:
   ```
   ppm> install DBI
   ```

6. If this succeeds, run the following command:
   ```
   ppm> install DBD-mysql
   ```
Problems Using the Perl DBI/DBD Interface

This procedure should work with ActiveState Perl 5.6 or higher.

If you cannot get the procedure to work, you should install the ODBC driver instead and connect to the MySQL server through ODBC:

```
use DBI;
$dbh= DBI->connect("DBI:ODBC:$dsn",$user,$password) ||
    die "Got error $DBI::errstr when connecting to $dsn\n";
```

### 2.13.3 Problems Using the Perl DBI/DBD Interface

If Perl reports that it cannot find the `../mysql/mysql.so` module, the problem is probably that Perl cannot locate the `libmysqlclient.so` shared library. You should be able to fix this problem by one of the following methods:

- Copy `libmysqlclient.so` to the directory where your other shared libraries are located (probably `/usr/lib` or `/lib`).
- Modify the `-L` options used to compile `DBD::mysql` to reflect the actual location of `libmysqlclient.so`.
- On Linux, you can add the path name of the directory where `libmysqlclient.so` is located to the `/etc/ld.so.conf` file.
- Add the path name of the directory where `libmysqlclient.so` is located to the `LD_RUN_PATH` environment variable. Some systems use `LD_LIBRARY_PATH` instead.

Note that you may also need to modify the `-L` options if there are other libraries that the linker fails to find. For example, if the linker cannot find `libc` because it is in `/lib` and the link command specifies `-L/usr/lib`, change the `-L` option to `-L/lib` or add `-L/lib` to the existing link command.

If you get the following errors from `DBD::mysql`, you are probably using `gcc` (or using an old binary compiled with `gcc`):

```
/usr/bin/perl: can't resolve symbol '__moddi3'
/usr/bin/perl: can't resolve symbol '__divdi3'
```

Add `-L/usr/lib/gcc-lib/...` `-lgcc` to the link command when the `mysql.so` library gets built (check the output from `make` for `mysql.so` when you compile the Perl client). The `-L` option should specify the path name of the directory where `libgcc.a` is located on your system.

Another cause of this problem may be that Perl and MySQL are not both compiled with `gcc`. In this case, you can solve the mismatch by compiling both with `gcc`. 
Chapter 3 Tutorial

Table of Contents

3.1 Connecting to and Disconnecting from the Server ............................................................. 227
3.2 Entering Queries .................................................................................................................. 228
3.3 Creating and Using a Database ............................................................................................. 231
  3.3.1 Creating and Selecting a Database ............................................................................. 232
  3.3.2 Creating a Table .......................................................................................................... 233
  3.3.3 Loading Data into a Table .......................................................................................... 235
  3.3.4 Retrieving Information from a Table ......................................................................... 236
3.4 Getting Information About Databases and Tables ............................................................... 249
3.5 Using mysql in Batch Mode ............................................................................................... 250
3.6 Examples of Common Queries ............................................................................................. 251
  3.6.1 The Maximum Value for a Column ........................................................................... 252
  3.6.2 The Row Holding the Maximum of a Certain Column ........................................... 252
  3.6.3 Maximum of Column per Group ............................................................................. 253
  3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column ...................... 253
  3.6.5 Using User-Defined Variables .................................................................................. 254
  3.6.6 Using Foreign Keys .................................................................................................... 254
  3.6.7 Searching on Two Keys ............................................................................................. 256
  3.6.8 Calculating Visits Per Day ........................................................................................ 256
  3.6.9 Using AUTO_INCREMENT ....................................................................................... 257
3.7 Using MySQL with Apache .................................................................................................. 259

This chapter provides a tutorial introduction to MySQL by showing how to use the mysql client program to create and use a simple database. mysql (sometimes referred to as the “terminal monitor” or just “monitor”) is an interactive program that enables you to connect to a MySQL server, run queries, and view the results. mysql may also be used in batch mode: you place your queries in a file beforehand, then tell mysql to execute the contents of the file. Both ways of using mysql are covered here.

To see a list of options provided by mysql, invoke it with the --help option:

shell> mysql --help

This chapter assumes that mysql is installed on your machine and that a MySQL server is available to which you can connect. If this is not true, contact your MySQL administrator. (If you are the administrator, you need to consult the relevant portions of this manual, such as Chapter 5, MySQL Server Administration.)

This chapter describes the entire process of setting up and using a database. If you are interested only in accessing an existing database, you may want to skip the sections that describe how to create the database and the tables it contains.

Because this chapter is tutorial in nature, many details are necessarily omitted. Consult the relevant sections of the manual for more information on the topics covered here.

3.1 Connecting to and Disconnecting from the Server

To connect to the server, you will usually need to provide a MySQL user name when you invoke mysql and, most likely, a password. If the server runs on a machine other than the one where you log in, you will
also need to specify a host name. Contact your administrator to find out what connection parameters you should use to connect (that is, what host, user name, and password to use). Once you know the proper parameters, you should be able to connect like this:

```
shell> mysql -h host -u user -p
Enter password: ********
```

`host` and `user` represent the host name where your MySQL server is running and the user name of your MySQL account. Substitute appropriate values for your setup. The `********` represents your password; enter it when `mysql` displays the `Enter password:` prompt.

If that works, you should see some introductory information followed by a `mysql>` prompt:

```
shell> mysql -h host -u user -p
Enter password: ********
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 25338 to server version: 5.5.62-standard
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.
mysql>
```

The `mysql>` prompt tells you that `mysql` is ready for you to enter SQL statements.

If you are logging in on the same machine that MySQL is running on, you can omit the host, and simply use the following:

```
shell> mysql -u user -p
```

If, when you attempt to log in, you get an error message such as `ERROR 2002 (HY000): Can't connect to local MySQL server through socket '/tmp/mysql.sock' (2)`, it means that the MySQL server daemon (Unix) or service (Windows) is not running. Consult the administrator or see the section of Chapter 2, *Installing and Upgrading MySQL* that is appropriate to your operating system.

For help with other problems often encountered when trying to log in, see Section B.4.2, “Common Errors When Using MySQL Programs”.

Some MySQL installations permit users to connect as the anonymous (unnamed) user to the server running on the local host. If this is the case on your machine, you should be able to connect to that server by invoking `mysql` without any options:

```
shell> mysql
```

After you have connected successfully, you can disconnect any time by typing `QUIT` (or `\q`) at the `mysql>` prompt:

```
mysql> QUIT
Bye
```

On Unix, you can also disconnect by pressing Control+D.

Most examples in the following sections assume that you are connected to the server. They indicate this by the `mysql>` prompt.

### 3.2 Entering Queries

Make sure that you are connected to the server, as discussed in the previous section. Doing so does not in itself select any database to work with, but that is okay. At this point, it is more important to find out a little about how to issue queries than to jump right in creating tables, loading data into them, and retrieving data
from them. This section describes the basic principles of entering queries, using several queries you can try out to familiarize yourself with how mysql works.

Here is a simple query that asks the server to tell you its version number and the current date. Type it in as shown here following the mysql> prompt and press Enter:

```
mysql> SELECT VERSION(), CURRENT_DATE;
+--------------+--------------+
<table>
<thead>
<tr>
<th>VERSION()</th>
<th>CURRENT_DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.0-m2-log</td>
<td>2009-05-04</td>
</tr>
</tbody>
</table>
+--------------+--------------+
1 row in set (0.01 sec)
```

This query illustrates several things about mysql:

- A query normally consists of an SQL statement followed by a semicolon. (There are some exceptions where a semicolon may be omitted. QUIT, mentioned earlier, is one of them. We'll get to others later.)

- When you issue a query, mysql sends it to the server for execution and displays the results, then prints another mysql> prompt to indicate that it is ready for another query.

- mysql displays query output in tabular form (rows and columns). The first row contains labels for the columns. The rows following are the query results. Normally, column labels are the names of the columns you fetch from database tables. If you're retrieving the value of an expression rather than a table column (as in the example just shown), mysql labels the column using the expression itself.

- mysql shows how many rows were returned and how long the query took to execute, which gives you a rough idea of server performance. These values are imprecise because they represent wall clock time (not CPU or machine time), and because they are affected by factors such as server load and network latency. (For brevity, the “rows in set” line is sometimes not shown in the remaining examples in this chapter.)

Keywords may be entered in any lettercase. The following queries are equivalent:

```
mysql> SELECT VERSION(), CURRENT_DATE;
mysql> select version(), current_date;
mysql> SeLeCt vErSiOn(), current_DATE;
```

Here is another query. It demonstrates that you can use mysql as a simple calculator:

```
mysql> SELECT SIN(PI()/4), (4+1)*5;
+------------------+---------+
| SIN(PI()/4)      | (4+1)*5 |
|------------------+---------|
| 0.70710678118655 |      25 |
+------------------+---------+
1 row in set (0.02 sec)
```

The queries shown thus far have been relatively short, single-line statements. You can even enter multiple statements on a single line. Just end each one with a semicolon:

```
mysql> SELECT VERSION(); SELECT NOW();
+--------------+
<table>
<thead>
<tr>
<th>VERSION()</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.0-m2-log</td>
</tr>
</tbody>
</table>
+--------------+
1 row in set (0.00 sec)
```
A query need not be given all on a single line, so lengthy queries that require several lines are not a problem. `mysql` determines where your statement ends by looking for the terminating semicolon, not by looking for the end of the input line. (In other words, `mysql` accepts free-format input: it collects input lines but does not execute them until it sees the semicolon.)

Here is a simple multiple-line statement:

```sql
mysql> SELECT USER(), CURRENT_DATE;
```

In this example, notice how the prompt changes from `mysql>` to `-->` after you enter the first line of a multiple-line query. This is how `mysql` indicates that it has not yet seen a complete statement and is waiting for the rest. The prompt is your friend, because it provides valuable feedback. If you use that feedback, you can always be aware of what `mysql` is waiting for.

If you decide you do not want to execute a query that you are in the process of entering, cancel it by typing `\c`:

```sql
mysql> SELECT USER()
    \c
mysql>
```

Here, too, notice the prompt. It switches back to `mysql>` after you type `\c`, providing feedback to indicate that `mysql` is ready for a new query.

The following table shows each of the prompts you may see and summarizes what they mean about the state that `mysql` is in.

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>mysql&gt;</code></td>
<td>Ready for new query</td>
</tr>
<tr>
<td><code>--&gt;</code></td>
<td>Waiting for next line of multiple-line query</td>
</tr>
<tr>
<td><code>'&gt;</code></td>
<td>Waiting for next line, waiting for completion of a string that began with a single quote (')</td>
</tr>
<tr>
<td><code>&quot;&gt;</code></td>
<td>Waiting for next line, waiting for completion of a string that began with a double quote (&quot;)</td>
</tr>
<tr>
<td><code>\&gt;</code></td>
<td>Waiting for next line, waiting for completion of an identifier that began with a backtick (`)</td>
</tr>
<tr>
<td><code>/*&gt;</code></td>
<td>Waiting for next line, waiting for completion of a comment that began with /*</td>
</tr>
</tbody>
</table>

Multiple-line statements commonly occur by accident when you intend to issue a query on a single line, but forget the terminating semicolon. In this case, `mysql` waits for more input:

```sql
mysql> SELECT USER()
    -->
```
If this happens to you (you think you’ve entered a statement but the only response is a \-> prompt), most likely mysql is waiting for the semicolon. If you don’t notice what the prompt is telling you, you might sit there for a while before realizing what you need to do. Enter a semicolon to complete the statement, and mysql executes it:

```
mysql> SELECT USER()
\-> ;
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
```

The ' and " prompts occur during string collection (another way of saying that MySQL is waiting for completion of a string). In MySQL, you can write strings surrounded by either ' or " characters (for example, 'hello' or "goodbye"), and mysql lets you enter strings that span multiple lines. When you see a ' or " prompt, it means that you have entered a line containing a string that begins with a ' or " quote character, but have not yet entered the matching quote that terminates the string. This often indicates that you have inadvertently left out a quote character. For example:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
'>
```

If you enter this SELECT statement, then press Enter and wait for the result, nothing happens. Instead of wondering why this query takes so long, notice the clue provided by the ' prompt. It tells you that mysql expects to see the rest of an unterminated string. (Do you see the error in the statement? The string 'Smith is missing the second single quotation mark.)

At this point, what do you do? The simplest thing is to cancel the query. However, you cannot just type \c in this case, because mysql interprets it as part of the string that it is collecting. Instead, enter the closing quote character (so mysql knows you've finished the string), then type \c:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
'> '\c
mysql>
```

The prompt changes back to mysql>, indicating that mysql is ready for a new query.

The ' prompt is similar to the ' and " prompts, but indicates that you have begun but not completed a backtick-quoted identifier.

It is important to know what the '>, ">, and ' prompts signify, because if you mistakenly enter an unterminated string, any further lines you type appear to be ignored by mysql—including a line containing QUIT. This can be quite confusing, especially if you do not know that you need to supply the terminating quote before you can cancel the current query.

**Note**

Multiline statements from this point on are written without the secondary (\-> or other) prompts, to make it easier to copy and paste the statements to try for yourself.

### 3.3 Creating and Using a Database

Once you know how to enter SQL statements, you are ready to access a database.

Suppose that you have several pets in your home (your menagerie) and you would like to keep track of various types of information about them. You can do so by creating tables to hold your data and loading
them with the desired information. Then you can answer different sorts of questions about your animals by retrieving data from the tables. This section shows you how to perform the following operations:

- Create a database
- Create a table
- Load data into the table
- Retrieve data from the table in various ways
- Use multiple tables

The menagerie database is simple (deliberately), but it is not difficult to think of real-world situations in which a similar type of database might be used. For example, a database like this could be used by a farmer to keep track of livestock, or by a veterinarian to keep track of patient records. A menagerie distribution containing some of the queries and sample data used in the following sections can be obtained from the MySQL website. It is available in both compressed tar file and Zip formats at https://dev.mysql.com/doc/.

Use the `SHOW` statement to find out what databases currently exist on the server:

```
mysql> SHOW DATABASES;
+----------+
| Database |
+----------+
| mysql    |
| test     |
| tmp      |
+----------+
```

The `mysql` database describes user access privileges. The `test` database often is available as a workspace for users to try things out.

The list of databases displayed by the statement may be different on your machine; `SHOW DATABASES` does not show databases that you have no privileges for if you do not have the `SHOW DATABASES` privilege. See Section 13.7.5.15, “SHOW DATABASES Statement”.

If the `test` database exists, try to access it:

```
mysql> USE test
Database changed
```

The `USE` command does not require a semicolon. (You can terminate such statements with a semicolon if you like; it does no harm.) The `USE` statement is special in another way, too: it must be given on a single line.

You can use the `test` database (if you have access to it) for the examples that follow, but anything you create in that database can be removed by anyone else with access to it. For this reason, you should probably ask your MySQL administrator for permission to use a database of your own. Suppose that you want to call yours `menagerie`. The administrator needs to execute a statement like this:

```
mysql> GRANT ALL ON menagerie.* TO 'your_mysql_name'@'your_client_host';
```

where `your_mysql_name` is the MySQL user name assigned to you and `your_client_host` is the host from which you connect to the server.

### 3.3.1 Creating and Selecting a Database

If the administrator creates your database for you when setting up your permissions, you can begin using it. Otherwise, you need to create it yourself:
Creating a Table

mysql> CREATE DATABASE menagerie;

Under Unix, database names are case-sensitive (unlike SQL keywords), so you must always refer to your database as menagerie, not as Menagerie, MENAGERIE, or some other variant. This is also true for table names. (Under Windows, this restriction does not apply, although you must refer to databases and tables using the same lettercase throughout a given query. However, for a variety of reasons, the recommended best practice is always to use the same lettercase that was used when the database was created.)

Note

If you get an error such as `ERROR 1044 (42000): Access denied for user 'micah'@'localhost' to database 'menagerie'` when attempting to create a database, this means that your user account does not have the necessary privileges to do so. Discuss this with the administrator or see Section 6.2, “Access Control and Account Management”.

Creating a database does not select it for use; you must do that explicitly. To make menagerie the current database, use this statement:

mysql> USE menagerie
Database changed

Your database needs to be created only once, but you must select it for use each time you begin a mysql session. You can do this by issuing a `USE` statement as shown in the example. Alternatively, you can select the database on the command line when you invoke mysql. Just specify its name after any connection parameters that you might need to provide. For example:

shell> mysql -h host -u user -p menagerie
Enter password: ********

Important

menagerie in the command just shown is not your password. If you want to supply your password on the command line after the `-p` option, you must do so with no intervening space (for example, as `-ppassword`, not as `-p password`). However, putting your password on the command line is not recommended, because doing so exposes it to snooping by other users logged in on your machine.

Note

You can see at any time which database is currently selected using `SELECT DATABASE()`.

3.3.2 Creating a Table

Creating the database is the easy part, but at this point it is empty, as `SHOW TABLES` tells you:

mysql> SHOW TABLES;
Empty set (0.00 sec)

The harder part is deciding what the structure of your database should be: what tables you need and what columns should be in each of them.

You want a table that contains a record for each of your pets. This can be called the pet table, and it should contain, as a bare minimum, each animal's name. Because the name by itself is not very interesting, the table should contain other information. For example, if more than one person in your
family keeps pets, you might want to list each animal’s owner. You might also want to record some basic descriptive information such as species and sex.

How about age? That might be of interest, but it is not a good thing to store in a database. Age changes as time passes, which means you’d have to update your records often. Instead, it is better to store a fixed value such as date of birth. Then, whenever you need age, you can calculate it as the difference between the current date and the birth date. MySQL provides functions for doing date arithmetic, so this is not difficult. Storing birth date rather than age has other advantages, too:

• You can use the database for tasks such as generating reminders for upcoming pet birthdays. (If you think this type of query is somewhat silly, note that it is the same question you might ask in the context of a business database to identify clients to whom you need to send out birthday greetings in the current week or month, for that computer-assisted personal touch.)

• You can calculate age in relation to dates other than the current date. For example, if you store death date in the database, you can easily calculate how old a pet was when it died.

You can probably think of other types of information that would be useful in the pet table, but the ones identified so far are sufficient: name, owner, species, sex, birth, and death.

Use a CREATE TABLE statement to specify the layout of your table:

```sql
mysql> CREATE TABLE pet (name VARCHAR(20), owner VARCHAR(20),
    species VARCHAR(20), sex CHAR(1), birth DATE, death DATE);
```

VARCHAR is a good choice for the name, owner, and species columns because the column values vary in length. The lengths in those column definitions need not all be the same, and need not be 20. You can normally pick any length from 1 to 65535, whatever seems most reasonable to you. If you make a poor choice and it turns out later that you need a longer field, MySQL provides an ALTER TABLE statement.

Several types of values can be chosen to represent sex in animal records, such as 'm' and 'f', or perhaps 'male' and 'female'. It is simplest to use the single characters 'm' and 'f'.

The use of the DATE data type for the birth and death columns is a fairly obvious choice.

Once you have created a table, SHOW TABLES should produce some output:

```sql
mysql> SHOW TABLES;
+---------------------+
| Tables in menagerie |
+---------------------+
| pet                 |
+---------------------+
```

To verify that your table was created the way you expected, use a DESCRIBE statement:

```sql
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

You can use DESCRIBE any time, for example, if you forget the names of the columns in your table or what types they have.
For more information about MySQL data types, see Chapter 11, Data Types.

### 3.3.3 Loading Data into a Table

After creating your table, you need to populate it. The `LOAD DATA` and `INSERT` statements are useful for this.

Suppose that your pet records can be described as shown here. (Observe that MySQL expects dates in 'YYYY-MM-DD' format; this may differ from what you are used to.)

<table>
<thead>
<tr>
<th>name</th>
<th>owner</th>
<th>species</th>
<th>sex</th>
<th>birth</th>
<th>death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>Harold</td>
<td>cat</td>
<td>f</td>
<td>1993-02-04</td>
<td></td>
</tr>
<tr>
<td>Claws</td>
<td>Gwen</td>
<td>cat</td>
<td>m</td>
<td>1994-03-17</td>
<td></td>
</tr>
<tr>
<td>Buffy</td>
<td>Harold</td>
<td>dog</td>
<td>f</td>
<td>1989-05-13</td>
<td></td>
</tr>
<tr>
<td>Fang</td>
<td>Benny</td>
<td>dog</td>
<td>m</td>
<td>1990-08-27</td>
<td></td>
</tr>
<tr>
<td>Bowser</td>
<td>Diane</td>
<td>dog</td>
<td>m</td>
<td>1979-08-31</td>
<td>1995-07-29</td>
</tr>
<tr>
<td>Chirpy</td>
<td>Gwen</td>
<td>bird</td>
<td>f</td>
<td>1998-09-11</td>
<td></td>
</tr>
<tr>
<td>Whistler</td>
<td>Gwen</td>
<td>bird</td>
<td>f</td>
<td>1997-12-09</td>
<td></td>
</tr>
<tr>
<td>Slim</td>
<td>Benny</td>
<td>snake</td>
<td>m</td>
<td>1996-04-29</td>
<td></td>
</tr>
</tbody>
</table>

Because you are beginning with an empty table, an easy way to populate it is to create a text file containing a row for each of your animals, then load the contents of the file into the table with a single statement.

You could create a text file `pet.txt` containing one record per line, with values separated by tabs, and given in the order in which the columns were listed in the `CREATE TABLE` statement. For missing values (such as unknown sexes or death dates for animals that are still living), you can use `NULL` values. To represent these in your text file, use `\N` (backslash, capital-N). For example, the record for Whistler the bird would look like this (where the whitespace between values is a single tab character):

```
Whistler        Gwen    bird    \N      1997-12-09      \N
```

To load the text file `pet.txt` into the `pet` table, use this statement:

```sql
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
```

If you created the file on Windows with an editor that uses `\r\n` as a line terminator, you should use this statement instead:

```sql
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet
    
    LINES TERMINATED BY '\r\n';
```

(On an Apple machine running macOS, you would likely want to use `LINES TERMINATED BY '\r'`.)

You can specify the column value separator and end of line marker explicitly in the `LOAD DATA` statement if you wish, but the defaults are tab and linefeed. These are sufficient for the statement to read the file `pet.txt` properly.

If the statement fails, it is likely that your MySQL installation does not have local file capability enabled by default. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”, for information on how to change this.

When you want to add new records one at a time, the `INSERT` statement is useful. In its simplest form, you supply values for each column, in the order in which the columns were listed in the `CREATE TABLE`
Retrieving Information from a Table

statement. Suppose that Diane gets a new hamster named “Puffball.” You could add a new record using an `INSERT` statement like this:

```sql
mysql> INSERT INTO pet
    VALUES ('Puffball', 'Diane', 'hamster', 'f', '1999-03-30', NULL);
```

String and date values are specified as quoted strings here. Also, with `INSERT`, you can insert `NULL` directly to represent a missing value. You do not use `\N` like you do with `LOAD DATA`.

From this example, you should be able to see that there would be a lot more typing involved to load your records initially using several `INSERT` statements rather than a single `LOAD DATA` statement.

### 3.3.4 Retrieving Information from a Table

The `SELECT` statement is used to pull information from a table. The general form of the statement is:

```sql
SELECT what_to_select
FROM which_table
WHERE conditions_to_satisfy;
```

`what_to_select` indicates what you want to see. This can be a list of columns, or `*` to indicate “all columns.” `which_table` indicates the table from which you want to retrieve data. The `WHERE` clause is optional. If it is present, `conditions_to_satisfy` specifies one or more conditions that rows must satisfy to qualify for retrieval.

#### 3.3.4.1 Selecting All Data

The simplest form of `SELECT` retrieves everything from a table:

```sql
mysql> SELECT * FROM pet;
```

<table>
<thead>
<tr>
<th>name</th>
<th>owner</th>
<th>species</th>
<th>sex</th>
<th>birth</th>
<th>death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>Harold</td>
<td>cat</td>
<td>f</td>
<td>1993-02-04</td>
<td>NULL</td>
</tr>
<tr>
<td>Claws</td>
<td>Gwen</td>
<td>cat</td>
<td>m</td>
<td>1994-03-17</td>
<td>NULL</td>
</tr>
<tr>
<td>Buffy</td>
<td>Harold</td>
<td>dog</td>
<td>f</td>
<td>1989-05-13</td>
<td>NULL</td>
</tr>
<tr>
<td>Fang</td>
<td>Benny</td>
<td>dog</td>
<td>m</td>
<td>1990-08-27</td>
<td>NULL</td>
</tr>
<tr>
<td>Bowser</td>
<td>Diane</td>
<td>dog</td>
<td>m</td>
<td>1979-08-31</td>
<td>1995-07-29</td>
</tr>
<tr>
<td>Chirpy</td>
<td>Gwen</td>
<td>bird</td>
<td>f</td>
<td>1998-09-11</td>
<td>NULL</td>
</tr>
<tr>
<td>Whistler</td>
<td>Gwen</td>
<td>bird</td>
<td>NULL</td>
<td>1997-12-09</td>
<td>NULL</td>
</tr>
<tr>
<td>Slim</td>
<td>Benny</td>
<td>snake</td>
<td>m</td>
<td>1996-04-29</td>
<td>NULL</td>
</tr>
<tr>
<td>Puffball</td>
<td>Diane</td>
<td>hamster</td>
<td>f</td>
<td>1999-03-30</td>
<td>NULL</td>
</tr>
</tbody>
</table>

This form of `SELECT` is useful if you want to review your entire table, for example, after you've just loaded it with your initial data set. For example, you may happen to think that the birth date for Bowser doesn't seem quite right. Consulting your original pedigree papers, you find that the correct birth year should be 1989, not 1979.

There are at least two ways to fix this:

- Edit the file `pet.txt` to correct the error, then empty the table and reload it using `DELETE` and `LOAD DATA`:

  ```sql
  mysql> DELETE FROM pet;
  mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
  ```

  However, if you do this, you must also re-enter the record for Puffball.

- Fix only the erroneous record with an `UPDATE` statement:
Retrieving Information from a Table

3.3.4.2 Selecting Particular Rows

As shown in the preceding section, it is easy to retrieve an entire table. Just omit the `WHERE` clause from the `SELECT` statement. But typically you don't want to see the entire table, particularly when it becomes large. Instead, you're usually more interested in answering a particular question, in which case you specify some constraints on the information you want. Let's look at some selection queries in terms of questions about your pets that they answer.

You can select only particular rows from your table. For example, if you want to verify the change that you made to Bowser's birth date, select Bowser's record like this:

```
mysql> SELECT * FROM pet WHERE name = 'Bowser';
```

```
+--------+-------+---------+------+------------+------------+
| name   | owner | species | sex  | birth      | death      |
|--------+-------+---------+------+------------+------------+
| Bowser | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+-------+---------+------+------------+------------+
```

The output confirms that the year is correctly recorded as 1989, not 1979.

String comparisons normally are case-insensitive, so you can specify the name as 'bowser', 'BOWSER', and so forth. The query result is the same.

You can specify conditions on any column, not just `name`. For example, if you want to know which animals were born during or after 1998, test the `birth` column:

```
mysql> SELECT * FROM pet WHERE birth >= '1998-1-1';
```

```
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
|----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Puffball | Diane | hamster | f    | 1999-03-30 | NULL  |
+----------+-------+---------+------+------------+-------+
```

You can combine conditions, for example, to locate female dogs:

```
mysql> SELECT * FROM pet WHERE species = 'dog' AND sex = 'f';
```

```
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
|-------+--------+---------+------+------------+-------+
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The preceding query uses the `AND` logical operator. There is also an `OR` operator:

```
mysql> SELECT * FROM pet WHERE species = 'snake' OR species = 'bird';
```

```
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
|----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL  |
| Slim     | Benny | snake   | m    | 1996-04-29 | NULL  |
+----------+-------+---------+------+------------+-------+
```

`AND` and `OR` may be intermixed, although `AND` has higher precedence than `OR`. If you use both operators, it is a good idea to use parentheses to indicate explicitly how conditions should be grouped:

```
mysql> SELECT * FROM pet WHERE (species = 'cat' AND sex = 'm')
```

237
3.3.4.3 Selecting Particular Columns

If you do not want to see entire rows from your table, just name the columns in which you are interested, separated by commas. For example, if you want to know when your animals were born, select the `name` and `birth` columns:

```sql
SELECT name, birth FROM pet;
```

<table>
<thead>
<tr>
<th>name</th>
<th>birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>1993-02-04</td>
</tr>
<tr>
<td>Claws</td>
<td>1994-03-17</td>
</tr>
<tr>
<td>Buffy</td>
<td>1989-05-13</td>
</tr>
<tr>
<td>Fang</td>
<td>1990-08-27</td>
</tr>
<tr>
<td>Bowser</td>
<td>1989-08-31</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1998-09-11</td>
</tr>
<tr>
<td>Whistler</td>
<td>1997-12-09</td>
</tr>
<tr>
<td>Slim</td>
<td>1996-04-29</td>
</tr>
<tr>
<td>Puffball</td>
<td>1999-03-30</td>
</tr>
</tbody>
</table>

To find out who owns pets, use this query:

```sql
SELECT owner FROM pet;
```

<table>
<thead>
<tr>
<th>owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harold</td>
</tr>
<tr>
<td>Gwen</td>
</tr>
<tr>
<td>Harold</td>
</tr>
<tr>
<td>Benny</td>
</tr>
<tr>
<td>Diane</td>
</tr>
<tr>
<td>Gwen</td>
</tr>
<tr>
<td>Benny</td>
</tr>
<tr>
<td>Diane</td>
</tr>
</tbody>
</table>

Notice that the query simply retrieves the `owner` column from each record, and some of them appear more than once. To minimize the output, retrieve each unique output record just once by adding the keyword `DISTINCT`:

```sql
SELECT DISTINCT owner FROM pet;
```

<table>
<thead>
<tr>
<th>owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benny</td>
</tr>
<tr>
<td>Diane</td>
</tr>
<tr>
<td>Gwen</td>
</tr>
<tr>
<td>Harold</td>
</tr>
</tbody>
</table>

You can use a `WHERE` clause to combine row selection with column selection. For example, to get birth dates for dogs and cats only, use this query:

```sql
SELECT name, species, birth FROM pet
```
WHERE species = 'dog' OR species = 'cat';

<table>
<thead>
<tr>
<th>name</th>
<th>species</th>
<th>birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>cat</td>
<td>1993-02-04</td>
</tr>
<tr>
<td>Claws</td>
<td>cat</td>
<td>1994-03-17</td>
</tr>
<tr>
<td>Buffy</td>
<td>dog</td>
<td>1989-05-13</td>
</tr>
<tr>
<td>Fang</td>
<td>dog</td>
<td>1990-08-27</td>
</tr>
<tr>
<td>Bowser</td>
<td>dog</td>
<td>1989-08-31</td>
</tr>
</tbody>
</table>

### 3.3.4.4 Sorting Rows

You may have noticed in the preceding examples that the result rows are displayed in no particular order. It is often easier to examine query output when the rows are sorted in some meaningful way. To sort a result, use an `ORDER BY` clause.

Here are animal birthdays, sorted by date:

```sql
mysql> SELECT name, birth FROM pet ORDER BY birth;
```

<table>
<thead>
<tr>
<th>name</th>
<th>birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffy</td>
<td>1989-05-13</td>
</tr>
<tr>
<td>Bowser</td>
<td>1989-08-31</td>
</tr>
<tr>
<td>Fang</td>
<td>1990-08-27</td>
</tr>
<tr>
<td>Fluffy</td>
<td>1993-02-04</td>
</tr>
<tr>
<td>Claws</td>
<td>1994-03-17</td>
</tr>
<tr>
<td>Slim</td>
<td>1996-04-29</td>
</tr>
<tr>
<td>Whistler</td>
<td>1997-12-09</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1998-09-11</td>
</tr>
<tr>
<td>Puffball</td>
<td>1999-03-30</td>
</tr>
</tbody>
</table>

On character type columns, sorting—like all other comparison operations—is normally performed in a case-insensitive fashion. This means that the order is undefined for columns that are identical except for their case. You can force a case-sensitive sort for a column by using `BINARY` like so: `ORDER BY BINARY col_name`.

The default sort order is ascending, with smallest values first. To sort in reverse (descending) order, add the `DESC` keyword to the name of the column you are sorting by:

```sql
mysql> SELECT name, birth FROM pet ORDER BY birth DESC;
```

<table>
<thead>
<tr>
<th>name</th>
<th>birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puffball</td>
<td>1999-03-30</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1998-09-11</td>
</tr>
<tr>
<td>Whistler</td>
<td>1997-12-09</td>
</tr>
<tr>
<td>Slim</td>
<td>1996-04-29</td>
</tr>
<tr>
<td>Claws</td>
<td>1994-03-17</td>
</tr>
<tr>
<td>Fluffy</td>
<td>1993-02-04</td>
</tr>
<tr>
<td>Fang</td>
<td>1990-08-27</td>
</tr>
<tr>
<td>Bowser</td>
<td>1989-08-31</td>
</tr>
<tr>
<td>Buffy</td>
<td>1989-05-13</td>
</tr>
</tbody>
</table>

You can sort on multiple columns, and you can sort different columns in different directions. For example, to sort by type of animal in ascending order, then by birth date within animal type in descending order (youngest animals first), use the following query:

```sql
mysql> SELECT name, species, birth FROM pet
ORDER BY species, birth DESC;
```
Retrieving Information from a Table

<table>
<thead>
<tr>
<th>name</th>
<th>species</th>
<th>birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chirpy</td>
<td>bird</td>
<td>1998-09-11</td>
</tr>
<tr>
<td>Whistler</td>
<td>bird</td>
<td>1997-12-09</td>
</tr>
<tr>
<td>Claws</td>
<td>cat</td>
<td>1994-03-17</td>
</tr>
<tr>
<td>Fluffy</td>
<td>cat</td>
<td>1993-02-04</td>
</tr>
<tr>
<td>Fang</td>
<td>dog</td>
<td>1990-08-27</td>
</tr>
<tr>
<td>Bowser</td>
<td>dog</td>
<td>1989-08-31</td>
</tr>
<tr>
<td>Buffy</td>
<td>dog</td>
<td>1989-05-13</td>
</tr>
<tr>
<td>Puffball</td>
<td>hamster</td>
<td>1999-03-30</td>
</tr>
<tr>
<td>Slim</td>
<td>snake</td>
<td>1996-04-29</td>
</tr>
</tbody>
</table>

The **DESC** keyword applies only to the column name immediately preceding it (**birth**); it does not affect the **species** column sort order.

### 3.3.4.5 Date Calculations

MySQL provides several functions that you can use to perform calculations on dates, for example, to calculate ages or extract parts of dates.

To determine how many years old each of your pets is, use the **TIMESTAMPDIFF()** function. Its arguments are the unit in which you want the result expressed, and the two dates for which to take the difference. The following query shows, for each pet, the birth date, the current date, and the age in years. An alias (**age**) is used to make the final output column label more meaningful.

```sql
mysql> SELECT name, birth, CURDATE(),
       TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
       FROM pet;
```

<table>
<thead>
<tr>
<th>name</th>
<th>birth</th>
<th>CURDATE()</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>1993-02-04</td>
<td>2003-08-19</td>
<td>10</td>
</tr>
<tr>
<td>Claws</td>
<td>1994-03-17</td>
<td>2003-08-19</td>
<td>9</td>
</tr>
<tr>
<td>Buffy</td>
<td>1989-05-13</td>
<td>2003-08-19</td>
<td>14</td>
</tr>
<tr>
<td>Fang</td>
<td>1990-08-27</td>
<td>2003-08-19</td>
<td>12</td>
</tr>
<tr>
<td>Bowser</td>
<td>1989-08-31</td>
<td>2003-08-19</td>
<td>13</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1998-09-11</td>
<td>2003-08-19</td>
<td>4</td>
</tr>
<tr>
<td>Whistler</td>
<td>1997-12-09</td>
<td>2003-08-19</td>
<td>14</td>
</tr>
<tr>
<td>Slim</td>
<td>1996-04-29</td>
<td>2003-08-19</td>
<td>7</td>
</tr>
<tr>
<td>Puffball</td>
<td>1999-03-30</td>
<td>2003-08-19</td>
<td>4</td>
</tr>
</tbody>
</table>

The query works, but the result could be scanned more easily if the rows were presented in some order. This can be done by adding an **ORDER BY name** clause to sort the output by name:

```sql
mysql> SELECT name, birth, CURDATE(),
       TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
       FROM pet ORDER BY name;
```

<table>
<thead>
<tr>
<th>name</th>
<th>birth</th>
<th>CURDATE()</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowser</td>
<td>1989-08-31</td>
<td>2003-08-19</td>
<td>13</td>
</tr>
<tr>
<td>Buffy</td>
<td>1989-05-13</td>
<td>2003-08-19</td>
<td>14</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1998-09-11</td>
<td>2003-08-19</td>
<td>4</td>
</tr>
<tr>
<td>Claws</td>
<td>1994-03-17</td>
<td>2003-08-19</td>
<td>9</td>
</tr>
<tr>
<td>Fang</td>
<td>1990-08-27</td>
<td>2003-08-19</td>
<td>12</td>
</tr>
<tr>
<td>Fluffy</td>
<td>1993-02-04</td>
<td>2003-08-19</td>
<td>10</td>
</tr>
<tr>
<td>Puffball</td>
<td>1999-03-30</td>
<td>2003-08-19</td>
<td>4</td>
</tr>
<tr>
<td>Slim</td>
<td>1996-04-29</td>
<td>2003-08-19</td>
<td>7</td>
</tr>
<tr>
<td>Whistler</td>
<td>1997-12-09</td>
<td>2003-08-19</td>
<td>5</td>
</tr>
</tbody>
</table>

To sort the output by **age** rather than **name**, just use a different **ORDER BY** clause:
Retrieving Information from a Table

```
mysql> SELECT name, birth, CURDATE(),
TIMESTAMPDIFF(YEAR, birth, CURDATE()) AS age
FROM pet ORDER BY age;
```
```
+----------+------------+-----------------+------+
| name     | birth      | CURDATE()       | age  |
+----------+------------+-----------------+------+
| Chirpy   | 1998-09-11 | 2003-08-19      |    4 |
| Puffball | 1999-03-30 | 2003-08-19      |    4 |
| Whistler | 1997-12-09 | 2003-08-19      |    5 |
| Slim     | 1996-04-29 | 2003-08-19      |    7 |
| Claws    | 1994-01-17 | 2003-08-19      |    9 |
| Fluffy   | 1993-02-04 | 2003-08-19      |   10 |
| Fang     | 1990-08-27 | 2003-08-19      |   12 |
| Bowser   | 1989-08-31 | 2003-08-19      |   13 |
| Buffy    | 1989-05-13 | 2003-08-19      |   14 |
+----------+------------+-----------------+------+
```

A similar query can be used to determine age at death for animals that have died. You determine which animals these are by checking whether the `death` value is `NULL`. Then, for those with non-`NULL` values, compute the difference between the `death` and `birth` values:

```
mysql> SELECT name, birth, death,
TIMESTAMPDIFF(YEAR, birth, death) AS age
FROM pet WHERE death IS NOT NULL ORDER BY age;
```
```
+--------+------------+------------+------+
| name   | birth      | death      | age  |
+--------+------------+------------+------+
| Bowser | 1989-08-31 | 1995-07-29 |    5 |
+--------+------------+------------+------+
```

The query uses `death IS NOT NULL` rather than `death <> NULL` because `NULL` is a special value that cannot be compared using the usual comparison operators. This is discussed later. See Section 3.3.4.6, “Working with NULL Values”.

What if you want to know which animals have birthdays next month? For this type of calculation, year and day are irrelevant; you simply want to extract the month part of the `birth` column. MySQL provides several functions for extracting parts of dates, such as `YEAR()`, `MONTH()`, and `DAYOFMONTH()`. `MONTH()` is the appropriate function here. To see how it works, run a simple query that displays the value of both `birth` and `MONTH(birth)`:

```
mysql> SELECT name, birth, MONTH(birth) FROM pet;
```
```
+----------+------------+-------------+
| name     | birth      | MONTH(birth)|
+----------+------------+-------------+
| Fluffy   | 1993-02-04 | 2           |
| Claws    | 1994-03-17 | 3           |
| Buffy    | 1989-05-13 | 5           |
| Fang     | 1990-08-27 | 8           |
| Bowser   | 1989-08-31 | 8           |
| Chirpy   | 1998-09-11 | 9           |
| Whistler | 1997-12-09 | 12          |
| Slim     | 1996-04-29 | 4           |
| Puffball | 1999-03-30 | 3           |
+----------+------------+-------------+
```

Finding animals with birthdays in the upcoming month is also simple. Suppose that the current month is April. Then the month value is 4 and you can look for animals born in May (month 5) like this:

```
mysql> SELECT name, birth FROM pet WHERE MONTH(birth) = 5;
```
```
+-------+------------+
| name  | birth      |
+-------+------------+
| Buffy | 1989-05-13 |
+-------+------------+
```

241
Retrieving Information from a Table

There is a small complication if the current month is December. You cannot merely add one to the month number (12) and look for animals born in month 13, because there is no such month. Instead, you look for animals born in January (month 1).

You can write the query so that it works no matter what the current month is, so that you do not have to use the number for a particular month. DATE_ADD() enables you to add a time interval to a given date. If you add a month to the value of CURDATE(), then extract the month part with MONTH(), the result produces the month in which to look for birthdays:

\[
\text{mysql}> \quad \text{SELECT name, birth FROM pet}
\]
\[
\text{WHERE MONTH(birth) = MONTH(DATE_ADD(CURDATE(), INTERVAL 1 MONTH));}
\]

A different way to accomplish the same task is to add 1 to get the next month after the current one after using the modulo function (MOD) to wrap the month value to 0 if it is currently 12:

\[
\text{mysql}> \quad \text{SELECT name, birth FROM pet}
\]
\[
\text{WHERE MONTH(birth) = MOD(MONTH(CURDATE()), 12) + 1;}
\]

MONTH() returns a number between 1 and 12. And MOD(something,12) returns a number between 0 and 11. So the addition has to be after the MOD(), otherwise we would go from November (11) to January (1).

If a calculation uses invalid dates, the calculation fails and produces warnings:

\[
\text{mysql}> \quad \text{SELECT '2018-10-31' + INTERVAL 1 DAY;}
\]
\[
+-------------------------------+
| '2018-10-31' + INTERVAL 1 DAY |
| 2018-11-01                    |
+-------------------------------+
\]
\[
\text{mysql}> \quad \text{SELECT '2018-10-32' + INTERVAL 1 DAY;}
\]
\[
+-------------------------------+
| '2018-10-32' + INTERVAL 1 DAY |
| NULL                          |
+-------------------------------+
\]
\[
\text{mysql}> \quad \text{SHOW WARNINGS;}
\]
\[
+---------+------+----------------------------------------+
| Level   | Code | Message                                |
|---------+------+----------------------------------------+
| Warning | 1292 | Incorrect datetime value: '2018-10-32' |
+---------+------+----------------------------------------+

3.3.4.6 Working with NULL Values

The NULL value can be surprising until you get used to it. Conceptually, NULL means “a missing unknown value” and it is treated somewhat differently from other values.

To test for NULL, use the IS NULL and IS NOT NULL operators, as shown here:

\[
\text{mysql}> \quad \text{SELECT 1 IS NULL, 1 IS NOT NULL;}
\]
\[
+-----------+---------------+
| 1 IS NULL | 1 IS NOT NULL |
| 0          | 1             |
+-----------+---------------+
\]

You cannot use arithmetic comparison operators such as =, <, or <> to test for NULL. To demonstrate this for yourself, try the following query:

\[
\text{mysql}> \quad \text{SELECT 1 = NULL, 1 <> NULL, 1 < NULL, 1 > NULL;}
\]
\[
+----------+-----------+----------+----------+
| 1 = NULL | 1 <> NULL | 1 < NULL | 1 > NULL |
| 242       | NULL      | 0        | NULL     |
+----------+-----------+----------+----------+

242
Because the result of any arithmetic comparison with NULL is also NULL, you cannot obtain any meaningful results from such comparisons.

In MySQL, 0 or NULL means false and anything else means true. The default truth value from a boolean operation is 1.

This special treatment of NULL is why, in the previous section, it was necessary to determine which animals are no longer alive using death IS NOT NULL instead of death <> NULL.

Two NULL values are regarded as equal in a GROUP BY.

When doing an ORDER BY, NULL values are presented first if you do ORDER BY ... ASC and last if you do ORDER BY ... DESC.

A common error when working with NULL is to assume that it is not possible to insert a zero or an empty string into a column defined as NOT NULL, but this is not the case. These are in fact values, whereas NULL means “not having a value.” You can test this easily enough by using IS [NOT] NULL as shown:

```
mysql> SELECT 0 IS NULL, 0 IS NOT NULL, '' IS NULL, '' IS NOT NULL;
+-----------+---------------+------------+----------------+
| 0 IS NULL | 0 IS NOT NULL | '' IS NULL | '' IS NOT NULL |
+-----------+---------------+------------+----------------+
|         0 |             1 |          0 |              1 |
+-----------+---------------+------------+----------------+
```

Thus it is entirely possible to insert a zero or empty string into a NOT NULL column, as these are in fact NOT NULL. See Section B.4.4.3, “Problems with NULL Values”.

### 3.3.4.7 Pattern Matching

MySQL provides standard SQL pattern matching as well as a form of pattern matching based on extended regular expressions similar to those used by Unix utilities such as vi, grep, and sed.

SQL pattern matching enables you to use _ to match any single character and % to match an arbitrary number of characters (including zero characters). In MySQL, SQL patterns are case-insensitive by default. Some examples are shown here. Do not use = or <> when you use SQL patterns. Use the LIKE or NOT LIKE comparison operators instead.

To find names beginning with b:

```
mysql> SELECT * FROM pet WHERE name LIKE 'b%';
```

```
<table>
<thead>
<tr>
<th>name</th>
<th>owner</th>
<th>species</th>
<th>sex</th>
<th>birth</th>
<th>death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffy</td>
<td>Harold</td>
<td>dog</td>
<td>f</td>
<td>1989-05-13</td>
<td>NULL</td>
</tr>
<tr>
<td>Bowser</td>
<td>Diane</td>
<td>dog</td>
<td>m</td>
<td>1989-08-31</td>
<td>1995-07-29</td>
</tr>
</tbody>
</table>
```

To find names ending with fy:

```
mysql> SELECT * FROM pet WHERE name LIKE '%fy';
```

```
<table>
<thead>
<tr>
<th>name</th>
<th>owner</th>
<th>species</th>
<th>sex</th>
<th>birth</th>
<th>death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>Harold</td>
<td>cat</td>
<td>f</td>
<td>1993-02-04</td>
<td>NULL</td>
</tr>
<tr>
<td>Buffy</td>
<td>Harold</td>
<td>dog</td>
<td>f</td>
<td>1989-05-13</td>
<td>NULL</td>
</tr>
</tbody>
</table>
```
To find names containing a `w`:

```
mysql> SELECT * FROM pet WHERE name LIKE '%w%';
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

To find names containing exactly five characters, use five instances of the `_` pattern character:

```
mysql> SELECT * FROM pet WHERE name LIKE '_____';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The other type of pattern matching provided by MySQL uses extended regular expressions. When you test for a match for this type of pattern, use the `REGEXP` and `NOT REGEXP` operators (or `RLIKE` and `NOT RLIKE`, which are synonyms).

The following list describes some characteristics of extended regular expressions:

- . matches any single character.
- A character class `[…]` matches any character within the brackets. For example, `[abc]` matches `a`, `b`, or `c`. To name a range of characters, use a dash. `[a-z]` matches any letter, whereas `[0-9]` matches any digit.
- `*` matches zero or more instances of the thing preceding it. For example, `x*` matches any number of `x` characters, `[0-9]*` matches any number of digits, and `.*` matches any number of anything.
- A regular expression pattern match succeeds if the pattern matches anywhere in the value being tested. (This differs from a `LIKE` pattern match, which succeeds only if the pattern matches the entire value.)
- To anchor a pattern so that it must match the beginning or end of the value being tested, use `^` at the beginning or `$` at the end of the pattern.

To demonstrate how extended regular expressions work, the `LIKE` queries shown previously are rewritten here to use `REGEXP`.

To find names beginning with `b`, use `^` to match the beginning of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^b';
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

To force a `REGEXP` comparison to be case-sensitive, use the `BINARY` keyword to make one of the strings a binary string. This query matches only lowercase `b` at the beginning of a name:

```
SELECT * FROM pet WHERE name REGEXP BINARY '^b';
```

To find names ending with `fy`, use `$` to match the end of the name:
To find names containing a `w`, use this query:

```
mysql> SELECT * FROM pet WHERE name REGEXP 'w';
```

```
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

Because a regular expression pattern matches if it occurs anywhere in the value, it is not necessary in the previous query to put a wildcard on either side of the pattern to get it to match the entire value as would be true with an SQL pattern.

To find names containing exactly five characters, use `^` and `$` to match the beginning and end of the name, and five instances of `_` in between:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.....$';
```

```
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

You could also write the previous query using the `{n}` (“repeat-n-times”) operator:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.{5}$';
```

```
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

For more information about the syntax for regular expressions, see Section 12.7.2, “Regular Expressions”.

### 3.3.4.8 Counting Rows

Databases are often used to answer the question, “How often does a certain type of data occur in a table?” For example, you might want to know how many pets you have, or how many pets each owner has, or you might want to perform various kinds of census operations on your animals.

Counting the total number of animals you have is the same question as “How many rows are in the `pet` table?” because there is one record per pet. `COUNT(*)` counts the number of rows, so the query to count your animals looks like this:

```
mysql> SELECT COUNT(*) FROM pet;
```

```
+----------+
| COUNT(*) |
+----------+
|         9 |
+----------+
```
Earlier, you retrieved the names of the people who owned pets. You can use \texttt{COUNT()} if you want to find out how many pets each owner has:

\begin{verbatim}
mysql> SELECT owner, COUNT(*) FROM pet GROUP BY owner;
+--------+----------+
| owner  | COUNT(*) |
+--------+----------+
| Benny  |        2 |
| Diane  |        2 |
| Gwen   |        3 |
| Harold |        2 |
+--------+----------+
\end{verbatim}

The preceding query uses \texttt{GROUP BY} to group all records for each \texttt{owner}. The use of \texttt{COUNT()} in conjunction with \texttt{GROUP BY} is useful for characterizing your data under various groupings. The following examples show different ways to perform animal census operations.

\textbf{Number of animals per species:}

\begin{verbatim}
mysql> SELECT species, COUNT(*) FROM pet GROUP BY species;
+---------+----------+
| species | COUNT(*) |
+---------+----------+
| bird    |        2 |
| cat     |        2 |
| dog     |        3 |
| hamster |        1 |
| snake   |        1 |
+---------+----------+
\end{verbatim}

\textbf{Number of animals per sex:}

\begin{verbatim}
mysql> SELECT sex, COUNT(*) FROM pet GROUP BY sex;
+------+----------+
| sex  | COUNT(*) |
+------+----------+
| NULL |        1 |
| f    |        4 |
| m    |        4 |
+------+----------+
\end{verbatim}

(In this output, \texttt{NULL} indicates that the sex is unknown.)

\textbf{Number of animals per combination of species and sex:}

\begin{verbatim}
mysql> SELECT species, sex, COUNT(*) FROM pet GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | NULL |        1 |
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
\end{verbatim}

You need not retrieve an entire table when you use \texttt{COUNT()}. For example, the previous query, when performed just on dogs and cats, looks like this:

\begin{verbatim}
mysql> SELECT species, sex, COUNT(*) FROM pet
WHERE species = 'dog' OR species = 'cat'
GROUP BY species, sex;
\end{verbatim}
Retrieving Information from a Table

<table>
<thead>
<tr>
<th>species</th>
<th>sex</th>
<th>COUNT(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cat</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>cat</td>
<td>m</td>
<td>1</td>
</tr>
<tr>
<td>dog</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>dog</td>
<td>m</td>
<td>2</td>
</tr>
</tbody>
</table>

Or, if you wanted the number of animals per sex only for animals whose sex is known:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    WHERE sex IS NOT NULL
    GROUP BY species, sex;
```

<table>
<thead>
<tr>
<th>species</th>
<th>sex</th>
<th>COUNT(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>bird</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>cat</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>cat</td>
<td>m</td>
<td>1</td>
</tr>
<tr>
<td>dog</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>dog</td>
<td>m</td>
<td>2</td>
</tr>
<tr>
<td>hamster</td>
<td>f</td>
<td>1</td>
</tr>
<tr>
<td>snake</td>
<td>m</td>
<td>1</td>
</tr>
</tbody>
</table>

If you name columns to select in addition to the `COUNT(*)` value, a `GROUP BY` clause should be present that names those same columns. Otherwise, the following occurs:

- If the `ONLY_FULL_GROUP_BY` SQL mode is enabled, an error occurs:

  ```
  mysql> SET sql_mode = 'ONLY_FULL_GROUP_BY';
  Query OK, 0 rows affected (0.00 sec)
  mysql> SELECT owner, COUNT(*) FROM pet;
  ERROR 1140 (42000): Mixing of GROUP columns (MIN(), MAX(), COUNT()...) with no GROUP BY clause
  ```

- If `ONLY_FULL_GROUP_BY` is not enabled, the query is processed by treating all rows as a single group, but the value selected for each named column is nondeterministic. The server is free to select the value from any row:

  ```
  mysql> SET sql_mode = '';
  Query OK, 0 rows affected (0.00 sec)
  mysql> SELECT owner, COUNT(*) FROM pet;
  +--------+----------+
  | owner  | COUNT(*) |
  +--------+----------+
  | Harold | 8        |
  +--------+----------+
  1 row in set (0.00 sec)
  ```

See also Section 12.17.3, “MySQL Handling of GROUP BY”. See Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions” for information about `COUNT(expr)` behavior and related optimizations.

### 3.3.4.9 Using More Than One Table

The `pet` table keeps track of which pets you have. If you want to record other information about them, such as events in their lives like visits to the vet or when litters are born, you need another table. What should this table look like? It needs to contain the following information:

- The pet name so that you know which animal each event pertains to.
Retrieving Information from a Table

- A date so that you know when the event occurred.
- A field to describe the event.
- An event type field, if you want to be able to categorize events.

Given these considerations, the `CREATE TABLE` statement for the `event` table might look like this:

```sql
mysql> CREATE TABLE event (name VARCHAR(20), date DATE, type VARCHAR(15), remark VARCHAR(255));
```

As with the `pet` table, it is easiest to load the initial records by creating a tab-delimited text file containing the following information.

<table>
<thead>
<tr>
<th>name</th>
<th>date</th>
<th>type</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>1995-05-15</td>
<td>litter</td>
<td>4 kittens, 3 female, 1 male</td>
</tr>
<tr>
<td>Buffy</td>
<td>1993-06-23</td>
<td>litter</td>
<td>5 puppies, 2 female, 3 male</td>
</tr>
<tr>
<td>Buffy</td>
<td>1994-06-19</td>
<td>litter</td>
<td>3 puppies, 3 female</td>
</tr>
<tr>
<td>Chirpy</td>
<td>1999-03-21</td>
<td>vet</td>
<td>needed beak straightened</td>
</tr>
<tr>
<td>Slim</td>
<td>1997-08-03</td>
<td>vet</td>
<td>broken rib</td>
</tr>
<tr>
<td>Bowser</td>
<td>1991-10-12</td>
<td>kennel</td>
<td></td>
</tr>
<tr>
<td>Fang</td>
<td>1991-10-12</td>
<td>kennel</td>
<td></td>
</tr>
<tr>
<td>Fang</td>
<td>1998-08-28</td>
<td>birthday</td>
<td>Gave him a new chew toy</td>
</tr>
<tr>
<td>Claws</td>
<td>1998-03-17</td>
<td>birthday</td>
<td>Gave him a new flea collar</td>
</tr>
<tr>
<td>Whistler</td>
<td>1998-12-09</td>
<td>birthday</td>
<td>First birthday</td>
</tr>
</tbody>
</table>

Load the records like this:

```sql
mysql> LOAD DATA LOCAL INFILE 'event.txt' INTO TABLE event;
```

Based on what you have learned from the queries that you have run on the `pet` table, you should be able to perform retrievals on the records in the `event` table; the principles are the same. But when is the `event` table by itself insufficient to answer questions you might ask?

Suppose that you want to find out the ages at which each pet had its litters. We saw earlier how to calculate ages from two dates. The litter date of the mother is in the `event` table, but to calculate her age on that date you need her birth date, which is stored in the `pet` table. This means the query requires both tables:

```sql
mysql> SELECT pet.name, TIMESTAMPDIFF(YEAR,birth,date) AS age, remark
    FROM pet INNER JOIN event
    ON pet.name = event.name
    WHERE event.type = 'litter';
```

<table>
<thead>
<tr>
<th>name</th>
<th>age</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluffy</td>
<td>2</td>
<td>4 kittens, 3 female, 1 male</td>
</tr>
<tr>
<td>Buffy</td>
<td>4</td>
<td>5 puppies, 2 female, 3 male</td>
</tr>
<tr>
<td>Buffy</td>
<td>5</td>
<td>3 puppies, 3 female</td>
</tr>
</tbody>
</table>

There are several things to note about this query:

- The `FROM` clause joins two tables because the query needs to pull information from both of them.
• When combining (joining) information from multiple tables, you need to specify how records in one table can be matched to records in the other. This is easy because they both have a name column. The query uses an ON clause to match up records in the two tables based on the name values.

The query uses an INNER JOIN to combine the tables. An INNER JOIN permits rows from either table to appear in the result if and only if both tables meet the conditions specified in the ON clause. In this example, the ON clause specifies that the name column in the pet table must match the name column in the event table. If a name appears in one table but not the other, the row will not appear in the result because the condition in the ON clause fails.

• Because the name column occurs in both tables, you must be specific about which table you mean when referring to the column. This is done by prepending the table name to the column name.

You need not have two different tables to perform a join. Sometimes it is useful to join a table to itself, if you want to compare records in a table to other records in that same table. For example, to find breeding pairs among your pets, you can join the pet table with itself to produce candidate pairs of live males and females of like species:

```sql
mysql> SELECT p1.name, p1.sex, p2.name, p2.sex, p1.species
FROM pet AS p1 INNER JOIN pet AS p2
ON p1.species = p2.species
AND p1.sex = 'f' AND p1.death IS NULL
AND p2.sex = 'm' AND p2.death IS NULL;

+--------+------+-------+------+---------+
| name   | sex  | name  | sex  | species |
+--------+------+-------+------+---------+
| Fluffy | f    | Claws | m    | cat     |
| Buffy  | f    | Fang  | m    | dog     |
```

In this query, we specify aliases for the table name to refer to the columns and keep straight which instance of the table each column reference is associated with.

### 3.4 Getting Information About Databases and Tables

What if you forget the name of a database or table, or what the structure of a given table is (for example, what its columns are called)? MySQL addresses this problem through several statements that provide information about the databases and tables it supports.

You have previously seen `SHOW DATABASES`, which lists the databases managed by the server. To find out which database is currently selected, use the `DATABASE()` function:

```sql
mysql> SELECT DATABASE();
+------------+
| DATABASE() |
+------------+
| menagerie  |
```

If you have not yet selected any database, the result is `NULL`.

To find out what tables the default database contains (for example, when you are not sure about the name of a table), use this statement:

```sql
mysql> SHOW TABLES;
+---------------------+
| Tables_in_menagerie |
+---------------------+
| event               |
| pet                 |
```
Using mysql in Batch Mode

The name of the column in the output produced by this statement is always `Tables_in_db_name`, where `db_name` is the name of the database. See Section 13.7.5.38, “SHOW TABLES Statement”, for more information.

If you want to find out about the structure of a table, the `DESCRIBE` statement is useful; it displays information about each of a table’s columns:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

Field indicates the column name, Type is the data type for the column, NULL indicates whether the column can contain NULL values, Key indicates whether the column is indexed, and Default specifies the column's default value. Extra displays special information about columns: If a column was created with the AUTO_INCREMENT option, the value will be auto_increment rather than empty.

`DESC` is a short form of DESCRIBE. See Section 13.8.1, “DESCRIBE Statement”, for more information.

You can obtain the `CREATE TABLE` statement necessary to create an existing table using the `SHOW CREATE TABLE` statement. See Section 13.7.5.12, “SHOW CREATE TABLE Statement”.

If you have indexes on a table, `SHOW INDEX FROM tbl_name` produces information about them. See Section 13.7.5.23, “SHOW INDEX Statement”, for more about this statement.

### 3.5 Using mysql in Batch Mode

In the previous sections, you used `mysql` interactively to enter statements and view the results. You can also run `mysql` in batch mode. To do this, put the statements you want to run in a file, then tell `mysql` to read its input from the file:

```
shell> mysql < batch-file
```

If you are running `mysql` under Windows and have some special characters in the file that cause problems, you can do this:

```
C:\> mysql -e "source batch-file"
```

If you need to specify connection parameters on the command line, the command might look like this:

```
shell> mysql -h host -u user -p < batch-file
Enter password: ********
```

When you use `mysql` this way, you are creating a script file, then executing the script.

If you want the script to continue even if some of the statements in it produce errors, you should use the `--force` command-line option.

Why use a script? Here are a few reasons:

- If you run a query repeatedly (say, every day or every week), making it a script enables you to avoid retyping it each time you execute it.
Examples of Common Queries

- You can generate new queries from existing ones that are similar by copying and editing script files.

- Batch mode can also be useful while you're developing a query, particularly for multiple-line statements or multiple-statement sequences. If you make a mistake, you don't have to retype everything. Just edit your script to correct the error, then tell `mysql` to execute it again.

- If you have a query that produces a lot of output, you can run the output through a pager rather than watching it scroll off the top of your screen:

```
shell> mysql < batch-file | more
```

- You can catch the output in a file for further processing:

```
shell> mysql < batch-file > mysql.out
```

- You can distribute your script to other people so that they can also run the statements.

- Some situations do not allow for interactive use, for example, when you run a query from a `cron` job. In this case, you must use batch mode.

The default output format is different (more concise) when you run `mysql` in batch mode than when you use it interactively. For example, the output of `SELECT DISTINCT species FROM pet` looks like this when `mysql` is run interactively:

```
+---------+
| species |
+---------+
| bird    |
| cat     |
| dog     |
| hamster |
| snake   |
```

In batch mode, the output looks like this instead:

```
species
bird
cat
dog
hamster
snake
```

If you want to get the interactive output format in batch mode, use `mysql -t`. To echo to the output the statements that are executed, use `mysql -v`.

You can also use scripts from the `mysql` prompt by using the `source` command or `.` command:

```
mysql> source filename;
mysql> . filename
```

See Section 4.5.1.5, “Executing SQL Statements from a Text File”, for more information.

### 3.6 Examples of Common Queries

Here are examples of how to solve some common problems with MySQL.

Some of the examples use the table `shop` to hold the price of each article (item number) for certain traders (dealers). Supposing that each trader has a single fixed price per article, then `(article, dealer)` is a primary key for the records.
Start the command-line tool `mysql` and select a database:

```
shell> mysql your-database-name
```

To create and populate the example table, use these statements:

```sql
CREATE TABLE shop (  
article INT UNSIGNED  DEFAULT '0000' NOT NULL,  
dealer  CHAR(20)      DEFAULT ''     NOT NULL,  
price   DECIMAL(16,2) DEFAULT '0.00' NOT NULL,  
PRIMARY KEY(article, dealer));

INSERT INTO shop VALUES  
(1,'A',3.45),(1,'B',3.99),(2,'A',10.99),(3,'B',1.45),  
(3,'C',1.69),(3,'D',1.25),(4,'D',19.95);
```

After issuing the statements, the table should have the following contents:

```
+---------+--------+-------+  
| article | dealer | price |  
+---------+--------+-------+  
|       1 | A      | 3.45  |  
|       1 | B      | 3.99  |  
|       2 | A      | 10.99 |  
|       3 | B      | 1.45  |  
|       3 | C      | 1.69  |  
|       3 | D      | 1.25  |  
|       4 | D      | 19.95 |  
+---------+--------+-------+
```

### 3.6.1 The Maximum Value for a Column

“What is the highest item number?”

```
SELECT MAX(article) AS article FROM shop;
```

```
+---------+
| article |
+---------+
|       4 |
+---------+
```

### 3.6.2 The Row Holding the Maximum of a Certain Column

Task: Find the number, dealer, and price of the most expensive article.

This is easily done with a subquery:

```
SELECT article, dealer, price  
FROM shop  
WHERE price=(SELECT MAX(price) FROM shop);
```

```
+---------+--------+-------+  
| article | dealer | price |  
+---------+--------+-------+  
|    0004 | D      | 19.95 |  
+---------+--------+-------+  
```

Other solutions are to use a `LEFT JOIN` or to sort all rows descending by price and get only the first row using the MySQL-specific `LIMIT` clause:

```
SELECT s1.article, s1.dealer, s1.price  
FROM shop s1  
WHERE price=(SELECT MAX(price) FROM shop)  
LIMIT 1;
```

```
+---------+--------+-------+  
| article | dealer | price |  
+---------+--------+-------+  
|    0004 | D      | 19.95 |  
+---------+--------+-------+  
```
3.6.3 Maximum of Column per Group

**Task:** Find the highest price per article.

```
SELECT article, MAX(price) AS price
FROM shop
GROUP BY article
ORDER BY article;
```

<table>
<thead>
<tr>
<th>article</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>3.99</td>
</tr>
<tr>
<td>0002</td>
<td>10.99</td>
</tr>
<tr>
<td>0003</td>
<td>1.69</td>
</tr>
<tr>
<td>0004</td>
<td>19.95</td>
</tr>
</tbody>
</table>

3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column

**Task:** For each article, find the dealer or dealers with the most expensive price.

This problem can be solved with a subquery like this one:

```
SELECT article, dealer, price
FROM shop s1
WHERE price=(SELECT MAX(s2.price)
            FROM shop s2
            WHERE s1.article = s2.article)
ORDER BY article;
```

<table>
<thead>
<tr>
<th>article</th>
<th>dealer</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>B</td>
<td>3.99</td>
</tr>
<tr>
<td>0002</td>
<td>A</td>
<td>10.99</td>
</tr>
<tr>
<td>0003</td>
<td>C</td>
<td>1.69</td>
</tr>
<tr>
<td>0004</td>
<td>D</td>
<td>19.95</td>
</tr>
</tbody>
</table>

The preceding example uses a correlated subquery, which can be inefficient (see Section 13.2.10.7, "Correlated Subqueries"). Other possibilities for solving the problem are to use an uncorrelated subquery in the `FROM` clause or a `LEFT JOIN`.

Uncorrelated subquery:

```
SELECT s1.article, dealer, s1.price
FROM shop s1
JOIN (
3.6.5 Using User-Defined Variables

You can employ MySQL user variables to remember results without having to store them in temporary variables in the client. (See Section 9.4, “User-Defined Variables”.)

For example, to find the articles with the highest and lowest price you can do this:

```sql
mysql> SELECT @min_price:=MIN(price),@max_price:=MAX(price) FROM shop;
```

```sql
+--------+-------+
<table>
<thead>
<tr>
<th>article</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0003</td>
<td>1.25</td>
</tr>
<tr>
<td>0004</td>
<td>19.95</td>
</tr>
</tbody>
</table>
+---------+-------+
```

3.6.6 Using Foreign Keys

In MySQL, InnoDB tables support checking of foreign key constraints. See Chapter 14, The InnoDB Storage Engine, and Section 1.7.2.3, “FOREIGN KEY Constraint Differences”.

A foreign key constraint is not required merely to join two tables. For storage engines other than InnoDB, it is possible when defining a column to use a REFERENCES tbl_name(col_name) clause, which has no actual effect, and serves only as a memo or comment to you that the column which you are currently defining is intended to refer to a column in another table. It is extremely important to realize when using this syntax that:

- MySQL does not perform any sort of check to make sure that col_name actually exists in tbl_name (or even that tbl_name itself exists).
- MySQL does not perform any sort of action on tbl_name such as deleting rows in response to actions taken on rows in the table which you are defining; in other words, this syntax induces no ON DELETE or ON UPDATE behavior whatsoever. (Although you can write an ON DELETE or ON UPDATE clause as part of the REFERENCES clause, it is also ignored.)
• This syntax creates a *column*; it does **not** create any sort of index or key.

You can use a column so created as a join column, as shown here:

```sql
CREATE TABLE person (  
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,  
    name CHAR(60) NOT NULL,  
    PRIMARY KEY (id)  
);  
CREATE TABLE shirt (  
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,  
    style ENUM('t-shirt', 'polo', 'dress') NOT NULL,  
    color ENUM('red', 'blue', 'orange', 'white', 'black') NOT NULL,  
    owner SMALLINT UNSIGNED NOT NULL REFERENCES person(id),  
    PRIMARY KEY (id)  
);  
INSERT INTO person VALUES (NULL, 'Antonio Paz');  
SELECT @last := LAST_INSERT_ID();  
INSERT INTO shirt VALUES  
(NULL, 'polo', 'blue', @last),  
(NULL, 'dress', 'white', @last),  
(NULL, 't-shirt', 'blue', @last);  
INSERT INTO person VALUES (NULL, 'Lilliana Angelovska');  
SELECT @last := LAST_INSERT_ID();  
INSERT INTO shirt VALUES  
(NULL, 'dress', 'orange', @last),  
(NULL, 'polo', 'red', @last),  
(NULL, 'dress', 'blue', @last),  
(NULL, 't-shirt', 'white', @last);  
SELECT * FROM person;  
+----+---------------------+  
| id | name                |  
+----+---------------------+  
|  1 | Antonio Paz         |  
|  2 | Lilliana Angelovska |  
+----+---------------------+  
SELECT * FROM shirt;  
+----+-------+--------+-------+  
| id | style | color  | owner |  
+----+-------+--------+-------+  
|  1 | polo  | blue   | 1     |  
|  2 | dress | white  | 1     |  
|  3 | t-shirt | blue | 1     |  
|  4 | dress | orange | 2     |  
|  5 | polo  | red    | 2     |  
|  6 | dress | blue   | 2     |  
|  7 | t-shirt | white | 2     |  
+----+-------+--------+-------+  
SELECT s.* FROM person p INNER JOIN shirt s  
ON s.owner = p.id  
WHERE p.name LIKE 'Lilliana%'  
AND s.color <> 'white';  
+----+-------+--------+-------+  
| id | style | color  | owner |  
+----+-------+--------+-------+  
| 255 |------|-------|-------|  
```
When used in this fashion, the `REFERENCES` clause is not displayed in the output of `SHOW CREATE TABLE` or `DESCRIBE`:

```
SHOW CREATE TABLE shirt\G
*************************** 1. row ***************************
Table: shirt
Create Table: CREATE TABLE `shirt` (  
`id` smallint(5) unsigned NOT NULL auto_increment,  
`style` enum('t-shirt','polo','dress') NOT NULL,  
`color` enum('red','blue','orange','white','black') NOT NULL,  
`owner` smallint(5) unsigned NOT NULL,  
PRIMARY KEY (`id`)  
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

The use of `REFERENCES` in this way as a comment or “reminder” in a column definition works with MyISAM tables.

### 3.6.7 Searching on Two Keys

An `OR` using a single key is well optimized, as is the handling of `AND`.

The one tricky case is that of searching on two different keys combined with `OR`:

```
SELECT field1_index, field2_index FROM test_table  
WHERE field1_index = '1' OR field2_index = '1'
```

This case is optimized. See Section 8.2.1.3, “Index Merge Optimization”.

You can also solve the problem efficiently by using a `UNION` that combines the output of two separate `SELECT` statements. See Section 13.2.9.3, “UNION Clause”.

Each `SELECT` searches only one key and can be optimized:

```
SELECT field1_index, field2_index  
FROM test_table WHERE field1_index = '1'  
UNION  
SELECT field1_index, field2_index  
FROM test_table WHERE field2_index = '1';
```

### 3.6.8 Calculating Visits Per Day

The following example shows how you can use the bit group functions to calculate the number of days per month a user has visited a Web page.

```
CREATE TABLE t1 (year YEAR, month INT UNSIGNED,  
day INT UNSIGNED);  
INSERT INTO t1 VALUES(2000,1,1),(2000,1,20),(2000,1,30),(2000,2,2),  
(2000,2,23),(2000,2,23);  
```

The example table contains year-month-day values representing visits by users to the page. To determine how many different days in each month these visits occur, use this query:

```
SELECT year,month,BIT_COUNT(BIT_OR(1<<day)) AS days FROM t1  
GROUP BY year,month;
```

Which returns:
Using AUTO_INCREMENT

The query calculates how many different days appear in the table for each year/month combination, with automatic removal of duplicate entries.

### 3.6.9 Using AUTO_INCREMENT

The **AUTO_INCREMENT** attribute can be used to generate a unique identity for new rows:

```sql
CREATE TABLE animals (  
    id MEDIUMINT NOT NULL AUTO_INCREMENT,  
    name CHAR(30) NOT NULL,  
    PRIMARY KEY (id)  
);  
INSERT INTO animals (name) VALUES  
('dog'),('cat'),('penguin'),  
('lax'),('whale'),('ostrich');  
SELECT * FROM animals;
```

Which returns:

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dog</td>
</tr>
<tr>
<td>2</td>
<td>cat</td>
</tr>
<tr>
<td>3</td>
<td>penguin</td>
</tr>
<tr>
<td>4</td>
<td>lax</td>
</tr>
<tr>
<td>5</td>
<td>whale</td>
</tr>
<tr>
<td>6</td>
<td>ostrich</td>
</tr>
</tbody>
</table>

No value was specified for the **AUTO_INCREMENT** column, so MySQL assigned sequence numbers automatically. You can also explicitly assign 0 to the column to generate sequence numbers, unless the **NO_AUTO_VALUE_ON_ZERO** SQL mode is enabled. For example:

```sql
INSERT INTO animals (id,name) VALUES(0,'groundhog');
```

If the column is declared **NOT NULL**, it is also possible to assign **NULL** to the column to generate sequence numbers. For example:

```sql
INSERT INTO animals (id,name) VALUES(NULL,'squirrel');
```

When you insert any other value into an **AUTO_INCREMENT** column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the largest column value. For example:

```sql
INSERT INTO animals (id,name) VALUES(100,'rabbit');  
INSERT INTO animals (id,name) VALUES(NULL,'mouse');  
SELECT * FROM animals;
```

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dog</td>
</tr>
<tr>
<td>2</td>
<td>cat</td>
</tr>
<tr>
<td>3</td>
<td>penguin</td>
</tr>
<tr>
<td>4</td>
<td>lax</td>
</tr>
</tbody>
</table>
Using AUTO_INCREMENT

|   5 | whale     |
|   6 | ostrich   |
|   7 | groundhog |
|   8 | squirrel  |
| 100 | rabbit    |
| 101 | mouse     |

Updating an existing AUTO_INCREMENT column value in an InnoDB table does not reset the AUTO_INCREMENT sequence as it does for MyISAM and NDB tables.

You can retrieve the most recent automatically generated AUTO_INCREMENT value with the LAST_INSERT_ID() SQL function or the mysql_insert_id() C API function. These functions are connection-specific, so their return values are not affected by another connection which is also performing inserts.

Use the smallest integer data type for the AUTO_INCREMENT column that is large enough to hold the maximum sequence value you will need. When the column reaches the upper limit of the data type, the next attempt to generate a sequence number fails. Use the UNSIGNED attribute if possible to allow a greater range. For example, if you use TINYINT, the maximum permissible sequence number is 127. For TINYINT UNSIGNED, the maximum is 255. See Section 11.1.2, "Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT" for the ranges of all the integer types.

Note

For a multiple-row insert, LAST_INSERT_ID() and mysql_insert_id() actually return the AUTO_INCREMENT key from the first of the inserted rows. This enables multiple-row inserts to be reproduced correctly on other servers in a replication setup.

To start with an AUTO_INCREMENT value other than 1, set that value with CREATE TABLE or ALTER TABLE, like this:

```sql
mysql> ALTER TABLE tbl AUTO_INCREMENT = 100;
```

InnoDB Notes

For information about AUTO_INCREMENT usage specific to InnoDB, see Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”.

MyISAM Notes

- For MyISAM tables, you can specify AUTO_INCREMENT on a secondary column in a multiple-column index. In this case, the generated value for the AUTO_INCREMENT column is calculated as MAX(auto_increment_column) + 1 WHERE prefix=given-prefix. This is useful when you want to put data into ordered groups.

```sql
CREATE TABLE animals (  
grp ENUM('fish', 'mammal', 'bird') NOT NULL,  
id MEDIUMINT NOT NULL AUTO_INCREMENT,  
name CHAR(30) NOT NULL,  
PRIMARY KEY (grp, id)  
) ENGINE=MyISAM;

INSERT INTO animals (grp, name) VALUES  
('mammal', 'dog'), ('mammal', 'cat'),  
('bird', 'penguin'), ('fish', 'lax'), ('mammal', 'whale'),  
('bird', 'ostrich');

SELECT * FROM animals ORDER BY grp, id;
```
Which returns:

<table>
<thead>
<tr>
<th>grp</th>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>fish</td>
<td>1</td>
<td>lax</td>
</tr>
<tr>
<td>mammal</td>
<td>1</td>
<td>dog</td>
</tr>
<tr>
<td>mammal</td>
<td>2</td>
<td>cat</td>
</tr>
<tr>
<td>mammal</td>
<td>3</td>
<td>whale</td>
</tr>
<tr>
<td>bird</td>
<td>1</td>
<td>penguin</td>
</tr>
<tr>
<td>bird</td>
<td>2</td>
<td>ostrich</td>
</tr>
</tbody>
</table>

In this case (when the AUTO_INCREMENT column is part of a multiple-column index), AUTO_INCREMENT values are reused if you delete the row with the biggest AUTO_INCREMENT value in any group. This happens even for MyISAM tables, for which AUTO_INCREMENT values normally are not reused.

- If the AUTO_INCREMENT column is part of multiple indexes, MySQL generates sequence values using the index that begins with the AUTO_INCREMENT column, if there is one. For example, if the animals table contained indexes PRIMARY KEY (grp, id) and INDEX (id), MySQL would ignore the PRIMARY KEY for generating sequence values. As a result, the table would contain a single sequence, not a sequence per grp value.

Further Reading

More information about AUTO_INCREMENT is available here:

- How to assign the AUTO_INCREMENT attribute to a column: Section 13.1.17, “CREATE TABLE Statement”, and Section 13.1.7, “ALTER TABLE Statement”.

- How AUTO_INCREMENT behaves depending on the NO_AUTO_VALUE_ON_ZERO SQL mode: Section 5.1.10, “Server SQL Modes”.

- How to use the LAST_INSERT_ID() function to find the row that contains the most recent AUTO_INCREMENT value: Section 12.15, “Information Functions”.

- Setting the AUTO_INCREMENT value to be used: Section 5.1.7, “Server System Variables”.

- Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”

- AUTO_INCREMENT and replication: Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- Server-system variables related to AUTO_INCREMENT (auto_increment_increment and auto_increment_offset) that can be used for replication: Section 5.1.7, “Server System Variables”.

3.7 Using MySQL with Apache

There are programs that let you authenticate your users from a MySQL database and also let you write your log files into a MySQL table.

You can change the Apache logging format to be easily readable by MySQL by putting the following into the Apache configuration file:

```
LogFormat "\%h\",\%{Y%m%d%H%M%S}t,\%s,\%b",\%{Content-Type}o",  \
\%U",\%{Referer}i",\%{User-Agent}i""
```

To load a log file in that format into MySQL, you can use a statement something like this:
LOAD DATA INFILE '/local/access_log' INTO TABLE tbl_name
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"' ESCAPED BY '\\'

The named table should be created to have columns that correspond to those that the LogFormat line writes to the log file.
Chapter 4 MySQL Programs

Table of Contents

4.1 Overview of MySQL Programs ............................................................................................................. 262
4.2 Using MySQL Programs ......................................................................................................................... 266
  4.2.1 Invoking MySQL Programs ............................................................................................................. 266
  4.2.2 Specifying Program Options ......................................................................................................... 267
  4.2.3 Command Options for Connecting to the Server ............................................................................. 280
  4.2.4 Connecting to the MySQL Server Using Command Options ......................................................... 285
  4.2.5 Connection Compression Control .................................................................................................. 288
  4.2.6 Setting Environment Variables ..................................................................................................... 288
4.3 Server and Server-Startup Programs ..................................................................................................... 289
  4.3.1 mysqld — The MySQL Server ....................................................................................................... 289
  4.3.2 mysqld_safe — MySQL Server Startup Script ............................................................................. 290
  4.3.3 mysql.server — MySQL Server Startup Script ........................................................................... 295
  4.3.4 mysqld_multi — Manage Multiple MySQL Servers ...................................................................... 297
4.4 Installation-Related Programs .............................................................................................................. 301
  4.4.1 comp_err — Compile MySQL Error Message File ........................................................................... 301
  4.4.2 mysqlbug — Generate Bug Report .................................................................................................. 302
  4.4.3 mysql_install_db — Initialize MySQL Data Directory .................................................................. 303
  4.4.4 mysql_plugin — Configure MySQL Server Plugins ...................................................................... 305
  4.4.5 mysql_secure_installation — Improve MySQL Installation Security ........................................ 307
  4.4.6 mysql_tzinfo_to_sql — Load the Time Zone Tables .................................................................... 308
  4.4.7 mysql_upgrade — Check and Upgrade MySQL Tables ................................................................. 308
4.5 Client Programs .................................................................................................................................. 314
  4.5.1 mysql — The MySQL Command-Line Client .................................................................................. 314
  4.5.2 mysqladmin — Client for Administering a MySQL Server ............................................................ 337
  4.5.3 mysqlcheck — A Table Maintenance Program ............................................................................ 345
  4.5.4 mysqldump — A Database Backup Program ............................................................................... 353
  4.5.5 mysqlimport — A Data Import Program ...................................................................................... 372
  4.5.6 mysqlshow — Display Database, Table, and Column Information ............................................. 378
  4.5.7 mysqldumpslow — Load Emulation Client .................................................................................... 383
4.6 Administrative and Utility Programs ................................................................................................... 391
  4.6.1 innochecksum — Offline InnoDB File Checksum Utility ............................................................... 391
  4.6.2 myisam_ftdump — Display Full-Text Index information ............................................................... 392
  4.6.3 myisamchk — MyISAM Table-Maintenance Utility ....................................................................... 393
  4.6.4 myisamlog — Display MyISAM Log File Contents ........................................................................ 410
  4.6.5 myisampack — Generate Compressed, Read-Only MyISAM Tables ........................................... 411
  4.6.6 mysqlaccess — Client for Checking Access Privileges ................................................................ 417
  4.6.7 mysqlbinlog — Utility for Processing Binary Log Files .............................................................. 420
  4.6.8 mysqldumpslow — Summarize Slow Query Log Files ................................................................. 434
  4.6.9 mysqlhotcopy — A Database Backup Program ......................................................................... 436
  4.6.10 mysql_convert_table_format — Convert Tables to Use a Given Storage Engine ..................... 439
  4.6.11 mysql_find_rows — Extract SQL Statements from Files ............................................................ 440
  4.6.12 mysql_fix_extensions — Normalize Table File Name Extensions .............................................. 441
  4.6.13 mysql_setpermission — Interactively Set Permissions in Grant Tables .................................... 441
  4.6.14 mysql_waitpid — Kill Process and Wait for Its Termination ...................................................... 442
  4.6.15 mysql_zap — Kill Processes That Match a Pattern ...................................................................... 442
4.7 Program Development Utilities ......................................................................................................... 443
  4.7.1 msq12mysql — Convert mSQL Programs for Use with MySQL .................................................... 443
  4.7.2 mysql_config — Display Options for Compiling Clients ............................................................. 443
This chapter provides a brief overview of the MySQL command-line programs provided by Oracle Corporation. It also discusses the general syntax for specifying options when you run these programs. Most programs have options that are specific to their own operation, but the option syntax is similar for all of them. Finally, the chapter provides more detailed descriptions of individual programs, including which options they recognize.

4.1 Overview of MySQL Programs

There are many different programs in a MySQL installation. This section provides a brief overview of them. Later sections provide a more detailed description of each one, with the exception of NDB Cluster programs. Each program's description indicates its invocation syntax and the options that it supports. Chapter 18, MySQL NDB Cluster 7.2, describes programs specific to NDB Cluster.

Most MySQL distributions include all of these programs, except for those programs that are platform-specific. (For example, the server startup scripts are not used on Windows.) The exception is that RPM distributions are more specialized. There is one RPM for the server, another for client programs, and so forth. If you appear to be missing one or more programs, see Chapter 2, Installing and Upgrading MySQL, for information on types of distributions and what they contain. It may be that you have a distribution that does not include all programs and you need to install an additional package.

Each MySQL program takes many different options. Most programs provide a --help option that you can use to get a description of the program's different options. For example, try mysql --help.

You can override default option values for MySQL programs by specifying options on the command line or in an option file. See Section 4.2, "Using MySQL Programs", for general information on invoking programs and specifying program options.

The MySQL server, mysqld, is the main program that does most of the work in a MySQL installation. The server is accompanied by several related scripts that assist you in starting and stopping the server:

- mysqld
  
  The SQL daemon (that is, the MySQL server). To use client programs, mysqld must be running, because clients gain access to databases by connecting to the server. See Section 4.3.1, "mysqld — The MySQL Server".

- mysqld_safe
  
  A server startup script. mysqld_safe attempts to start mysqld. See Section 4.3.2, "mysqld_safe — MySQL Server Startup Script".

- mysql.server
  
  A server startup script. This script is used on systems that use System V-style run directories containing scripts that start system services for particular run levels. It invokes mysqld_safe to start the MySQL server. See Section 4.3.3, "mysql.server — MySQL Server Startup Script".

- mysqld_multi
Overview of MySQL Programs

A server startup script that can start or stop multiple servers installed on the system. See Section 4.3.4, "mysqld_multi — Manage Multiple MySQL Servers".

Several programs perform setup operations during MySQL installation or upgrading:

- **comp_err**
  This program is used during the MySQL build/installation process. It compiles error message files from the error source files. See Section 4.4.1, "comp_err — Compile MySQL Error Message File".

- **mysql_install_db**
  This program initializes the MySQL data directory, creates the mysql database, and initializes its grant tables with default privileges. It is usually executed only once, when first installing MySQL on a system. See Section 4.4.3, "mysql_install_db — Initialize MySQL Data Directory", and Section 2.10, "Postinstallation Setup and Testing".

- **mysql_plugin**
  This program configures MySQL server plugins. See Section 4.4.4, "mysql_plugin — Configure MySQL Server Plugins".

- **mysql_secure_installation**
  This program enables you to improve the security of your MySQL installation. See Section 4.4.5, "mysql_secure_installation — Improve MySQL Installation Security".

- **mysql_tzinfo_to_sql**
  This program loads the time zone tables in the mysql database using the contents of the host system zoneinfo database (the set of files describing time zones). See Section 4.4.6, "mysql_tzinfo_to_sql — Load the Time Zone Tables".

- **mysql_upgrade**
  This program is used after a MySQL upgrade operation. It updates the grant tables with any changes that have been made in newer versions of MySQL, and checks tables for incompatibilities and repairs them if necessary. See Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables".

MySQL client programs that connect to the MySQL server:

- **mysql**
  The command-line tool for interactively entering SQL statements or executing them from a file in batch mode. See Section 4.5.1, "mysql — The MySQL Command-Line Client".

- **mysqladmin**
  A client that performs administrative operations, such as creating or dropping databases, reloading the grant tables, flushing tables to disk, and reopening log files. mysqladmin can also be used to retrieve version, process, and status information from the server. See Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server".

- **mysqlcheck**
  A table-maintenance client that checks, repairs, analyzes, and optimizes tables. See Section 4.5.3, "mysqlcheck — A Table Maintenance Program".
Overview of MySQL Programs

• **mysqldump**

A client that dumps a MySQL database into a file as SQL, text, or XML. See Section 4.5.4, “mysqldump — A Database Backup Program”.

• **mysqlimport**

A client that imports text files into their respective tables using `LOAD DATA`. See Section 4.5.5, “mysqlimport — A Data Import Program”.

• **mysqlshow**

A client that displays information about databases, tables, columns, and indexes. See Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”.

• **mysqlslap**

A client that is designed to emulate client load for a MySQL server and report the timing of each stage. It works as if multiple clients are accessing the server. See Section 4.5.7, “mysqlslap — Load Emulation Client”.

MySQL administrative and utility programs:

• **innochecksum**

An offline InnoDB offline file checksum utility. See Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”.

• **myisam_ftdump**

A utility that displays information about full-text indexes in MyISAM tables. See Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”.

• **myisamchk**

A utility to describe, check, optimize, and repair MyISAM tables. See Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

• **myisamlog**

A utility that processes the contents of a MyISAM log file. See Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”.

• **myisampack**

A utility that compresses MyISAM tables to produce smaller read-only tables. See Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”.

• **mysqlaccess**

A script that checks the access privileges for a host name, user name, and database combination. See Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”.

• **mysqlbinlog**

A utility for reading statements from a binary log. The log of executed statements contained in the binary log files can be used to help recover from a crash. See Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”.

264
Overview of MySQL Programs

- **mysqldumpslow**
  A utility to read and summarize the contents of a slow query log. See Section 4.6.8, "mysqldumpslow — Summarize Slow Query Log Files".

- **mysqlhotcopy**
  A utility that quickly makes backups of MyISAM tables while the server is running. See Section 4.6.9, "mysqlhotcopy — A Database Backup Program".

- **mysql_convert_table_format**
  A utility that converts tables in a database to use a given storage engine. See Section 4.6.10, "mysql_convert_table_format — Convert Tables to Use a Given Storage Engine".

- **mysql_find_rows**
  A utility that reads files containing SQL statements (such as update logs) and extracts statements that match a given regular expression. See Section 4.6.11, "mysql_find_rows — Extract SQL Statements from Files".

- **mysql_fix_extensions**
  A utility that converts the extensions for MyISAM table files to lowercase. This can be useful after transferring the files from a system with case-insensitive file names to a system with case-sensitive file names. See Section 4.6.12, "mysql_fix_extensions — Normalize Table File Name Extensions".

- **mysql_setpermission**
  A utility for interactively setting permissions in the MySQL grant tables. See Section 4.6.13, "mysql_setpermission — Interactively Set Permissions in Grant Tables".

- **mysql_waitpid**
  A utility that kills the process with a given process ID. See Section 4.6.14, "mysql_waitpid — Kill Process and Wait for Its Termination".

- **mysql_zap**
  A utility that kills processes that match a pattern. See Section 4.6.15, "mysql_zap — Kill Processes That Match a Pattern".

MySQL program-development utilities:

- **msql2mysql**
  A shell script that converts mSQL programs to MySQL. It doesn't handle every case, but it gives a good start when converting. See Section 4.7.1, "msql2mysql — Convert mSQL Programs for Use with MySQL".

- **mysql_config**
  A shell script that produces the option values needed when compiling MySQL programs. See Section 4.7.2, "mysql_config — Display Options for Compiling Clients".

- **my_print_defaults**
  A utility that shows which options are present in option groups of option files. See Section 4.7.3, "my_print_defaults — Display Options from Option Files".
Using MySQL Programs

- **resolve_stack_dump**
  A utility program that resolves a numeric stack trace dump to symbols. See Section 4.7.4, "resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols".

Miscellaneous utilities:

- **perror**
  A utility that displays the meaning of system or MySQL error codes. See Section 4.8.1, "perror — Display MySQL Error Message Information".

- **replace**
  A utility program that performs string replacement in the input text. See Section 4.8.2, "replace — A String-Replacement Utility".

- **resolveip**
  A utility program that resolves a host name to an IP address or vice versa. See Section 4.8.3, "resolveip — Resolve Host name to IP Address or Vice Versa".

Oracle Corporation also provides the MySQL Workbench GUI tool, which is used to administer MySQL servers and databases, to create, execute, and evaluate queries, and to migrate schemas and data from other relational database management systems for use with MySQL. Additional GUI tools include MySQL Notifier MySQL for Excel.

MySQL client programs that communicate with the server using the MySQL client/server library use the following environment variables.

<table>
<thead>
<tr>
<th>Environment Variable</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYSQL_UNIX_PORT</td>
<td>The default Unix socket file; used for connections to <code>localhost</code></td>
</tr>
<tr>
<td>MYSQL_TCP_PORT</td>
<td>The default port number; used for TCP/IP connections</td>
</tr>
<tr>
<td>MYSQL_PWD</td>
<td>The default password</td>
</tr>
<tr>
<td>MYSQL_DEBUG</td>
<td>Debug trace options when debugging</td>
</tr>
<tr>
<td>TMPDIR</td>
<td>The directory where temporary tables and files are created</td>
</tr>
</tbody>
</table>

For a full list of environment variables used by MySQL programs, see Section 4.9, "Environment Variables".

Use of `MYSQL_PWD` is insecure. See Section 4.9.1, "End-User Guidelines for Password Security".

### 4.2 Using MySQL Programs

#### 4.2.1 Invoking MySQL Programs

To invoke a MySQL program from the command line (that is, from your shell or command prompt), enter the program name followed by any options or other arguments needed to instruct the program what you want it to do. The following commands show some sample program invocations. `shell>` represents the prompt for your command interpreter; it is not part of what you type. The particular prompt you see depends on your command interpreter. Typical prompts are `$` for `sh`, `ksh`, or `bash`, `%` for `csh` or `tcsh`, and `C:\>` for the Windows `command.com` or `cmd.exe` command interpreters.

`shell> mysql --user=root test`
Specifying Program Options

Arguments that begin with a single or double dash (–, --) specify program options. Options typically indicate the type of connection a program should make to the server or affect its operational mode. Option syntax is described in Section 4.2.2, “Specifying Program Options”.

Nonoption arguments (arguments with no leading dash) provide additional information to the program. For example, the mysql program interprets the first nonoption argument as a database name, so the command `mysql --user=root test` indicates that you want to use the `test` database.

Later sections that describe individual programs indicate which options a program supports and describe the meaning of any additional nonoption arguments.

Some options are common to a number of programs. The most frequently used of these are the `--host` (or `-h`), `--user` (or `-u`), and `--password` (or `-p`) options that specify connection parameters. They indicate the host where the MySQL server is running, and the user name and password of your MySQL account. All MySQL client programs understand these options; they enable you to specify which server to connect to and the account to use on that server. Other connection options are `--port` (or `-P`) to specify a TCP/IP port number and `--socket` (or `-S`) to specify a Unix socket file on Unix (or named-pipe name on Windows). For more information on options that specify connection options, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

You may find it necessary to invoke MySQL programs using the path name to the `bin` directory in which they are installed. This is likely to be the case if you get a “program not found” error whenever you attempt to run a MySQL program from any directory other than the `bin` directory. To make it more convenient to use MySQL, you can add the path name of the `bin` directory to your `PATH` environment variable setting. That enables you to run a program by typing only its name, not its entire path name. For example, if `mysql` is installed in `/usr/local/mysql/bin`, you can run the program by invoking it as `mysql`, and it is not necessary to invoke it as `/usr/local/mysql/bin/mysql`.

Consult the documentation for your command interpreter for instructions on setting your `PATH` variable. The syntax for setting environment variables is interpreter-specific. (Some information is given in Section 4.2.6, “Setting Environment Variables”.) After modifying your `PATH` setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

### 4.2.2 Specifying Program Options

There are several ways to specify options for MySQL programs:

- List the options on the command line following the program name. This is common for options that apply to a specific invocation of the program.

- List the options in an option file that the program reads when it starts. This is common for options that you want the program to use each time it runs.

- List the options in environment variables (see Section 4.2.6, “Setting Environment Variables”). This method is useful for options that you want to apply each time the program runs. In practice, option files are used more commonly for this purpose, but Section 5.7.3, “Running Multiple MySQL Instances on Unix”, discusses one situation in which environment variables can be very helpful. It describes a handy technique that uses such variables to specify the TCP/IP port number and Unix socket file for the server and for client programs.

Options are processed in order, so if an option is specified multiple times, the last occurrence takes precedence. The following command causes `mysql` to connect to the server running on `localhost`:
Specifying Program Options

mysql -h example.com -h localhost

There is one exception: For mysqld, the first instance of the --user option is used as a security precaution, to prevent a user specified in an option file from being overridden on the command line.

If conflicting or related options are given, later options take precedence over earlier options. The following command runs mysql in "no column names" mode:

```
mysql --column-names --skip-column-names
```

MySQL programs determine which options are given first by examining environment variables, then by processing option files, and then by checking the command line. Because later options take precedence over earlier ones, the processing order means that environment variables have the lowest precedence and command-line options the highest.

You can take advantage of the way that MySQL programs process options by specifying default option values for a program in an option file. That enables you to avoid typing them each time you run the program while enabling you to override the defaults if necessary by using command-line options.

An option can be specified by writing it in full or as any unambiguous prefix. For example, the --compress option can be given to mysqldump as --compr, but not as --comp because the latter is ambiguous:

```
shell> mysqldump --comp
mysqldump: ambiguous option '--comp' (compatible, compress)
```

Be aware that the use of option prefixes can cause problems in the event that new options are implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

**Note**

As of MySQL 5.5.33, unambiguous prefixes are deprecated. If an unambiguous prefix is given, a warning occurs to provide feedback. Option prefixes are no longer supported as of MySQL 5.7; only full options are accepted.

4.2.2.1 Using Options on the Command Line

Program options specified on the command line follow these rules:

- Options are given after the command name.
- An option argument begins with one dash or two dashes, depending on whether it is a short form or long form of the option name. Many options have both short and long forms. For example, -? and --help are the short and long forms of the option that instructs a MySQL program to display its help message.
- Option names are case-sensitive. -v and --verbose are both legal and have different meanings. (They are the corresponding short forms of the --verbose and --version options.)
- Some options take a value following the option name. For example, -h localhost or --host=localhost indicate the MySQL server host to a client program. The option value tells the program the name of the host where the MySQL server is running.
- For a long option that takes a value, separate the option name and the value by an = sign. For a short option that takes a value, the option value can immediately follow the option letter, or there can be a space between: -h localhost and -h localhost are equivalent. An exception to this rule is the option for specifying your MySQL password. This option can be given in long form as --password=pass_val or as --password. In the latter case (with no password value given), the
program interactively prompts you for the password. The password option also may be given in short form as `-p pass_val` or as `-p`. However, for the short form, if the password value is given, it must follow the option letter with *no intervening space*: If a space follows the option letter, the program has no way to tell whether a following argument is supposed to be the password value or some other kind of argument. Consequently, the following two commands have two completely different meanings:

```
mysql -ptest
mysql -p test
```

The first command instructs `mysql` to use a password value of `test`, but specifies no default database. The second instructs `mysql` to prompt for the password value and to use `test` as the default database.

- Within option names, dash (`-`) and underscore (`_`) may be used interchangeably. For example, `--skip-grant-tables` and `--skip_grant_tables` are equivalent. (However, the leading dashes cannot be given as underscores.)

- The MySQL server has certain command options that may be specified only at startup, and a set of system variables, some of which may be set at startup, at runtime, or both. System variable names use underscores rather than dashes, and when referenced at runtime (for example, using `SET` or `SELECT` statements), must be written using underscores:

  ```
  SET GLOBAL general_log = ON;
  SELECT @@GLOBAL.general_log;
  ```

  At server startup, the syntax for system variables is the same as for command options, so within variable names, dashes and underscores may be used interchangeably. For example, `--general_log=ON` and `--general-log=ON` are equivalent. (This is also true for system variables set within option files.)

- For options that take a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, $1024^2$ or $1024^3$. For example, the following command tells `mysqladmin` to ping the server 1024 times, sleeping 10 seconds between each ping:

  ```
  mysqladmin --count=1K --sleep=10 ping
  ```

- When specifying file names as option values, avoid the use of the ~ shell metacharacter. It might not be interpreted as you expect.

Option values that contain spaces must be quoted when given on the command line. For example, the `--execute` (or `-e`) option can be used with `mysql` to pass one or more semicolon-separated SQL statements to the server. When this option is used, `mysql` executes the statements in the option value and exits. The statements must be enclosed by quotation marks. For example:

```
shell> mysql -u root -p -e "SELECT VERSION();SELECT NOW();"
Enter password: ******
+------------+
<table>
<thead>
<tr>
<th>VERSION()</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.67</td>
</tr>
</tbody>
</table>
+------------+
+---------------------+
| NOW()               |
+---------------------+
| 2019-09-03 10:35:27 |
+---------------------+
shell>
```

**Note**

The long form (`--execute`) is followed by an equal sign (`=`).
To use quoted values within a statement, you must either escape the inner quotation marks, or use a
different type of quotation marks within the statement from those used to quote the statement itself. The
capabilities of your command processor dictate your choices for whether you can use single or double
quotation marks and the syntax for escaping quote characters. For example, if your command processor
supports quoting with single or double quotation marks, you can use double quotation marks around the
statement, and single quotation marks for any quoted values within the statement.

4.2.2.2 Using Option Files

Most MySQL programs can read startup options from option files (sometimes called configuration files).
Option files provide a convenient way to specify commonly used options so that they need not be entered
on the command line each time you run a program. For the MySQL server, MySQL provides a number of
preconfigured option files.

To determine whether a program reads option files, invoke it with the \texttt{--help} option. (For \texttt{mysqld}, use \texttt{--
verbose} and \texttt{--help}.) If the program reads option files, the help message indicates which files it looks for
and which option groups it recognizes.

\begin{itemize}
  \item \textbf{Note} A MySQL program started with the \texttt{--no-defaults} option reads no option files.
\end{itemize}

Option files are plain text files, created using any text editor.

MySQL looks for option files in the order described in the following discussion and reads any that exist. If
an option file you want to use does not exist, create it with a plain text editor.

\begin{itemize}
  \item \textbf{Note} For information about option files used with NDB Cluster programs, see
     \textbf{Section 18.3, “Configuration of NDB Cluster”}.
\end{itemize}

On Windows, MySQL programs read startup options from the files shown in the following table, in the
specified order (files listed first are read first, files read later take precedence).

\begin{table}[h]
\begin{center}
\begin{tabular}{|l|l|}
\hline
File Name & Purpose \\
\hline
\texttt{\%WINDIR\%\my.ini, \%WINDIR \%\my.cnf} & Global options \\
\hline
\texttt{C:\my.ini, C:\my.cnf} & Global options \\
\texttt{BASEDIR\my.ini, BASEDIR\my.cnf} & Global options \\
\texttt{defaults-extra-file} & The file specified with \texttt{--defaults-extra-file}, if any \\
\hline
\end{tabular}
\end{center}
\end{table}

In the preceding table, \texttt{\%WINDIR\%} represents the location of your Windows directory. This is commonly
\texttt{C:\WINDOWS}. Use the following command to determine its exact location from the value of the \texttt{WINDIR}
environment variable:

\begin{verbatim}
C:\> echo \%WINDIR\%
\end{verbatim}

\begin{itemize}
  \item \textbf{Option File Processing Order}
  \item \textbf{Option File Syntax}
\end{itemize}
Specifying Program Options

• Option File Inclusions

Option File Processing Order

%APPDATA% represents the value of the Windows application data directory. Use the following command to determine its exact location from the value of the APPDATA environment variable:

```
C:\> echo %APPDATA%
```

BASEDIR represents the MySQL base installation directory. When MySQL 5.5 has been installed using MySQL Installer, this is typically C:\PROGRAMDIR\MySQL\MySQL 5.5 Server where PROGRAMDIR represents the programs directory (usually Program Files on English-language versions of Windows), See Section 2.3.3, “MySQL Installer for Windows”.

On Unix and Unix-like systems, MySQL programs read startup options from the files shown in the following table, in the specified order (files listed first are read first, files read later take precedence).

Note

On Unix platforms, MySQL ignores configuration files that are world-writable. This is intentional as a security measure.

Table 4.2 Option Files Read on Unix and Unix-Like Systems

<table>
<thead>
<tr>
<th>File Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/my.cnf</td>
<td>Global options</td>
</tr>
<tr>
<td>/etc/mysql/my.cnf</td>
<td>Global options</td>
</tr>
<tr>
<td>SYSCONFDIR/my.cnf</td>
<td>Global options</td>
</tr>
<tr>
<td>$MYSQL_HOME/my.cnf</td>
<td>Server-specific options (server only)</td>
</tr>
<tr>
<td>defaults-extra-file</td>
<td>The file specified with --defaults-extra-file, if any</td>
</tr>
<tr>
<td>~/my.cnf</td>
<td>User-specific options</td>
</tr>
</tbody>
</table>

In the preceding table, ~ represents the current user's home directory (the value of $HOME).

SYSCONFDIR represents the directory specified with the SYSCONFDIR option to CMake when MySQL was built. By default, this is the etc directory located under the compiled-in installation directory.

MYSQL_HOME is an environment variable containing the path to the directory in which the server-specific my.cnf file resides. If MYSQL_HOME is not set and you start the server using the mysqld_safe program, mysqld_safe attempts to set MYSQL_HOME as follows:

• Let BASEDIR and DATADIR represent the path names of the MySQL base directory and data directory, respectively.

• If there is a my.cnf file in DATADIR but not in BASEDIR, mysqld_safe sets MYSQL_HOME to DATADIR.

• Otherwise, if MYSQL_HOME is not set and there is no my.cnf file in DATADIR, mysqld_safe sets MYSQL_HOME to BASEDIR.

In MySQL 5.5, use of DATADIR as the location for my.cnf is deprecated.

DATADIR is commonly /usr/local/mysql/data, although this can vary per platform or installation method. The value is the data directory location built in when MySQL was compiled, not the location specified with the --datadir option when mysqld starts. Use of --datadir at runtime has no effect on where the server looks for option files that it reads before processing any options.
If multiple instances of a given option are found, the last instance takes precedence, with one exception: For `mysqld`, the first instance of the `--user` option is used as a security precaution, to prevent a user specified in an option file from being overridden on the command line.

**Option File Syntax**

The following description of option file syntax applies to files that you edit manually. This excludes `.mylogin.cnf`, which is created using `mysql_config_editor` and is encrypted.

Any long option that may be given on the command line when running a MySQL program can be given in an option file as well. To get the list of available options for a program, run it with the `--help` option. (For `mysqld`, use `--verbose` and `--help`.)

The syntax for specifying options in an option file is similar to command-line syntax (see Section 4.2.2.1, “Using Options on the Command Line”). However, in an option file, you omit the leading two dashes from the option name and you specify only one option per line. For example, `--quick` and `--host=localhost` on the command line should be specified as `quick` and `host=localhost` on separate lines in an option file. To specify an option of the form `--loose-opt_name` in an option file, write it as `loose-opt_name`.

Empty lines in option files are ignored. Nonempty lines can take any of the following forms:

- `#comment, ;comment`
  
  Comment lines start with `#` or `;`. A `#` comment can start in the middle of a line as well.

- `[group]`

  `group` is the name of the program or group for which you want to set options. After a group line, any option-setting lines apply to the named group until the end of the option file or another group line is given. Option group names are not case-sensitive.

- `opt_name`

  This is equivalent to `--opt_name` on the command line.

- `opt_name=value`

  This is equivalent to `--opt_name=value` on the command line. In an option file, you can have spaces around the `=` character, something that is not true on the command line. The value optionally can be enclosed within single quotation marks or double quotation marks, which is useful if the value contains a `#` comment character.

Leading and trailing spaces are automatically deleted from option names and values.

You can use the escape sequences \b, \t, \n, \r, \", and \s in option values to represent the backspace, tab, newline, carriage return, backslash, and space characters. In option files, these escaping rules apply:

- A backslash followed by a valid escape sequence character is converted to the character represented by the sequence. For example, `\s` is converted to a space.

- A backslash not followed by a valid escape sequence character remains unchanged. For example, `\s` is retained as is.

The preceding rules mean that a literal backslash can be given as `\`, or as `\` if it is not followed by a valid escape sequence character.
The rules for escape sequences in option files differ slightly from the rules for escape sequences in string literals in SQL statements. In the latter context, if "x" is not a valid escape sequence character, \x becomes "x" rather than \x. See Section 9.1.1, “String Literals”.

The escaping rules for option file values are especially pertinent for Windows path names, which use \ as a path name separator. A separator in a Windows path name must be written as \ if it is followed by an escape sequence character. It can be written as \ or \ if it is not. Alternatively, / may be used in Windows path names and will be treated as \. Suppose that you want to specify a base directory of C:\Program Files\MySQL\MySQL Server 5.5 in an option file. This can be done several ways. Some examples:

```
basedir="C:\Program Files\MySQL\MySQL Server 5.5"
basedir=C:\\Program Files\\MySQL\\MySQL Server 5.5"
basedir=C:\Program Files\MySQL\MySQL Server 5.5"
basedir=C:\Programs\MySQL\MySQL\sServer\s5.5
```

If an option group name is the same as a program name, options in the group apply specifically to that program. For example, the [mysqld] and [mysql] groups apply to the mysqld server and the mysql client program, respectively.

The [client] option group is read by all client programs provided in MySQL distributions (but not by mysqld). To understand how third-party client programs that use the C API can use option files, see the C API documentation at Section 23.7.6.49, "mysql_options()".

The [client] group enables you to specify options that apply to all clients. For example, [client] is the appropriate group to use to specify the password for connecting to the server. (But make sure that the option file is accessible only by yourself, so that other people cannot discover your password.) Be sure not to put an option in the [client] group unless it is recognized by all client programs that you use. Programs that do not understand the option quit after displaying an error message if you try to run them.

List more general option groups first and more specific groups later. For example, a [client] group is more general because it is read by all client programs, whereas a [mysqldump] group is read only by mysqldump. Options specified later override options specified earlier, so putting the option groups in the order [client], [mysqldump] enables mysqldump-specific options to override [client] options.

Here is a typical global option file:

```
[client]
port=3306
socket=/tmp/mysql.sock

[mysqld]
port=3306
socket=/tmp/mysql.sock
key_buffer_size=16M
max_allowed_packet=8M

[mysqldump]
quick
```

Here is a typical user option file:

```
[client]
# The following password will be sent to all standard MySQL clients
password="my password"

[mysql]
no-auto-rehash
connect_timeout=2

[mysqlhotcopy]
```
Specifying Program Options

**interactive-timeout**

To create option groups to be read only by `mysqld` servers from specific MySQL release series, use groups with names of `[mysqld-5.1]`, `[mysqld-5.5]`, and so forth. The following group indicates that the `sql_mode` setting should be used only by MySQL servers with 5.5.x version numbers:

```
[mysqld-5.5]
sql_mode=TRADITIONAL
```

Option File Inclusions

It is possible to use `!include` directives in option files to include other option files and `!includedir` to search specific directories for option files. For example, to include the `/home/mydir/myopt.cnf` file, use the following directive:

```
!include /home/mydir/myopt.cnf
```

To search the `/home/mydir` directory and read option files found there, use this directive:

```
!includedir /home/mydir
```

MySQL makes no guarantee about the order in which option files in the directory are read.

**Note**

Any files to be found and included using the `!includedir` directive on Unix operating systems must have file names ending in `.cnf`. On Windows, this directive checks for files with the `.ini` or `.cnf` extension.

Write the contents of an included option file like any other option file. That is, it should contain groups of options, each preceded by a `[group]` line that indicates the program to which the options apply.

While an included file is being processed, only those options in groups that the current program is looking for are used. Other groups are ignored. Suppose that a `my.cnf` file contains this line:

```
!include /home/mydir/myopt.cnf
```

And suppose that `/home/mydir/myopt.cnf` looks like this:

```
[mysqldadmin]
force

[mysqld]
key_buffer_size=16M
```

If `my.cnf` is processed by `mysqld`, only the `[mysqld]` group in `/home/mydir/myopt.cnf` is used. If the file is processed by `mysqldadmin`, only the `[mysqldadmin]` group is used. If the file is processed by any other program, no options in `/home/mydir/myopt.cnf` are used.

The `!includedir` directive is processed similarly except that all option files in the named directory are read.

If an option file contains `!include` or `!includedir` directives, files named by those directives are processed whenever the option file is processed, no matter where they appear in the file.

For inclusion directives to work, the file path should not be specified within quotes and should have no escape sequences. For example, the following statements provided in `my.ini` will read the option file `myopts.ini`:

```
!include C:/ProgramData/MySQL/MySQL Server/myopts.ini
!include C:\ProgramData\MySQL\MySQL Server\myopts.ini
!include C:\\ProgramData\\MySQL\\MySQL Server\\myopts.ini
```
On Windows, if `include /path/to/extra.ini` is the last line in the file, make sure that a newline is appended at the end or the line will be ignored.

### 4.2.2.3 Command-Line Options that Affect Option-File Handling

Most MySQL programs that support option files handle the following options. Because these options affect option-file handling, they must be given on the command line and not in an option file. To work properly, each of these options must be given before other options, with these exceptions:

- `--print-defaults` may be used immediately after `--defaults-file` or `--defaults-extra-file`.

- On Windows, if the server is started with the `--defaults-file` and `--install` options, `--install` must be first. See Section 2.3.6.7, “Starting MySQL as a Windows Service”.

When specifying file names as option values, avoid the use of the `~` shell metacharacter because it might not be interpreted as you expect.

- `--defaults-extra-file=file_name`

Read this option file after the global option file but (on Unix) before the user option file. (For information about the order in which option files are used, see Section 4.2.2.2, “Using Option Files.”) If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

See the introduction to this section regarding constraints on the position in which this option may be specified.

- `--defaults-file=file_name`

Read only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

See the introduction to this section regarding constraints on the position in which this option may be specified.

- `--defaults-group-suffix=str`

Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, the `mysql` client normally reads the `[client]` and `[mysql]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql` also reads the `[client_other]` and `[mysql_other]` groups.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--print-defaults`

Print the program name and all options that it gets from option files.

See the introduction to this section regarding constraints on the position in which this option may be specified.

### 4.2.2.4 Program Option Modifiers
Some options are “boolean” and control behavior that can be turned on or off. For example, the `mysql` client supports a `--column-names` option that determines whether or not to display a row of column names at the beginning of query results. By default, this option is enabled. However, you may want to disable it in some instances, such as when sending the output of `mysql` into another program that expects to see only data and not an initial header line.

To disable column names, you can specify the option using any of these forms:

- `--disable-column-names`
- `--skip-column-names`
- `--column-names=0`

The `--disable` and `--skip` prefixes and the `=0` suffix all have the same effect: They turn the option off.

The “enabled” form of the option may be specified in any of these ways:

- `--column-names`
- `--enable-column-names`
- `--column-names=1`

As of MySQL 5.5.10, the values `ON`, `TRUE`, `OFF`, and `FALSE` are also recognized for boolean options (not case-sensitive).

If an option is prefixed by `--loose`, a program does not exit with an error if it does not recognize the option, but instead issues only a warning:

```
shell> mysql --loose-no-such-option
mysql: WARNING: unknown option '--loose-no-such-option'
```

The `--loose` prefix can be useful when you run programs from multiple installations of MySQL on the same machine and list options in an option file. An option that may not be recognized by all versions of a program can be given using the `--loose` prefix (or `loose` in an option file). Versions of the program that recognize the option process it normally, and versions that do not recognize it issue a warning and ignore it.

The `--maximum` prefix is available for `mysqld` only and permits a limit to be placed on how large client programs can set session system variables. To do this, use a `--maximum` prefix with the variable name. For example, `--maximum-max_heap_table_size=32M` prevents any client from making the heap table size limit larger than 32M.

The `--maximum` prefix is intended for use with system variables that have a session value. If applied to a system variable that has only a global value, an error occurs. For example, with `--maximum-back_log=200`, the server produces this error:

```
Maximum value of 'back_log' cannot be set
```

### 4.2.2.5 Using Options to Set Program Variables

Many MySQL programs have internal variables that can be set at runtime using the `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”, and Section 5.1.8, “Using System Variables”.

Most of these program variables also can be set at server startup by using the same syntax that applies to specifying program options. For example, `mysql` has a `max_allowed_packet` variable that controls the maximum size of its communication buffer. To set the `max_allowed_packet` variable for `mysql` to a value of 16MB, use either of the following commands:

```
mysql --max_allowed_packet=16777216
mysql --max_allowed_packet=16M
```

The first command specifies the value in bytes. The second specifies the value in megabytes. For variables that take a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase).
Specifying Program Options

to indicate a multiplier of 1024, \(1024^2\) or \(1024^3\). (For example, when used to set `max_allowed_packet`,
the suffixes indicate units of kilobytes, megabytes, or gigabytes.)

In an option file, variable settings are given without the leading dashes:

```ini
[mysql]
max_allowed_packet=16777216
```

Or:

```ini
[mysql]
max_allowed_packet=16M
```

If you like, underscores in a variable name can be specified as dashes. The following option groups are
equivalent. Both set the size of the server’s key buffer to 512MB:

```ini
[mysqld]
key_buffer_size=512M
```

```ini
[mysqld]
key-buffer-size=512M
```

A variable can be specified by writing it in full or as any unambiguous prefix. For example, the `max_allowed_packet`
variable can be set for `mysql` as `--max_a`, but not as `--max` because the latter
is ambiguous:

```bash
shell> mysql --max=1000000
mysql: ambiguous option '--max=1000000' (max_allowed_packet, max_join_size)
```

Be aware that the use of variable prefixes can cause problems in the event that new variables are
implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

Suffixes for specifying a value multiplier can be used when setting a variable at program invocation time,
but not to set the value with `SET` at runtime. On the other hand, with `SET`, you can assign a variable’s value
using an expression, which is not true when you set a variable at server startup. For example, the first of
the following lines is legal at program invocation time, but the second is not:

```bash
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
```

Conversely, the second of the following lines is legal at runtime, but the first is not:

```bash
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
```

### 4.2.2.6 Option Defaults, Options Expecting Values, and the = Sign

By convention, long forms of options that assign a value are written with an equals (=) sign, like this:

```
mysql --host=tonfisk --user=jon
```

For options that require a value (that is, not having a default value), the equal sign is not required, and so
the following is also valid:

```
mysql --host tonfisk --user jon
```

In both cases, the `mysql` client attempts to connect to a MySQL server running on the host named
“tonfisk” using an account with the user name “jon”.

Due to this behavior, problems can occasionally arise when no value is provided for an option that expects
one. Consider the following example, where a user connects to a MySQL server running on host `tonfisk`
as user `jon`:
Specifying Program Options

shell> mysql --host 85.224.35.45 --user jon
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 3
Server version: 5.5.62 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
+----------------+
| jon@%          |
+----------------+
1 row in set (0.00 sec)

Omitting the required value for one of these option yields an error, such as the one shown here:

shell> mysql --host 85.224.35.45 --user
mysql: option '--user' requires an argument

In this case, mysql was unable to find a value following the --user option because nothing came after it on the command line. However, if you omit the value for an option that is not the last option to be used, you obtain a different error that you may not be expecting:

shell> mysql --host --user jon
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)

Because mysql assumes that any string following --host on the command line is a host name, --host --user is interpreted as --host=--user, and the client attempts to connect to a MySQL server running on a host named "--user".

Options having default values always require an equal sign when assigning a value; failing to do so causes an error. For example, the MySQL server --log-error option has the default value host_name.err, where host_name is the name of the host on which MySQL is running. Assume that you are running MySQL on a computer whose host name is "tonfisk", and consider the following invocation of mysqld_safe:

shell> mysqld_safe &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
shell>

After shutting down the server, restart it as follows:

shell> mysqld_safe --log-error &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
shell>

The result is the same, since --log-error is not followed by anything else on the command line, and it supplies its own default value. (The & character tells the operating system to run MySQL in the background; it is ignored by MySQL itself.) Now suppose that you wish to log errors to a file named my- errors.err. You might try starting the server with --log-error my-errors, but this does not have the intended effect, as shown here:

shell> mysqld_safe --log-error my-errors &
[1] 31357
shell> 080111 22:53:31 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080111 22:53:32 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended
Specifying Program Options

The server attempted to start using `/usr/local/mysql/var/tonfisk.err` as the error log, but then shut down. Examining the last few lines of this file shows the reason:

```shell
shell> tail /usr/local/mysql/var/tonfisk.err
080111 22:53:32  InnoDB: Started; log sequence number 0 46409
080111 22:53:32  InnoDB: Starting shutdown...
080111 22:53:34  InnoDB: Shutdown completed; log sequence number 0 46409
080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended
```

Because the `--log-error` option supplies a default value, you must use an equal sign to assign a different value to it, as shown here:

```shell
shell> mysqld_safe --log-error=my-errors &
[1] 31437
shell> 080111 22:54:15 mysqld_safe Logging to '/usr/local/mysql/var/my-errors.err'.
080111 22:54:15 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
```

Now the server has been started successfully, and is logging errors to the file `/usr/local/mysql/var/my-errors.err`.

Similar issues can arise when specifying option values in option files. For example, consider a `my.cnf` file that contains the following:

```
[mysql]
host
user
```

When the `mysql` client reads this file, these entries are parsed as `--host --user` or `--host=--user`, with the result shown here:

```shell
shell> mysql
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)
```

However, in option files, an equal sign is not assumed. Suppose the `my.cnf` file is as shown here:

```
[mysql]
user=jon
```

Trying to start `mysql` in this case causes a different error:

```shell
shell> mysql
mysql: unknown option '--user jon'
```

A similar error would occur if you were to write `host tonfisk` in the option file rather than `host=tonfisk`. Instead, you must use the equal sign:

```
[mysql]
user=tonfisk
```

Now the login attempt succeeds:

```shell
shell> mysql
```
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 5
Server version: 5.5.62 Source distribution
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
1 row in set (0.00 sec)

This is not the same behavior as with the command line, where the equal sign is not required:

shell> mysql --user jon --host tonfisk
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 6
Server version: 5.5.62 Source distribution
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
| USER()        |
+---------------+
| jon@tonfisk   |
+---------------+
1 row in set (0.00 sec)

Specifying an option requiring a value without a value in an option file causes the server to abort with an error.

4.2.3 Command Options for Connecting to the Server

This section describes options supported by most MySQL client programs that control how client programs establish connections to the server and whether connections are encrypted. These options can be given on the command line or in an option file.

- Command Options for Connection Establishment
- Command Options for Encrypted Connections

Command Options for Connection Establishment

This section describes options that control how client programs establish connections to the server. For additional information and examples showing how to use them, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

Table 4.3 Connection-Establishment Option Summary

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--default-auth</td>
<td>Authentication plugin to use</td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
</tr>
</tbody>
</table>
Command Options for Connecting to the Server

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
</tr>
<tr>
<td>--secure-auth</td>
<td>Do not send passwords to server in old (pre-4.1) format</td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
</tr>
<tr>
<td>--default-auth=plugin</td>
<td>A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.</td>
</tr>
<tr>
<td>--host=host_name, -h host_name</td>
<td>The host on which the MySQL server is running. The value can be a host name, IPv4 address, or IPv6 address. The default value is localhost.</td>
</tr>
<tr>
<td>--password[=pass_val], -p[pass_val]</td>
<td>The password of the MySQL account used for connecting to the server. The password value is optional. If not given, the program prompts for one. If given, there must be no space between --password= or -p and the password following it. If no password option is specified, the default is to send no password. Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”. To explicitly specify that there is no password and that the client program should not prompt for one, use the --skip-password option.</td>
</tr>
<tr>
<td>--pipe, -W</td>
<td>On Windows, connect to the server using a named pipe. This option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.</td>
</tr>
<tr>
<td>--plugin-dir=dir_name</td>
<td>The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but the client program does not find it. See Section 6.2.10, “Pluggable Authentication”.</td>
</tr>
<tr>
<td>--port=port_num, -P port_num</td>
<td>For TCP/IP connections, the port number to use. The default port number is 3306.</td>
</tr>
</tbody>
</table>
| --protocol={TCP|SOCKET|PIPE|MEMORY} | This option explicitly specifies which protocol to use for connecting to the server. It is useful when other connection parameters normally result in use of a protocol other than the one you want. For example, connections on Unix to localhost are made using a Unix socket file by default: 

mysql --host=localhost

To force a TCP/IP connection to be used instead, specify a --protocol option: 

mysql --host=localhost --protocol=TCP |
Command Options for Connecting to the Server

The following table shows the permissible `--protocol` option values and indicates the platforms on which each value may be used. The values are not case-sensitive.

<table>
<thead>
<tr>
<th><code>--protocol</code> Value</th>
<th>Connection Protocol</th>
<th>Permissible Operating Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>TCP/IP connection to local or remote server</td>
<td>All</td>
</tr>
<tr>
<td>SOCKET</td>
<td>Unix socket file connection to local server</td>
<td>Unix only</td>
</tr>
<tr>
<td>PIPE</td>
<td>Named-pipe connection to local or remote server</td>
<td>Windows only</td>
</tr>
<tr>
<td>MEMORY</td>
<td>Shared-memory connection to local server</td>
<td>Windows only</td>
</tr>
</tbody>
</table>

- **--secure-auth**

Do not send passwords to the server in old (pre-4.1) format. This prevents connections except for servers that use the newer password format.

**Note**

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.

This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

- **--socket=path, -S path**

On Unix, the name of the Unix socket file to use for connections made using a named pipe to a local server. The default Unix socket file name is `/tmp/mysql.sock`.

On Windows, the name of the named pipe to use for connections to a local server. The default Windows pipe name is `MySQL`. The pipe name is not case-sensitive.

On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- **--user=user_name, -u user_name**

The user name of the MySQL account to use for connecting to the server. The default user name is ODBC on Windows or your Unix login name on Unix.

Command Options for Encrypted Connections

This section describes options that specify whether to use encrypted connections, the names of certificate and key files, and other parameters related to encrypted-connection support. They are not available unless MySQL has been built with SSL support. See Section 2.9.6, “Configuring SSL Library Support”. For examples of suggested use and how to check whether a connection is encrypted, see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

For information about using encrypted connections from the MySQL C API, see Section 23.7.14, “C API Encrypted Connection Support”.

282
Command Options for Connecting to the Server

Table 4.4 Connection-Encryption Option Summary

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--skip-ssl</td>
<td>Disable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
</tbody>
</table>

- **--ssl, --skip-ssl**

For the MySQL server, this option specifies that the server permits but does not require encrypted connections.

For MySQL client programs, this option permits but does not require the client to connect to the server using encryption. Therefore, this option is not sufficient in itself to cause an encrypted connection to be used. For example, if you specify this option for a client program but the server has not been configured to support encrypted connections, the client falls back to an unencrypted connection.

As a recommended set of options to enable encrypted connections, consider using at least **--ssl-cert** and **--ssl-key** on the server side and **--ssl-ca** on the client side. See Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

**--ssl** may be implied by other **--ssl-xxx** options, as indicated in the descriptions for those options.

The **--ssl** option in negated form indicates that encryption should not be used and overrides other **--ssl-xxx** options. Specify the option as **--skip-ssl** or a synonym (**--ssl=0, --disable-ssl**). For example, you might have options specified in the [client] group of your option file to use encrypted connections by default when you invoke MySQL client programs. To use an unencrypted connection instead, invoke the client program with **--ssl=0** on the command line to override the options in the option file.

To require use of encrypted connections by a MySQL account, use a **GRANT** statement for the account that includes a **REQUIRE SSL** clause. This causes connection attempts by clients that use the account to be rejected unless MySQL supports encrypted connections and an encrypted connection can be established.

The **REQUIRE** clause permits other encryption-related options, which can be used to enforce security requirements stricter than **REQUIRE SSL**. For additional details about which command options may or must be specified by clients that connect using accounts configured using the various **REQUIRE** options, see the description of **REQUIRE** in Section 13.7.1.3, “GRANT Statement”.

- **--ssl-ca=file_name**

The path name of the Certificate Authority (CA) certificate file in PEM format. This option implies **--ssl**.
Command Options for Connecting to the Server

To tell the client not to authenticate the server certificate when establishing an encrypted connection to the server, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified on the server side.

- `--ssl-capath=dir_name`

  The path name of the directory that contains trusted SSL certificate authority (CA) certificate files in PEM format. This option implies `--ssl`.

  To tell the client not to authenticate the server certificate when establishing an encrypted connection to the server, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified on the server side.

Support for this option depends on the SSL library used to compile MySQL. See Section 6.3.4, “SSL Library-Dependent Capabilities”.

- `--ssl-cert=file_name`

  The path name of the SSL public key certificate file in PEM format. On the client side, this is the client public key certificate. On the server side, this is the server public key certificate. This option implies `--ssl`.

- `--ssl-cipher=cipher_list`

  The list of permissible ciphers for connection encryption. If no cipher in the list is supported, encrypted connections will not work. This option implies `--ssl`.

  For greatest portability, `cipher_list` should be a list of one or more cipher names, separated by colons. This format is understood both by OpenSSL and yaSSL. Examples:

  ```bash
  --ssl-cipher=AES128-SHA
  --ssl-cipher=DHE-RSA-AES256-SHA:AES128-SHA
  ```

  OpenSSL supports a more flexible syntax for specifying ciphers, as described in the OpenSSL documentation at https://www.openssl.org/docs/manmaster/man1/ciphers.html. yaSSL does not, so attempts to use that extended syntax fail for a MySQL distribution compiled using yaSSL.

  For information about which encryption ciphers MySQL supports, see Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”.

- `--ssl-key=file_name`

  The path name of the SSL private key file in PEM format. On the client side, this is the client private key. On the server side, this is the server private key. This option implies `--ssl`.

  If the MySQL distribution was compiled using OpenSSL and the key file is protected by a passphrase, the program prompts the user for the passphrase. The password must be given interactively; it cannot be stored in a file. If the passphrase is incorrect, the program continues as if it could not read the key. If the MySQL distribution was built using yaSSL and the key file is protected by a passphrase, an error occurs.
Connecting to the MySQL Server Using Command Options

• **--ssl-mode=mode**

  This option is available only for client programs, not the server. It specifies the desired security state of the connection to the server:

  • If this option is not specified, the default is to establish an unencrypted connection. This is like the **--ssl=0** option or its synonyms (**--skip-ssl**, **--disable-ssl**).

  • If this option is specified, the only permissible value is **REQUIRED** (establish an encrypted connection if the server supports encrypted connections). The connection attempt fails if an encrypted connection cannot be established.

  The **--ssl-mode** option was added in MySQL 5.5.49.

  **Note**

  To require encrypted connections in MySQL 5.5, the standard MySQL client programs check whether the connection is encrypted if **--ssl-mode=REQUIRED** was specified. If not, the client exits with an error. Third-party applications that must be able to require encrypted connections can use the same technique. For details, see Section 23.7.6.67, "mysql_ssl_set()".

• **--ssl-verify-server-cert**

  This option is available only for client programs, not the server. It causes the client to perform host name identity verification by checking the host name the client uses for connecting to the server against the identity in the certificate that the server sends to the client. The client checks whether the host name that it uses for connecting matches the Common Name value in the server certificate. The connection fails if there is a mismatch. For encrypted connections, this option helps prevent man-in-the-middle attacks. Host name identity verification is disabled by default.

4.2.4 Connecting to the MySQL Server Using Command Options

This section describes use of command-line options to specify how to establish connections to the MySQL server, for clients such as `mysql` or `mysqldump`. For additional information if you are unable to connect, see Section 6.2.13, "Troubleshooting Problems Connecting to MySQL".

For a client program to connect to the MySQL server, it must use the proper connection parameters, such as the name of the host where the server is running and the user name and password of your MySQL account. Each connection parameter has a default value, but you can override default values as necessary using program options specified either on the command line or in an option file.

The examples here use the `mysql` client program, but the principles apply to other clients such as `mysqldump`, `mysqladmin`, or `mysqlshow`.

This command invokes `mysql` without specifying any explicit connection parameters:

```
mysql
```

Because there are no parameter options, the default values apply:

• The default host name is `localhost`. On Unix, this has a special meaning, as described later.

• The default user name is `ODBC` on Windows or your Unix login name on Unix.

• No password is sent because neither **--password** nor **-p** is given.
Connecting to the MySQL Server Using Command Options

• For mysql, the first nonoption argument is taken as the name of the default database. Because there is no such argument, mysql selects no default database.

To specify the host name and user name explicitly, as well as a password, supply appropriate options on the command line. To select a default database, add a database-name argument. Examples:

```
mysql --host=localhost --user=myname --password=password mydb
mysql -h localhost -u myname -p password mydb
```

For password options, the password value is optional:

• If you use a `--password` or `-p` option and specify a password value, there must be no space between `--password=` or `-p` and the password following it.

• If you use `--password` or `-p` but do not specify a password value, the client program prompts you to enter the password. The password is not displayed as you enter it. This is more secure than giving the password on the command line, which might enable other users on your system to see the password line by executing a command such as `ps`. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

• To explicitly specify that there is no password and that the client program should not prompt for one, use the `--skip-password` option.

As just mentioned, including the password value on the command line can be a security risk. To avoid this risk, specify the `--password` or `-p` option without any following password value:

```
mysql --host=localhost --user=myname --password mydb
mysql -h localhost -u myname -p mydb
```

When the `--password` or `-p` option is given with no password value, the client program prints a prompt and waits for you to enter the password. (In these examples, `mydb` is not interpreted as a password because it is separated from the preceding password option by a space.)

On some systems, the library routine that MySQL uses to prompt for a password automatically limits the password to eight characters. That limitation is a property of the system library, not MySQL. Internally, MySQL does not have any limit for the length of the password. To work around the limitation on systems affected by it, specify your password in an option file (see Section 4.2.2.2, “Using Option Files”). Another workaround is to change your MySQL password to a value that has eight or fewer characters, but that may be unacceptable because shorter passwords tend to be less secure.

Client programs determine what type of connection to make as follows:

• If the host is not specified or is `localhost`, a connection to the local host occurs:

  • On Windows, the client connects using a shared-memory connection, if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

  • On Unix, MySQL programs treat the host name `localhost` specially, in a way that is likely different from what you expect compared to other network-based programs: the client connects using a Unix socket file. The `--socket` option or the `MYSQL_UNIX_PORT` environment variable may be used to specify the socket name.

• On Windows, if `host` is . (period), or TCP/IP is not enabled and `--socket` is not specified or the host is empty, the client connects using a named pipe, if the server was started with the `named_pipe` system variable enabled to support named-pipe connections. If named-pipe connections are not enabled, an error occurs.

• Otherwise, the connection uses TCP/IP.
The `--protocol` option enables you to establish a particular type of connection even when other options normally result in use of a different protocol. That is, `--protocol` specifies the connection protocol explicitly and overrides the preceding rules, even for `localhost`.

Only connection options that are relevant to the selected protocol are used or checked. Other connection options are ignored. For example, with `--host=localhost` on Unix, the client attempts to connect to the local server using a Unix socket file. This occurs even if a `--port` or `-P` option is given to specify a port number.

To ensure that the client makes a TCP/IP connection to the local server, use `--host` or `-h` to specify a host name value of `127.0.0.1`, or the IP address or name of the local server. You can also specify the connection protocol explicitly, even for `localhost`, by using the `--protocol=TCP` option. Examples:

```bash
mysql --host=127.0.0.1
mysql --protocol=TCP
```

If the server is configured to accept IPv6 connections, clients can connect to the local server over IPv6 using `--host=::1`. See Section 5.1.11, “IPv6 Support”.

On Windows, you can force a MySQL client to use a named-pipe connection by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying . (period) as the host name. If the server was not started with the `named_pipe` system variable enabled to support named-pipe connections, an error occurs. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

Connections to remote servers use TCP/IP. This command connects to the server running on `remote.example.com` using the default port number (3306):

```bash
mysql --host=remote.example.com
```

To specify a port number explicitly, use the `--port` or `-P` option:

```bash
mysql --host=remote.example.com --port=13306
```

You can specify a port number for connections to a local server, too. However, as indicated previously, connections to `localhost` on Unix use a socket file by default, so unless you force a TCP/IP connection as previously described, any option that specifies a port number is ignored.

For this command, the program uses a socket file on Unix and the `--port` option is ignored:

```bash
mysql --port=13306 --host=localhost
```

To cause the port number to be used, force a TCP/IP connection. For example, invoke the program in either of these ways:

```bash
mysql --port=13306 --host=127.0.0.1
mysql --port=13306 --protocol=TCP
```

For additional information about options that control how client programs establish connections to the server, see Section 4.2.3, “Command Options for Connecting to the Server”.

It is possible to specify connection parameters without entering them on the command line each time you invoke a client program:

- Specify the connection parameters in the `[client]` section of an option file. The relevant section of the file might look like this:

  ```ini
  [client]
  host=host_name
  user=user_name
  ```
For more information, see Section 4.2.2, “Using Option Files”.

- Some connection parameters can be specified using environment variables. Examples:
  - To specify the host for `mysql`, use `MYSQL_HOST`.
  - On Windows, to specify the MySQL user name, use `USER`.
  - To specify the password, use `MYSQL_PWD`. However, this is insecure; see Section 6.1.2.1, “End-User Guidelines for Password Security”.

For a list of supported environment variables, see Section 4.9, “Environment Variables”.

### 4.2.5 Connection Compression Control

Connections to the server can use a compressed protocol that reduces the number of bytes sent over the connection. By default, connections are uncompressed, but can be compressed if the server and the client both support compression.

Compressed connections originate on the client side but affect CPU load on both the client and server sides because both sides perform compression and decompression operations. Because enabling compression decreases performance, its benefits occur primarily when there is low network bandwidth, network transfer time dominates the cost of compression and decompression operations, and result sets are large.

Compression control applies to connections to the server by client programs and by servers participating in master/slave replication. Compression control does not apply to connections for `FEDERATED` tables.

These configuration parameters are available for controlling connection compression:

- Client programs support a `--compress` command-line option to specify use of compression for the connection to the server.

- For programs that use the MySQL C API, enabling the `MYSQL_OPT_COMPRESS` option for the `mysql_options()` function specifies use of compression for the connection to the server.

- For master/server replication, enabling the `slave_compressed_protocol` system variable specifies use of compression for slave connections to the master.

In each case, when use of compression is specified, the connection uses the `zlib` compression algorithm if both sides support it, with fallback to an uncompressed connection otherwise.

### 4.2.6 Setting Environment Variables

Environment variables can be set at the command prompt to affect the current invocation of your command processor, or set permanently to affect future invocations. To set a variable permanently, you can set it in a startup file or by using the interface provided by your system for this purpose. Consult the documentation for your command interpreter for specific details. Section 4.9, “Environment Variables”, lists all environment variables that affect MySQL program operation.

To specify a value for an environment variable, use the syntax appropriate for your command processor. For example, on Windows, you can set the `USER` variable to specify your MySQL account name. To do so, use this syntax:

```
SET USER=your_name
```
The syntax on Unix depends on your shell. Suppose that you want to specify the TCP/IP port number using the `MYSQL_TCP_PORT` variable. Typical syntax (such as for `sh`, `ksh`, `bash`, `zsh`, and so on) is as follows:

```
MYSQL_TCP_PORT=3306
export MYSQL_TCP_PORT
```

The first command sets the variable, and the `export` command exports the variable to the shell environment so that its value becomes accessible to MySQL and other processes.

For `csh` and `tcsh`, use `setenv` to make the shell variable available to the environment:

```
setenv MYSQL_TCP_PORT 3306
```

The commands to set environment variables can be executed at your command prompt to take effect immediately, but the settings persist only until you log out. To have the settings take effect each time you log in, use the interface provided by your system or place the appropriate command or commands in a startup file that your command interpreter reads each time it starts.

On Windows, you can set environment variables using the System Control Panel (under Advanced).

On Unix, typical shell startup files are `.bashrc` or `.bash_profile` for `bash`, or `.tcshrc` for `tcsh`.

Suppose that your MySQL programs are installed in `/usr/local/mysql/bin` and that you want to make it easy to invoke these programs. To do this, set the value of the `PATH` environment variable to include that directory. For example, if your shell is `bash`, add the following line to your `.bashrc` file:

```
PATH=${PATH}:/usr/local/mysql/bin
```

`bash` uses different startup files for login and nonlogin shells, so you might want to add the setting to `.bashrc` for login shells and to `.bash_profile` for nonlogin shells to make sure that `PATH` is set regardless.

If your shell is `tcsh`, add the following line to your `.tcshrc` file:

```
setenv PATH ${PATH}:/usr/local/mysql/bin
```

If the appropriate startup file does not exist in your home directory, create it with a text editor.

After modifying your `PATH` setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

### 4.3 Server and Server-Startup Programs

This section describes `mysqld`, the MySQL server, and several programs that are used to start the server.

#### 4.3.1 `mysqld` — The MySQL Server

`mysqld`, also known as MySQL Server, is the main program that does most of the work in a MySQL installation. MySQL Server manages access to the MySQL data directory that contains databases and tables. The data directory is also the default location for other information such as log files and status files.

**Note**

Some installation packages contain a debugging version of the server named `mysqld-debug`. Invoke this version instead of `mysqld` for debugging support, memory allocation checking, and trace file support (see Section 24.5.1.2, "Creating Trace Files").

When MySQL server starts, it listens for network connections from client programs and manages access to databases on behalf of those clients.
The `mysqld` program has many options that can be specified at startup. For a complete list of options, run this command:

```
shell> mysqld --verbose --help
```

MySQL Server also has a set of system variables that affect its operation as it runs. System variables can be set at server startup, and many of them can be changed at runtime to effect dynamic server reconfiguration. MySQL Server also has a set of status variables that provide information about its operation. You can monitor these status variables to access runtime performance characteristics.

For a full description of MySQL Server command options, system variables, and status variables, see Section 5.1, “The MySQL Server”. For information about installing MySQL and setting up the initial configuration, see Chapter 2, *Installing and Upgrading MySQL*.

### 4.3.2 `mysqld_safe` — MySQL Server Startup Script

`mysqld_safe` is the recommended way to start a `mysqld` server on Unix. `mysqld_safe` adds some safety features such as restarting the server when an error occurs and logging runtime information to an error log. A description of error logging is given later in this section.

`mysqld_safe` tries to start an executable named `mysqld`. To override the default behavior and specify explicitly the name of the server you want to run, specify a `--mysqld` or `--mysqld-version` option to `mysqld_safe`. You can also use `--ledir` to indicate the directory where `mysqld_safe` should look for the server.

Many of the options to `mysqld_safe` are the same as the options to `mysqld`. See Section 5.1.6, “Server Command Options”.

Options unknown to `mysqld_safe` are passed to `mysqld` if they are specified on the command line, but ignored if they are specified in the `[mysqld_safe]` group of an option file. See Section 4.2.2.2, “Using Option Files”.

`mysqld_safe` reads all options from the `[mysqld]`, `[server]`, and `[mysqld_safe]` sections in option files. For example, if you specify a `[mysqld]` section like this, `mysqld_safe` will find and use the `--log-error` option:

```
[mysqld]
log-error=error.log
```

For backward compatibility, `mysqld_safe` also reads `[safe_mysqld]` sections, but to be current you should rename such sections to `[mysqld_safe]`.

`mysqld_safe` supports the following options. It also reads option files and supports the options for processing them described at Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

#### Table 4.5 `mysqld_safe` Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--basedir</code></td>
<td>Path to MySQL installation directory</td>
</tr>
<tr>
<td><code>--core-file-size</code></td>
<td>Size of core file that mysqld should be able to create</td>
</tr>
<tr>
<td><code>--datadir</code></td>
<td>Path to data directory</td>
</tr>
<tr>
<td><code>--defaults-extra-file</code></td>
<td>Read named option file in addition to usual option files</td>
</tr>
<tr>
<td><code>--defaults-file</code></td>
<td>Read only named option file</td>
</tr>
<tr>
<td><code>--help</code></td>
<td>Display help message and exit</td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--ledir</td>
<td>Path to directory where server is located</td>
</tr>
<tr>
<td>--log-error</td>
<td>Write error log to named file</td>
</tr>
<tr>
<td>--malloc-lib</td>
<td>Alternative malloc library to use for mysqld</td>
</tr>
<tr>
<td>--mysqld</td>
<td>Name of server program to start (in ledir directory)</td>
</tr>
<tr>
<td>--mysql-version</td>
<td>Suffix for server program name</td>
</tr>
<tr>
<td>--nice</td>
<td>Use nice program to set server scheduling priority</td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
</tr>
<tr>
<td>--open-files-limit</td>
<td>Number of files that mysqld should be able to open</td>
</tr>
<tr>
<td>--pid-file</td>
<td>Path name of server process ID file</td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
</tr>
<tr>
<td>--port</td>
<td>Port number on which to listen for TCP/IP connections</td>
</tr>
<tr>
<td>--skip-kill-mysqld</td>
<td>Do not try to kill stray mysqld processes</td>
</tr>
<tr>
<td>--skip-syslog</td>
<td>Do not write error messages to syslog; use error log file</td>
</tr>
<tr>
<td>--socket</td>
<td>Socket file on which to listen for Unix socket connections</td>
</tr>
<tr>
<td>--syslog</td>
<td>Write error messages to syslog</td>
</tr>
<tr>
<td>--syslog-tag</td>
<td>Tag suffix for messages written to syslog</td>
</tr>
<tr>
<td>--timezone</td>
<td>Set TZ time zone environment variable to named value</td>
</tr>
<tr>
<td>--user</td>
<td>Run mysqld as user having name user_name or numeric user ID user_id</td>
</tr>
</tbody>
</table>

- **--help**

  Display a help message and exit.

- **--basedir=dir_name**

  The path to the MySQL installation directory.

- **--core-file-size=size**

  The size of the core file that mysqld should be able to create. The option value is passed to `ulimit -c`.

- **--datadir=dir_name**

  The path to the data directory.

- **--defaults-extra-file=file_name**

  Read this option file in addition to the usual option files. If the file does not exist or is otherwise inaccessible, the server will exit with an error. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

  For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

- **--defaults-file=file_name**

  291
Use only the given option file. If the file does not exist or is otherwise inaccessible, the server will exit with an error. file_name is interpreted relative to the current directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

For additional information about this and other option-file options, see Section 4.2.3, “Command-Line Options that Affect Option-File Handling”.

• --ledir=dir_name

If mysqld_safe cannot find the server, use this option to indicate the path name to the directory where the server is located.

As of MySQL 5.5.54, this option is accepted only on the command line, not in option files.

• --log-error=file_name

Write the error log to the given file. See Section 5.4.2, “The Error Log”.

• --malloc-lib=[lib_name]

The name of the library to use for memory allocation instead of the system malloc() library. As of MySQL 5.5.52, the option value must be one of the directories /usr/lib, /usr/lib64, /usr/lib/i386-linux-gnu, or /usr/lib/x86_64-linux-gnu. Prior to MySQL 5.5.52, any library can be used by specifying its path name, but there is a shortcut form to enable use of the tcmalloc library that is shipped with binary MySQL distributions for Linux in MySQL 5.5. It is possible that the shortcut form will not work under certain configurations, in which case you should specify a path name instead.

Note

As of MySQL 5.5.50, MySQL distributions no longer include a tcmalloc library.

The --malloc-lib option works by modifying the LD_PRELOAD environment value to affect dynamic linking to enable the loader to find the memory-allocation library when mysqld runs:

• If the option is not given, or is given without a value (--malloc-lib=), LD_PRELOAD is not modified and no attempt is made to use tcmalloc.

• If the option is given as --malloc-lib=tcmalloc, mysqld_safe looks for a tcmalloc library in /usr/lib and then in the MySQL pkglibdir location (for example, /usr/local/mysql/lib or whatever is appropriate). If tmalloc is found, its path name is added to the beginning of the LD_PRELOAD value for mysqld. If tcmalloc is not found, mysqld_safe aborts with an error.

• If the option is given as --malloc-lib=/path/to/some/library, that full path is added to the beginning of the LD_PRELOAD value. If the full path points to a nonexistent or unreadable file, mysqld_safe aborts with an error.

• For cases where mysqld_safe adds a path name to LD_PRELOAD, it adds the path to the beginning of any existing value the variable already has.

Linux users can use the libtcmalloc_minimal.so included in binary packages by adding these lines to the my.cnf file:
Those lines also suffice for users on any platform who have installed a tcmalloc package in /usr/lib. To use a specific tcmalloc library, specify its full path name. Example:

```
[mysqld_safe]
malloc-lib=/opt/lib/libtcmalloc_minimal.so
```

• **--mysqld=prog_name**

The name of the server program (in the ledir directory) that you want to start. This option is needed if you use the MySQL binary distribution but have the data directory outside of the binary distribution. If mysqld_safe cannot find the server, use the --ledir option to indicate the path name to the directory where the server is located.

As of MySQL 5.5.52, this option is accepted only on the command line, not in option files.

• **--mysqld-version=suffix**

This option is similar to the --mysqld option, but you specify only the suffix for the server program name. The base name is assumed to be mysqld. For example, if you use --mysqld-version=debug, mysqld_safe starts the mysqld-debug program in the ledir directory. If the argument to --mysqld-version is empty, mysqld_safe uses mysqld in the ledir directory.

As of MySQL 5.5.52, this option is accepted only on the command line, not in option files.

• **--nice=priority**

Use the nice program to set the server's scheduling priority to the given value.

• **--no-defaults**

Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read. This must be the first option on the command line if it is used.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--open-files-limit=count**

The number of files that mysqld should be able to open. The option value is passed to ulimit -n.

**Note**
You must start mysqld_safe as root for this to function properly.

• **--pid-file=file_name**

The path name that mysqld should use for its process ID file.

• **--plugin-dir=dir_name**

The path name of the plugin directory. This option was added in MySQL 5.5.3.

• **--port=port_num**

The port number that the server should use when listening for TCP/IP connections. The port number must be 1024 or higher unless the server is started by the root operating system user.
--skip-kill-mysqld
Do not try to kill stray mysqld processes at startup. This option works only on Linux.

--socket=path
The Unix socket file that the server should use when listening for local connections.

--syslog, --skip-syslog
--syslog causes error messages to be sent to syslog on systems that support the logger program.
--skip-syslog suppresses the use of syslog; messages are written to an error log file.

When syslog is used, the daemon.err syslog facility/severity is used for all log messages.
mysqld_safe ignores --syslog if --log-error is also given.

--syslog-tag=tag
For logging to syslog, messages from mysqld_safe and mysqld are written with identifiers of
mysqld_safe and mysqld, respectively. To specify a suffix for the identifiers, use --syslog-
tag=tag, which modifies the identifiers to be mysqld_safe-tag and mysqld-tag.

--timezone=timezone
Set the TZ time zone environment variable to the given option value. Consult your operating system
documentation for legal time zone specification formats.

--user={user_name|user_id}
Run the mysqld server as the user having the name user_name or the numeric user ID user_id.
(“User” in this context refers to a system login account, not a MySQL user listed in the grant tables.)

If you execute mysqld_safe with the --defaults-file or --defaults-extra-file option to name
an option file, the option must be the first one given on the command line or the option file will not be used.
For example, this command will not use the named option file:

mysql> mysqld_safe --port=port_num --defaults-file=file_name

Instead, use the following command:

mysql> mysqld_safe --defaults-file=file_name --port=port_num

The mysqld_safe script is written so that it normally can start a server that was installed from either
a source or a binary distribution of MySQL, even though these types of distributions typically install the
server in slightly different locations. (See Section 2.1.4, “Installation Layouts”.) mysqld_safe expects one
of the following conditions to be true:

• The server and databases can be found relative to the working directory (the directory from which
mysqld_safe is invoked). For binary distributions, mysqld_safe looks under its working directory
for bin and data directories. For source distributions, it looks for libexec and var directories. This
condition should be met if you execute mysqld_safe from your MySQL installation directory (for
example, /usr/local/mysql for a binary distribution).

• If the server and databases cannot be found relative to the working directory, mysqld_safe attempts to
locate them by absolute path names. Typical locations are /usr/local/libexec and /usr/local/
var. The actual locations are determined from the values configured into the distribution at the time it
was built. They should be correct if MySQL is installed in the location specified at configuration time.
Because `mysqld_safe` tries to find the server and databases relative to its own working directory, you can install a binary distribution of MySQL anywhere, as long as you run `mysqld_safe` from the MySQL installation directory:

```bash
shell> cd mysql_installation_directory
shell> bin/mysqld_safe &
```

If `mysqld_safe` fails, even when invoked from the MySQL installation directory, specify the `--ledir` and `--datadir` options to indicate the directories in which the server and databases are located on your system.

Beginning with MySQL 5.5.21, `mysqld_safe` tries to use the `sleep` and `date` system utilities to determine how many times it has attempted to start this second, and—if these are present and this is greater than 5 times—is forced to wait 1 full second before starting again. This is intended to prevent excessive CPU usage in the event of repeated failures. (Bug #11761530, Bug #54035)

When you use `mysqld_safe` to start `mysqld`, `mysqld_safe` arranges for error (and notice) messages from itself and from `mysqld` to go to the same destination.

There are several `mysqld_safe` options for controlling the destination of these messages:

- `--log-error=file_name`: Write error messages to the named error file.
- `--syslog`: Write error messages to `syslog` on systems that support the `logger` program.
- `--skip-syslog`: Do not write error messages to `syslog`. Messages are written to the default error log file (`host_name.err` in the data directory), or to a named file if the `--log-error` option is given.

If none of these options is given, the default is `--skip-syslog`.

If `--log-error` and `--syslog` are both given, a warning is issued and `--log-error` takes precedence.

When `mysqld_safe` writes a message, notices go to the logging destination (`syslog` or the error log file) and `stdout`. Errors go to the logging destination and `stderr`.

Normally, you should not edit the `mysqld_safe` script. Instead, configure `mysqld_safe` by using command-line options or options in the `[mysqld_safe]` section of a `my.cnf` option file. In rare cases, it might be necessary to edit `mysqld_safe` to get it to start the server properly. However, if you do this, your modified version of `mysqld_safe` might be overwritten if you upgrade MySQL in the future, so you should make a copy of your edited version that you can reinstall.

### 4.3.3 mysql.server — MySQL Server Startup Script

MySQL distributions on Unix and Unix-like system include a script named `mysql.server`, which starts the MySQL server using `mysqld_safe`. It can be used on systems such as Linux and Solaris that use System V-style run directories to start and stop system services. It is also used by the macOS Startup Item for MySQL.

`mysql.server` is the script name as used within the MySQL source tree. The installed name might be different (for example, `mysqld` or `mysql`). In the following discussion, adjust the name `mysql.server` as appropriate for your system.

To start or stop the server manually using the `mysql.server` script, invoke it from the command line with `start` or `stop` arguments:

```bash
shell> mysql.server start
```
mysql.server — MySQL Server Startup Script

shell> mysql.server stop

mysql.server changes location to the MySQL installation directory, then invokes mysqld_safe. To run the server as some specific user, add an appropriate user option to the [mysqld] group of the global /etc/my.cnf option file, as shown later in this section. (It is possible that you must edit mysql.server if you’ve installed a binary distribution of MySQL in a nonstandard location. Modify it to change location into the proper directory before it runs mysqld_safe. If you do this, your modified version of mysql.server may be overwritten if you upgrade MySQL in the future; make a copy of your edited version that you can reinstall.)

mysql.server stop stops the server by sending a signal to it. You can also stop the server manually by executing mysqladmin shutdown.

To start and stop MySQL automatically on your server, you must add start and stop commands to the appropriate places in your /etc/rc* files:

• If you use the Linux server RPM package (MySQL-server-VERSION.rpm), or a native Linux package installation, the mysql.server script may be installed in the /etc/init.d directory with the name mysqld or mysql. See Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”, for more information on the Linux RPM packages.

• If you install MySQL from a source distribution or using a binary distribution format that does not install mysql.server automatically, you can install the script manually. It can be found in the support-files directory under the MySQL installation directory or in a MySQL source tree. Copy the script to the /etc/init.d directory with the name mysql and make it executable:

shell> cp mysql.server /etc/init.d/mysql
shell> chmod +x /etc/init.d/mysql

After installing the script, the commands needed to activate it to run at system startup depend on your operating system. On Linux, you can use chkconfig:

shell> chkconfig --add mysql

On some Linux systems, the following command also seems to be necessary to fully enable the mysql script:

shell> chkconfig --level 345 mysql on

• On FreeBSD, startup scripts generally should go in /usr/local/etc/rc.d/. Install the mysql.server script as /usr/local/etc/rc.d/mysql.server.sh to enable automatic startup. The rc(8) manual page states that scripts in this directory are executed only if their base name matches the *.sh shell file name pattern. Any other files or directories present within the directory are silently ignored.

• As an alternative to the preceding setup, some operating systems also use /etc/rc.local or /etc/init.d/boot.local to start additional services on startup. To start up MySQL using this method, append a command like the one following to the appropriate startup file:

/bin/sh -c 'cd /usr/local/mysql; ./bin/mysqld_safe --user=mysql &'

• For other systems, consult your operating system documentation to see how to install startup scripts.

mysql.server reads options from the [mysql.server] and [mysqld] sections of option files. For backward compatibility, it also reads [mysql_server] sections, but to be current you should rename such sections to [mysql.server].

You can add options for mysql.server in a global /etc/my.cnf file. A typical my.cnf file might look like this:
The `mysql.server` script supports the options shown in the following table. If specified, they must be placed in an option file, not on the command line. `mysql.server` supports only start and stop as command-line arguments.

**Table 4.6 mysql.server Option-File Options**

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>basedir</td>
<td>Path to MySQL installation directory</td>
<td>Directory</td>
</tr>
<tr>
<td>datadir</td>
<td>Path to MySQL data directory</td>
<td>Directory</td>
</tr>
<tr>
<td>pid-file</td>
<td>File in which server should write its process ID</td>
<td>File name</td>
</tr>
<tr>
<td>service-startup-timeout</td>
<td>How long to wait for server startup</td>
<td>Integer</td>
</tr>
</tbody>
</table>

- **basedir=dir_name**
  The path to the MySQL installation directory.

- **datadir=dir_name**
  The path to the MySQL data directory.

- **pid-file=file_name**
  The path name of the file in which the server should write its process ID. The server creates the file in the data directory unless an absolute path name is given to specify a different directory.

  If this option is not given, `mysql.server` uses a default value of `host_name.pid`. The PID file value passed to `mysqld_safe` overrides any value specified in the `[mysqld_safe]` option file group. Because `mysql.server` reads the `[mysqld]` option file group but not the `[mysqld_safe]` group, you can ensure that `mysqld_safe` gets the same value when invoked from `mysql.server` as when invoked manually by putting the same `pid-file` setting in both the `[mysqld_safe]` and `[mysqld]` groups.

- **service-startup-timeout=seconds**
  How long in seconds to wait for confirmation of server startup. If the server does not start within this time, `mysql.server` exits with an error. The default value is 900. A value of 0 means not to wait at all for startup. Negative values mean to wait forever (no timeout).

### 4.3.4 mysqld_multi — Manage Multiple MySQL Servers

`mysqld_multi` is designed to manage several `mysqld` processes that listen for connections on different Unix socket files and TCP/IP ports. It can start or stop servers, or report their current status.
mysqld_multi — Manage Multiple MySQL Servers

mysqld_multi searches for groups named [mysqldN] in my.cnf (or in the file named by the --defaults-file option). N can be any positive integer. This number is referred to in the following discussion as the option group number, or GNR. Group numbers distinguish option groups from one another and are used as arguments to mysqld_multi to specify which servers you want to start, stop, or obtain a status report for. Options listed in these groups are the same that you would use in the [mysqld] group used for starting mysqld. (See, for example, Section 2.10.5, “Starting and Stopping MySQL Automatically”.) However, when using multiple servers, it is necessary that each one use its own value for options such as the Unix socket file and TCP/IP port number. For more information on which options must be unique per server in a multiple-server environment, see Section 5.7, “Running Multiple MySQL Instances on One Machine”.

To invoke mysqld_multi, use the following syntax:

```shell
shell> mysqld_multi [options] {start|stop|report} [GNR[, GNR] ...]
```

start, stop, and report indicate which operation to perform. You can perform the designated operation for a single server or multiple servers, depending on the GNR list that follows the option name. If there is no list, mysqld_multi performs the operation for all servers in the option file.

Each GNR value represents an option group number or range of group numbers. The value should be the number at the end of the group name in the option file. For example, the GNR for a group named [mysqld17] is 17. To specify a range of numbers, separate the first and last numbers by a dash. The GNR value 10-13 represents groups [mysqld10] through [mysqld13]. Multiple groups or group ranges can be specified on the command line, separated by commas. There must be no whitespace characters (spaces or tabs) in the GNR list; anything after a whitespace character is ignored.

This command starts a single server using option group [mysqld17]:

```shell
shell> mysqld_multi start 17
```

This command stops several servers, using option groups [mysqld8] and [mysqld10] through [mysqld13]:

```shell
shell> mysqld_multi stop 8,10-13
```

For an example of how you might set up an option file, use this command:

```shell
shell> mysqld_multi --example
```

mysqld_multi searches for option files as follows:

- With --no-defaults, no option files are read.
- With --defaults-file=file_name, only the named file is read.
- Otherwise, option files in the standard list of locations are read, including any file named by the --defaults-extra-file=file_name option, if one is given. (If the option is given multiple times, the last value is used.)

For additional information about these and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

Option files read are searched for [mysqld_multi] and [mysqldN] option groups. The [mysqld_multi] group can be used for options to mysqld_multi itself. [mysqldN] groups can be used for options passed to specific mysqld instances.

The [mysqld] or [mysqld_safe] groups can be used for common options read by all instances of mysqld or mysqld_safe. You can specify a --defaults-file=file_name option to use a different
configuration file for that instance, in which case the [mysqld] or [mysqld_safe] groups from that file will be used for that instance.

`mysqld_multi` supports the following options.

- **--help**
  
  Display a help message and exit.

- **--config-file=** `file_name`
  
  This option is deprecated. If given, it is treated the same way as `--defaults-extra-file`, described earlier. `--config-file` was removed in MySQL 5.5.3.

- **--example**
  
  Display a sample option file.

- **--log=** `file_name`
  
  Specify the name of the log file. If the file exists, log output is appended to it.

- **--mysqladmin=** `prog_name`
  
  The `mysqladmin` binary to be used to stop servers.

- **--mysqld=** `prog_name`
  
  The `mysqld` binary to be used. Note that you can specify `mysqld_safe` as the value for this option also. If you use `mysqld_safe` to start the server, you can include the `mysqld` or `ledir` options in the corresponding `[mysqldN]` option group. These options indicate the name of the server that `mysqld_safe` should start and the path name of the directory where the server is located. (See the descriptions for these options in Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script").

  Example:

  ```
  [mysqld38]
  mysqld = mysqld-debug
  ledir = /opt/local/mysql/libexec
  ```

- **--no-log**
  
  Print log information to `stdout` rather than to the log file. By default, output goes to the log file.

- **--password=** `password`
  
  The password of the MySQL account to use when invoking `mysqladmin`. The password value is not optional for this option, unlike for other MySQL programs.

- **--silent**
  
  Silent mode; disable warnings.

- **--tcp-ip**
  
  Connect to each MySQL server through the TCP/IP port instead of the Unix socket file. (If a socket file is missing, the server might still be running, but accessible only through the TCP/IP port.) By default, connections are made using the Unix socket file. This option affects `stop` and `report` operations.

- **--user=** `user_name`
mysqld_multi — Manage Multiple MySQL Servers

The user name of the MySQL account to use when invoking mysqladmin.

- **--verbose**
  Be more verbose.

- **--version**
  Display version information and exit.

Some notes about mysqld_multi:

- **Most important**: Before using mysqld_multi be sure that you understand the meanings of the options that are passed to the mysqld servers and why you would want to have separate mysqld processes. Beware of the dangers of using multiple mysqld servers with the same data directory. Use separate data directories, unless you know what you are doing. Starting multiple servers with the same data directory does not give you extra performance in a threaded system. See Section 5.7, “Running Multiple MySQL Instances on One Machine”.

  **Important**
  Make sure that the data directory for each server is fully accessible to the Unix account that the specific mysqld process is started as. Do not use the Unix root account for this, unless you know what you are doing. See Section 6.1.5, “How to Run MySQL as a Normal User”.

- Make sure that the MySQL account used for stopping the mysqld servers (with the mysqladmin program) has the same user name and password for each server. Also, make sure that the account has the SHUTDOWN privilege. If the servers that you want to manage have different user names or passwords for the administrative accounts, you might want to create an account on each server that has the same user name and password. For example, you might set up a common multi_admin account by executing the following commands for each server:

  ```
  shell> mysql -u root -S /tmp/mysql.sock -p
  Enter password:
  mysql> CREATE USER 'multi_admin'@'localhost' IDENTIFIED BY 'multipass';
  mysql> GRANT SHUTDOWN ON *.* TO 'multi_admin'@'localhost';
  ```

  See Section 6.2, “Access Control and Account Management”. You have to do this for each mysqld server. Change the connection parameters appropriately when connecting to each one. Note that the host name part of the account name must permit you to connect as multi_admin from the host where you want to run mysqld_multi.

- The Unix socket file and the TCP/IP port number must be different for every mysqld. (Alternatively, if the host has multiple network addresses, you can use --bind-address to cause different servers to listen to different interfaces.)

- The --pid-file option is very important if you are using mysql_safe to start mysqld (for example, --mysqld=mysqld_safe) Every mysqld should have its own process ID file. The advantage of using mysql_safe instead of mysqld is that mysql_safe monitors its mysqld process and restarts it if the process terminates due to a signal sent using kill -9 or for other reasons, such as a segmentation fault.

- You might want to use the --user option for mysqld, but to do this you need to run the mysqld_multi script as the Unix superuser (root). Having the option in the option file doesn't matter; you just get a warning if you are not the superuser and the mysqld processes are started under your own Unix account.
The following example shows how you might set up an option file for use with `mysqld_multi`. The order in which the `mysqld` programs are started or stopped depends on the order in which they appear in the option file. Group numbers need not form an unbroken sequence. The first and fifth `[mysqldN]` groups were intentionally omitted from the example to illustrate that you can have “gaps” in the option file. This gives you more flexibility.

```ini
# This is an example of a my.cnf file for mysqld_multi.
# Usually this file is located in home dir ~/.my.cnf or /etc/my.cnf

[mysqld_multi]
mysqld = /usr/local/mysql/bin/mysqld_safe
mysqladmin = /usr/local/mysql/bin/mysqladmin
user = multi_admin
password = my_password

[mysqld2]
socket = /tmp/mysql.sock2
port = 3307
pid-file = /usr/local/mysql/data2/hostname.pid2
datadir = /usr/local/mysql/data2
language = /usr/local/mysql/share/mysql/english
user = unix_user1

[mysqld3]
mysqld = /path/to/mysqld_safe
ledir = /path/to/mysqld-binary/
mysqladmin = /path/to/mysqladmin
socket = /tmp/mysql.sock3
port = 3308
pid-file = /usr/local/mysql/data3/hostname.pid3
datadir = /usr/local/mysql/data3
language = /usr/local/mysql/share/mysql/swedish
user = unix_user2

[mysqld4]
socket = /tmp/mysql.sock4
port = 3309
pid-file = /usr/local/mysql/data4/hostname.pid4
datadir = /usr/local/mysql/data4
language = /usr/local/mysql/share/mysql/estonia
user = unix_user3

[mysqld6]
socket = /tmp/mysql.sock6
port = 3311
pid-file = /usr/local/mysql/data6/hostname.pid6
datadir = /usr/local/mysql/data6
language = /usr/local/mysql/share/mysql/japanese
user = unix_user4
```

See Section 4.2.2.2, “Using Option Files”.

### 4.4 Installation-Related Programs

The programs in this section are used when installing or upgrading MySQL.

#### 4.4.1 `comp_err` — Compile MySQL Error Message File

`comp_err` creates the `errmsg.sys` file that is used by `mysqld` to determine the error messages to display for different error codes. `comp_err` normally is run automatically when MySQL is built. It compiles the `errmsg.sys` file from the text-format error information file located at `sql/share/errmsg-utf8.txt` in MySQL source distributions.
comp_err also generates the `mysqld_error.h`, `mysqld_ername.h`, and `sql_state.h` header files.

For more information about how error messages are defined, see the MySQL Internals Manual.

Invoke `comp_err` like this:

```sh
shell> comp_err [options]
```

`comp_err` supports the following options.

- **--help, -?**
  
  Display a help message and exit.

- **--charset=dir_name, -C dir_name**
  
  The character set directory. The default is `./sql/share/charsets`.

- **--debug=debug_options, -# debug_options**
  
  Write a debugging log. A typical `debug_options` string is `d:t:O, file_name`. The default is `d:t:O,/tmp/comp_err.trace`.

- **--debug-info, -T**
  
  Print some debugging information when the program exits.

- **--header-file=file_name, -H file_name**
  
  The name of the error header file. The default is `mysqld_error.h`.

- **--in-file=file_name, -F file_name**
  
  The name of the input file that defines error messages. The default is `../sql/share/errmsg-utf8.txt`.

- **--name-file=file_name, -N file_name**
  
  The name of the error name file. The default is `mysqld_ername.h`.

- **--out-dir=dir_name, -D dir_name**
  
  The name of the output base directory. The default is `../sql/share/`.

- **--out-file=file_name, -O file_name**
  
  The name of the output file. The default is `errmsg.sys`.

- **--state-file=file_name, -S file_name**
  
  The name for the SQLSTATE header file. The default is `sql_state.h`.

- **--version, -V**
  
  Display version information and exit.

### 4.4.2 mysqlbug — Generate Bug Report

This program is obsolete.
mysql_install_db — Initialize MySQL Data Directory

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports.

4.4.3 mysql_install_db — Initialize MySQL Data Directory

mysql_install_db initializes the MySQL data directory and creates the system tables that it contains, if they do not exist. mysql_install_db is a shell script and is available only on Unix platforms. (As of MySQL 5.6, mysql_install_db is a Perl script and can be used on any system with Perl installed.)

To invoke mysql_install_db, use the following syntax:

```shell
    mysql_install_db [options]
```

Because the MySQL server, mysqld, must access the data directory when it runs later, you should either run mysql_install_db from the same system account that will be used for running mysqld, or run it as root and specify the --user option to indicate the user name that mysqld will run as. It might be necessary to specify other options such as --basedir or --datadir if mysql_install_db does not use the correct locations for the installation directory or data directory. For example:

```shell
    scripts/mysql_install_db --user=mysql \
        --basedir=/opt/mysql/mysql \ 
        --datadir=/opt/mysql/mysql/data
```

Note

If you have set a custom TMPDIR environment variable when performing the installation, and the specified directory is not accessible, mysql_install_db may fail. If so, unset TMPDIR or set TMPDIR to point to the system temporary directory (usually /tmp).

mysql_install_db supports the following options, which can be specified on the command line or in the [mysql_install_db] group of an option file. (Options that are common to mysqld can also be specified in the [mysqld] group.) Other options are passed to mysqld. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

Table 4.7 mysql_install_db Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--basedir</td>
<td>Path to base directory</td>
</tr>
<tr>
<td>--builddir</td>
<td>Path to build directory (for out-of-source builds)</td>
</tr>
<tr>
<td>--cross-bootstrap</td>
<td>For internal use</td>
</tr>
<tr>
<td>--datadir</td>
<td>Path to data directory</td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
</tr>
<tr>
<td>--force</td>
<td>Run even if DNS does not work</td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
</tr>
<tr>
<td>--ldata</td>
<td>Synonym for --datadir</td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
</tr>
<tr>
<td>--rpm</td>
<td>For internal use</td>
</tr>
<tr>
<td>--skip-name-resolve</td>
<td>Use IP addresses rather than host names in grant tables</td>
</tr>
<tr>
<td>--srcrev</td>
<td>For internal use</td>
</tr>
</tbody>
</table>
mysql_install_db — Initialize MySQL Data Directory

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--user</td>
<td>Operating system user under which to execute mysqld</td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
</tr>
<tr>
<td>--windows</td>
<td>For internal use</td>
</tr>
</tbody>
</table>

- --help
  Display a help message and exit.

- --basedir=dir_name
  The path to the MySQL installation directory.

- --builddir=dir_name
  For use with --srcdir and out-of-source builds. Set this to the location of the directory where the built files reside.

- --cross-bootstrap
  For internal use. This option is used for building system tables on one host intended for another.

- --datadir=dir_name
  The path to the MySQL data directory.

- --defaults-extra-file=file_name
  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name rather than a full path name.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- --defaults-file=file_name
  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name rather than a full path name.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- --force
  Cause mysql_install_db to run even if DNS does not work. Grant table entries normally created using host names will use IP addresses instead.

- --ldata=dir_name
  A synonym for --datadir.

- --no-defaults
  Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read.
For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--rpm**
  For internal use. This option is used during the MySQL installation process for install operations performed using RPM packages.

- **--skip-name-resolve**
  Use IP addresses rather than host names when creating grant table entries. This option can be useful if your DNS does not work.

- **--srcdir=dir_name**
  For internal use. This option specifies the directory under which `mysql_install_db` looks for support files such as the error message file and the file for populating the help tables.

- **--user=user_name**
  The system (login) user name to use for running `mysqld`. Files and directories created by `mysqld` will be owned by this user. You must be the system root user to use this option. By default, `mysqld` runs using your current login name and files and directories that it creates will be owned by you.

- **--verbose**
  Verbose mode. Print more information about what the program does.

- **--windows**
  For internal use. This option is used for creating Windows distributions.

### 4.4.4 mysql_plugin — Configure MySQL Server Plugins

The `mysql_plugin` utility enables MySQL administrators to manage which plugins a MySQL server loads. It provides an alternative to manually specifying the `--plugin-load` option at server startup or using the `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements at runtime. `mysql_plugin` is available as of MySQL 5.5.16.

Depending on whether `mysql_plugin` is invoked to enable or disable plugins, it inserts or deletes rows in the `mysql.plugin` table that serves as a plugin registry. (To perform this operation, `mysql_plugin` invokes the MySQL server in bootstrap mode. This means that the server must not already be running.) For normal server startups, the server loads and enables plugins listed in `mysql.plugin` automatically. For additional control over plugin activation, use `--plugin_name` options named for specific plugins, as described in Section 5.5.1, “Installing and Uninstalling Plugins”.

Each invocation of `mysql_plugin` reads a configuration file to determine how to configure the plugins contained in a single plugin library file. To invoke `mysql_plugin`, use this syntax:

```
mysql_plugin [options] plugin {ENABLE|DISABLE}
```

`plugin` is the name of the plugin to configure. `ENABLE` or `DISABLE` (not case-sensitive) specify whether to enable or disable components of the plugin library named in the configuration file. The order of the `plugin` and `ENABLE` or `DISABLE` arguments does not matter.

For example, to configure components of a plugin library file named `myplugins.so` on Linux or `myplugins.dll` on Windows, specify a `plugin` value of `myplugins`. Suppose that this plugin library
contains three plugins, `plugin1`, `plugin2`, and `plugin3`, all of which should be configured under `mysql_plugin` control. By convention, configuration files have a suffix of `.ini` and the same base name as the plugin library, so the default configuration file name for this plugin library is `myplugins.ini`. The configuration file contents look like this:

```
myplugins
plugin1
plugin2
plugin3
```

The first line in the `myplugins.ini` file is the name of the library file, without any extension such as `.so` or `.dll`. The remaining lines are the names of the components to be enabled or disabled. Each value in the file should be on a separate line. Lines on which the first character is `#` are taken as comments and ignored.

To enable the plugins listed in the configuration file, invoke `mysql_plugin` this way:

```
shell> mysql_plugin myplugins ENABLE
```

To disable the plugins, use `DISABLE` rather than `ENABLE`.

An error occurs if `mysql_plugin` cannot find the configuration file or plugin library file, or if `mysql_plugin` cannot start the MySQL server.

`mysql_plugin` supports the following options, which can be specified on the command line or in the `[mysqld]` group of any option file. For options specified in a `[mysqld]` group, `mysql_plugin` recognizes the `--basedir`, `--datadir`, and `--plugin-dir` options and ignores others. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

### Table 4.8 mysql_plugin Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--basedir</code></td>
<td>The server base directory</td>
</tr>
<tr>
<td><code>--datadir</code></td>
<td>The server data directory</td>
</tr>
<tr>
<td><code>--help</code></td>
<td>Display help message and exit</td>
</tr>
<tr>
<td><code>--my-print-defaults</code></td>
<td>Path to my_print_defaults</td>
</tr>
<tr>
<td><code>--mysqld</code></td>
<td>Path to server</td>
</tr>
<tr>
<td><code>--no-defaults</code></td>
<td>Do not read configuration file</td>
</tr>
<tr>
<td><code>--plugin-dir</code></td>
<td>Directory where plugins are installed</td>
</tr>
<tr>
<td><code>--plugin-ini</code></td>
<td>The plugin configuration file</td>
</tr>
<tr>
<td><code>--print-defaults</code></td>
<td>Show configuration file defaults</td>
</tr>
<tr>
<td><code>--verbose</code></td>
<td>Verbose mode</td>
</tr>
<tr>
<td><code>--version</code></td>
<td>Display version information and exit</td>
</tr>
</tbody>
</table>

- `--help, -?`
  Display a help message and exit.
- `--basedir=dir_name, -b dir_name`
  The server base directory.
- `--datadir=dir_name, -d dir_name`
The server data directory.

- `--my-print-defaults=file_name, -b file_name`

The path to the my_print_defaults program.

- `--mysqld=file_name, -b file_name`

The path to the mysqld server.

- `--no-defaults, -p`

Do not read values from the configuration file. This option enables an administrator to skip reading defaults from the configuration file.

With mysql_plugin, this option need not be given first on the command line, unlike most other MySQL programs that support `--no-defaults`.

- `--plugin-dir=dir_name, -p dir_name`

The server plugin directory.

- `--plugin-ini=file_name, -i file_name`

The mysql_plugin configuration file. Relative path names are interpreted relative to the current directory. If this option is not given, the default is plugin.ini in the plugin directory, where plugin is the plugin argument on the command line.

- `--print-defaults, -P`

Display the default values from the configuration file. This option causes mysql_plugin to print the defaults for `--basedir, --datadir, and --plugin-dir` if they are found in the configuration file. If no value for a variable is found, nothing is shown.

With mysql_plugin, this option need not be given first on the command line, unlike most other MySQL programs that support `--print-defaults`.

- `--verbose, -v`

Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version, -V`

Display version information and exit.

4.4.5 mysql_secure_installation — Improve MySQL Installation Security

This program enables you to improve the security of your MySQL installation in the following ways:

- You can set a password for root accounts.

- You can remove root accounts that are accessible from outside the local host.

- You can remove anonymous-user accounts.

- You can remove the test database (which by default can be accessed by all users, even anonymous users), and privileges that permit anyone to access databases with names that start with test_.
mysql_secure_installation helps you implement security recommendations similar to those described at Section 2.10.4, "Securing the Initial MySQL Accounts".

Invoke mysql_secure_installation without arguments:

shell> mysql_secure_installation

When executed, the script prompts you to determine which actions to perform.

4.4.6 mysql_tzinfo_to_sql — Load the Time Zone Tables

The mysql_tzinfo_to_sql program loads the time zone tables in the mysql database. It is used on systems that have a zoneinfo database (the set of files describing time zones). Examples of such systems are Linux, FreeBSD, Solaris, and macOS. One likely location for these files is the /usr/share/zoneinfo directory (/usr/share/lib/zoneinfo on Solaris). If your system does not have a zoneinfo database, you can use the downloadable package described in Section 5.1.12, "MySQL Server Time Zone Support".

mysql_tzinfo_to_sql can be invoked several ways:

shell> mysql_tzinfo_to_sql tz_dir
shell> mysql_tzinfo_to_sql tz_file tz_name
shell> mysql_tzinfo_to_sql --leap tz_file

For the first invocation syntax, pass the zoneinfo directory path name to mysql_tzinfo_to_sql and send the output into the mysql program. For example:

shell> mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root mysql

mysql_tzinfo_to_sql reads your system's time zone files and generates SQL statements from them. mysql processes those statements to load the time zone tables.

The second syntax causes mysql_tzinfo_to_sql to load a single time zone file tz_file that corresponds to a time zone name tz_name:

shell> mysql_tzinfo_to_sql tz_file tz_name | mysql -u root mysql

If your time zone needs to account for leap seconds, invoke mysql_tzinfo_to_sql using the third syntax, which initializes the leap second information. tz_file is the name of your time zone file:

shell> mysql_tzinfo_to_sql --leap tz_file | mysql -u root mysql

After running mysql_tzinfo_to_sql, it is best to restart the server so that it does not continue to use any previously cached time zone data.

4.4.7 mysql_upgrade — Check and Upgrade MySQL Tables

Each time you upgrade MySQL, you should execute mysql_upgrade, which looks for incompatibilities with the upgraded MySQL server:

• It upgrades the system tables in the mysql schema so that you can take advantage of new privileges or capabilities that might have been added.

• It upgrades the Performance Schema.

• It examines user schemas.
If `mysql_upgrade` finds that a table has a possible incompatibility, it performs a table check and, if problems are found, attempts a table repair. If the table cannot be repaired, see Section 2.11.7, "Rebuilding or Repairing Tables or Indexes" for manual table repair strategies.

If you install MySQL from RPM packages on Linux, you must install the server and client RPMs. `mysql_upgrade` is included in the server RPM but requires the client RPM because the latter includes `mysqlcheck`. (See Section 2.5.1, "Installing MySQL on Linux Using RPM Packages".)

**Note**

On Windows, you must run `mysql_upgrade` with administrator privileges. You can do this by running a Command Prompt as Administrator and running the command. Failure to do so may result in the upgrade failing to execute correctly.

**Caution**

You should always back up your current MySQL installation *before* performing an upgrade. See Section 7.2, "Database Backup Methods".

Some upgrade incompatibilities may require special handling *before* upgrading your MySQL installation and running `mysql_upgrade`. See Section 2.11, "Upgrading MySQL", for instructions on determining whether any such incompatibilities apply to your installation and how to handle them.

Use `mysql_upgrade` like this:

1. Ensure that the server is running.
2. Invoke `mysql_upgrade` to upgrade the system tables in the `mysql` schema and check and repair tables in other schemas:
   ```
   shell> mysql_upgrade [options]
   ```
3. Stop the server and restart it so that any system table changes take effect.

If you have multiple MySQL server instances to upgrade, invoke `mysql_upgrade` with connection parameters appropriate for connecting to each of the desired servers. For example, with servers running on the local host on ports 3306 through 3308, upgrade each of them by connecting to the appropriate port:

   ```
   shell> mysql_upgrade --protocol=tcp -P 3306 [other_options]
   shell> mysql_upgrade --protocol=tcp -P 3307 [other_options]
   shell> mysql_upgrade --protocol=tcp -P 3308 [other_options]
   ```

   For local host connections on Unix, the `--protocol=tcp` option forces a connection using TCP/IP rather than the Unix socket file.

`mysql_upgrade` executes the following commands to check and repair tables and to upgrade the system tables:

   ```
   mysqlcheck --no-defaults --all-databases
   --fix-db-names --fix-table-names
   mysqlcheck --no-defaults --check-upgrade --all-databases
   --auto-repair
   mysql < fix_priv_tables
   ```

Notes about the preceding commands:

- `mysql_upgrade` also adds `--write-binlog` or `--skip-write-binlog` to the `mysqlcheck` commands, depending on whether the `--write-binlog` option was specified on the `mysql_upgrade` command.
• Unless invoked with the \--upgrade-system-tables option, mysql_upgrade processes all tables in all user schemas as necessary. Table checking might take a long time to complete. Each table is locked and therefore unavailable to other sessions while it is being processed. Check and repair operations can be time-consuming, particularly for large tables. Table checking uses mysqlcheck with the \--all-databases and \--check-upgrade option. For details about what \--check-upgrade entails, see the description of the FOR UPGRADE option of the CHECK TABLE statement in Section 13.7.2.2, "CHECK TABLE Statement".

• fix_priv_tables represents a script generated internally by mysql_upgrade that contains SQL statements to upgrade the tables in the mysql database.

mysql_upgrade marks all checked and repaired tables with the current MySQL version number. This ensures that the next time you run mysql_upgrade with the same version of the server, it can be determined whether there is any need to check or repair a given table again.

mysql_upgrade saves the MySQL version number in a file named mysql_upgrade_info in the data directory. This is used to quickly check whether all tables have been checked for this release so that table-checking can be skipped. To ignore this file and perform the check regardless, use the \--force option.

mysql_upgrade does not upgrade the contents of the time zone tables or help tables. For upgrade instructions, see Section 5.1.12, “MySQL Server Time Zone Support”, and Section 5.1.13, “Server-Side Help Support”.

mysql_upgrade supports the following options, which can be specified on the command line or in the [mysql_upgrade] and [client] groups of an option file. Unrecognized options are passed to mysqlcheck. For information about option files, see Section 4.2.2.2, “Using Option Files”.

Table 4.9 mysql_upgrade Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--basedir</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>--character-sets-dir</td>
<td>Directory where character sets are installed</td>
<td></td>
</tr>
<tr>
<td>--compress</td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td>--datadir</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td>--debug-check</td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td>--debug-info</td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td>--default-auth</td>
<td>Authentication plugin to use</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--default-character-set</td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Force execution even if mysql_upgrade has already been executed for current MySQL version</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
</tbody>
</table>
### mysql_upgrade — Check and Upgrade MySQL Tables

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--tmpdir</td>
<td>Directory for temporary files</td>
<td></td>
</tr>
<tr>
<td>--upgrade-system-tables</td>
<td>Update only system tables, not user schemas</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version-check</td>
<td>Check for proper server version</td>
<td>5.5.32</td>
</tr>
<tr>
<td>--write-binlog</td>
<td>Write all statements to binary log</td>
<td></td>
</tr>
</tbody>
</table>

- `--help`  
  Display a short help message and exit.

- `--basedir=dir_name`  
  The path to the MySQL installation directory. This option is accepted for backward compatibility but ignored. It is removed in MySQL 5.7.

- `--character-sets-dir=dir_name`  
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- `--compress`  
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- `--datadir=dir_name`  
  The path to the data directory. This option is accepted for backward compatibility but ignored. It is removed in MySQL 5.7.
mysql_upgrade — Check and Upgrade MySQL Tables

• **--debug=[debug_options],--# [debug_options]**

Write a debugging log. A typical `debug_options` string is `d:t:o, file_name`. The default is `d:t:o, / tmp/mysql_upgrade.trace`.

• **--debug-check**

Print some debugging information when the program exits.

• **--debug-info, -T**

Print debugging information and memory and CPU usage statistics when the program exits.

• **--default-auth=plugin**

A hint about which client-side authentication plugin to use. See Section 6.2.10, "Pluggable Authentication".

This option was added in MySQL 5.5.10.

• **--default-character-set=charset_name**

Use `charset_name` as the default character set. See Section 10.15, "Character Set Configuration".

• **--defaults-extra-file=file_name**

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

• **--defaults-file=file_name**

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

• **--defaults-group-suffix=str**

Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysql_upgrade` normally reads the `[client]` and `[mysql_upgrade]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql_upgrade` also reads the `[client_other]` and `[mysql_upgrade_other]` groups.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

• **--force**

Ignore the `mysql_upgrade_info` file and force execution even if `mysql_upgrade` has already been executed for the current version of MySQL.

• **--host=host_name, -h host_name**
mysql_upgrade — Check and Upgrade MySQL Tables

Connect to the MySQL server on the given host.

• **--no-defaults**

Do not read any option files. If program startup fails due to reading unknown options from an option file, **--no-defaults** can be used to prevent them from being read.

For additional information about this and other option-file options, see Section 4.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--password [=password], -p [password]**

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, mysql_upgrade prompts for one. If given, there must be no space between **--password=** or **-p** and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that mysql_upgrade should not prompt for one, use the **--skip-password** option.

• **--pipe, -W**

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the **named_pipe** system variable enabled to support named-pipe connections.

• **--plugin-dir=dir_name**

The directory in which to look for plugins. Specify this option if the **--default-auth** option is used to specify an authentication plugin but mysql_upgrade does not find it. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

• **--port=port_num, -P port_num**

For TCP/IP connections, the port number to use.

• **--print-defaults**

Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--protocol={TCP|SOCKET|PIPE|MEMORY}**

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

• **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is **MYSQL**. The shared-memory name is case-sensitive.
This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

- `--socket=path, -S path`

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- `--ssl*`

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

- `--tmpdir=dir_name, -t dir_name`

The path name of the directory to use for creating temporary files.

- `--upgrade-system-tables, -s`

Upgrade only the system tables in the `mysql` schema, do not upgrade user schemas.

- `--user=user_name, -u user_name`

The user name of the MySQL account to use for connecting to the server. The default user name is `root`.

- `--verbose`

Verbose mode. Print more information about what the program does.

- `--version-check, -k`

Check the version of the server to which `mysql_upgrade` is connecting to verify that it is the same as the version for which `mysql_upgrade` was built. If not, `mysql_upgrade` exits. This option is enabled by default; to disable the check, use `--skip-version-check`. This option was added in MySQL 5.5.32.

- `--write-binlog`

Cause binary logging to be enabled while `mysql_upgrade` runs. This is the default behavior; to disable binary logging during the upgrade, use the inverse of this option (that is, start the program with `--skip-write-binlog`).

### 4.5 Client Programs

This section describes client programs that connect to the MySQL server.

#### 4.5.1 `mysql` — The MySQL Command-Line Client

`mysql` is a simple SQL shell with input line editing capabilities. It supports interactive and noninteractive use. When used interactively, query results are presented in an ASCII-table format. When used noninteractively (for example, as a filter), the result is presented in tab-separated format. The output format can be changed using command options.
If you have problems due to insufficient memory for large result sets, use the \texttt{--quick} option. This forces \texttt{mysql} to retrieve results from the server a row at a time rather than retrieving the entire result set and buffering it in memory before displaying it. This is done by returning the result set using the \texttt{mysql_use_result()} C API function in the client/server library rather than \texttt{mysql_store_result()}.

Using \texttt{mysql} is very easy. Invoke it from the prompt of your command interpreter as follows:

\begin{verbatim}
shell> mysql db_name
\end{verbatim}

Or:

\begin{verbatim}
shell> mysql --user=user_name --password db_name
Enter password: your_password
\end{verbatim}

Then type an SQL statement, end it with ;, \texttt{\textbackslash g}, or \texttt{\textbackslash G} and press Enter.

Typing Control+C causes \texttt{mysql} to attempt to kill the current statement. If this cannot be done, or Control +C is typed again before the statement is killed, \texttt{mysql} exits.

You can execute SQL statements in a script file (batch file) like this:

\begin{verbatim}
shell> mysql db_name < script.sql > output.tab
\end{verbatim}

On Unix, the \texttt{mysql} client logs statements executed interactively to a history file. See Section 4.5.1.3, "mysql Client Logging".

\subsection*{4.5.1.1 mysql Client Options}

\texttt{mysql} supports the following options, which can be specified on the command line or in the \texttt{[mysql]} and \texttt{[client]} groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, "Using Option Files".

\begin{table}[h]
\centering
\caption{mysql Client Options}
\begin{tabular}{|l|l|l|}
\hline
\textbf{Option Name} & \textbf{Description} & \textbf{Introduced} \\
\hline
\texttt{--auto-rehash} & Enable automatic rehashing & \\
\hline
\texttt{--auto-vertical-output} & Enable automatic vertical result set display & \\
\hline
\texttt{--batch} & Do not use history file & \\
\hline
\texttt{--binary-as-hex} & Display binary values in hexadecimal notation & 5.5.57 \\
\hline
\texttt{--character-sets-dir} & Directory where character sets are installed & \\
\hline
\texttt{--column-names} & Write column names in results & \\
\hline
\texttt{--column-type-info} & Display result set metadata & \\
\hline
\texttt{--comments} & Whether to retain or strip comments in statements sent to the server & \\
\hline
\texttt{--compress} & Compress all information sent between client and server & \\
\hline
\texttt{--connect-timeout} & Number of seconds before connection timeout & \\
\hline
\texttt{--database} & The database to use & \\
\hline
\texttt{--debug} & Write debugging log; supported only if MySQL was built with debugging support & \\
\hline
\texttt{--debug-check} & Print debugging information when program exits & \\
\hline
\texttt{--debug-info} & Print debugging information, memory, and CPU statistics when program exits & \\
\hline
\texttt{--default-auth} & Authentication plugin to use & \\
\hline
\end{tabular}
\end{table}
<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--default-character-set</td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--delimiter</td>
<td>Set the statement delimiter</td>
<td></td>
</tr>
<tr>
<td>--enable-cleartext-plugin</td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.27</td>
</tr>
<tr>
<td>--execute</td>
<td>Execute the statement and quit</td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Continue even if an SQL error occurs</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--html</td>
<td>Produce HTML output</td>
<td></td>
</tr>
<tr>
<td>--ignore-spaces</td>
<td>Ignore spaces after function names</td>
<td></td>
</tr>
<tr>
<td>--init-command</td>
<td>SQL statement to execute after connecting</td>
<td></td>
</tr>
<tr>
<td>--line-numbers</td>
<td>Write line numbers for errors</td>
<td></td>
</tr>
<tr>
<td>--local-infile</td>
<td>Enable or disable for LOCAL capability for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--max-allowed-packet</td>
<td>Maximum packet length to send to or receive from server</td>
<td></td>
</tr>
<tr>
<td>--max-join-size</td>
<td>The automatic limit for rows in a join when using --safe-updates</td>
<td></td>
</tr>
<tr>
<td>--named-commands</td>
<td>Enable named mysql commands</td>
<td></td>
</tr>
<tr>
<td>--net-buffer-length</td>
<td>Buffer size for TCP/IP and socket communication</td>
<td></td>
</tr>
<tr>
<td>--no-auto-rehash</td>
<td>Disable automatic rehashing</td>
<td></td>
</tr>
<tr>
<td>--no-beep</td>
<td>Do not beep when errors occur</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--one-database</td>
<td>Ignore statements except those for the default database named on the command line</td>
<td></td>
</tr>
<tr>
<td>--pager</td>
<td>Use the given command for paging query output</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td></td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--prompt</td>
<td>Set the prompt to the specified format</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--quick</td>
<td>Do not cache each query result</td>
<td></td>
</tr>
<tr>
<td>--raw</td>
<td>Write column values without escape conversion</td>
<td></td>
</tr>
<tr>
<td>--reconnect</td>
<td>If the connection to the server is lost, automatically try to reconnect</td>
<td></td>
</tr>
<tr>
<td>--safe-updates, --i-am-a-dummy</td>
<td>Allow only UPDATE and DELETE statements that specify key values</td>
<td></td>
</tr>
</tbody>
</table>
### Option Name

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--secure-auth</td>
<td>Do not send passwords to server in old (pre-4.1) format</td>
<td></td>
</tr>
<tr>
<td>--select-limit</td>
<td>The automatic limit for SELECT statements when using --safe-updates</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--show-warnings</td>
<td>Show warnings after each statement if there are any</td>
<td></td>
</tr>
<tr>
<td>--sigint-ignore</td>
<td>Ignore SIGINT signals (typically the result of typing Control +C)</td>
<td></td>
</tr>
<tr>
<td>--silent</td>
<td>Silent mode</td>
<td></td>
</tr>
<tr>
<td>--skip-auto-rehash</td>
<td>Disable automatic rehashing</td>
<td></td>
</tr>
<tr>
<td>--skip-column-names</td>
<td>Do not write column names in results</td>
<td></td>
</tr>
<tr>
<td>--skip-line-numbers</td>
<td>Skip line numbers for errors</td>
<td></td>
</tr>
<tr>
<td>--skip-named-commands</td>
<td>Disable named mysql commands</td>
<td></td>
</tr>
<tr>
<td>--skip-pager</td>
<td>Disable paging</td>
<td></td>
</tr>
<tr>
<td>--skip-reconnect</td>
<td>Disable reconnecting</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--table</td>
<td>Display output in tabular format</td>
<td></td>
</tr>
<tr>
<td>--tee</td>
<td>Append a copy of output to named file</td>
<td></td>
</tr>
<tr>
<td>--unbuffered</td>
<td>Flush the buffer after each query</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
<tr>
<td>--vertical</td>
<td>Print query output rows vertically (one line per column value)</td>
<td></td>
</tr>
<tr>
<td>--wait</td>
<td>If the connection cannot be established, wait and retry instead of aborting</td>
<td></td>
</tr>
<tr>
<td>--xml</td>
<td>Produce XML output</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**

Display a help message and exit.
• **--auto-rehash**

Enable automatic rehashing. This option is on by default, which enables database, table, and column name completion. Use `--disable-auto-rehash` to disable rehashing. That causes `mysql` to start faster, but you must issue the `rehash` command or its `\#` shortcut if you want to use name completion.

To complete a name, enter the first part and press Tab. If the name is unambiguous, `mysql` completes it. Otherwise, you can press Tab again to see the possible names that begin with what you have typed so far. Completion does not occur if there is no default database.

**Note**

This feature requires a MySQL client that is compiled with the `readline` library. Typically, the `readline` library is not available on Windows.

• **--auto-vertical-output**

Cause result sets to be displayed vertically if they are too wide for the current window, and using normal tabular format otherwise. (This applies to statements terminated by ; or \G.)

• **--batch, -B**

Print results using tab as the column separator, with each row on a new line. With this option, `mysql` does not use the history file.

Batch mode results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the **--raw** option.

• **--binary-as-hex**

When this option is given, `mysql` displays binary data using hexadecimal notation (\0xvalue). This occurs whether the overall output display format is tabular, vertical, HTML, or XML.

This option was added in MySQL 5.5.57.

• **--bind-address=ip_address**

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of the `mysql` client that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

• **--character-sets-dir=dir_name**

The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

• **--column-names**

Write column names in results.

• **--column-type-info**

Display result set metadata.

• **--comments, -c**

Whether to strip or preserve comments in statements sent to the server. The default is **--skip-comments** (strip comments), enable with **--comments** (preserve comments).
• --compress, -C
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

• --connect-timeout=value
  The number of seconds before connection timeout. (Default value is 0.)

• --database=db_name, -D db_name
  The database to use. This is useful primarily in an option file.

• --debug[=debug_options], -# [debug_options]
  Write a debugging log. A typical debug_options string is d:t:o, file_name. The default is d:t:o, /tmp/mysql.trace.

  This option is available only if MySQL was built using WITH_DEBUG. MySQL release binaries provided by Oracle are not built using this option.

• --debug-check
  Print some debugging information when the program exits.

• --debug-info, -T
  Print debugging information and memory and CPU usage statistics when the program exits.

• --default-auth=plugin
  A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.

• --default-character-set=charset_name
  Use charset_name as the default character set for the client and connection.

  This option can be useful if the operating system uses one character set and the mysql client by default uses another. In this case, output may be formatted incorrectly. You can usually fix such issues by using this option to force the client to use the system character set instead.

  For more information, see Section 10.4, “Connection Character Sets and Collations”, and Section 10.15, “Character Set Configuration”.

• --defaults-extra-file=file_name
  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --defaults-file=file_name
  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.
• --defaults-group-suffix=\texttt{str}

Read not only the usual option groups, but also groups with the usual names and a suffix of \texttt{str}. For example, \texttt{mysql} normally reads the \texttt{[client]} and \texttt{[mysql]} groups. If the \texttt{--defaults-group-suffix=_other} option is given, \texttt{mysql} also reads the \texttt{[client_other]} and \texttt{[mysql_other]} groups.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --delimiter=\texttt{str}

Set the statement delimiter. The default is the semicolon character (\texttt{;}).

• --disable-named-commands

Disable named commands. Use the \texttt{\*} form only, or use named commands only at the beginning of a line ending with a semicolon (\texttt{;}). \texttt{mysql} starts with this option \textit{enabled} by default. However, even with this option, long-format commands still work from the first line. See Section 4.5.1.2, “mysql Client Commands”.

• --enable-cleartext-plugin

Enable the \texttt{mysql_clear_password} cleartext authentication plugin. (See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

• --execute=\texttt{statement}, -e \texttt{statement}

Execute the statement and quit. The default output format is like that produced with \texttt{--batch}. See Section 4.2.2.1, “Using Options on the Command Line”, for some examples. With this option, \texttt{mysql} does not use the history file.

• --force, -f

Continue even if an SQL error occurs.

• --host=\texttt{host_name}, -h \texttt{host_name}

Connect to the MySQL server on the given host.

• --html, -H

Produce HTML output.

• --ignore-spaces, -i

Ignore spaces after function names. The effect of this is described in the discussion for the \texttt{IGNORE_SPACE} SQL mode (see Section 5.1.10, “Server SQL Modes”).

• --init-command=\texttt{str}

SQL statement to execute after connecting to the server. If auto-reconnect is enabled, the statement is executed again after reconnection occurs.

• --line-numbers

Write line numbers for errors. Disable this with \texttt{--skip-line-numbers}.

• --local-infile[={0\mid1}]
Enable or disable LOCAL capability for LOAD DATA. For mysql, this capability is disabled by default. With no value, the option enables LOCAL. The option may be given as --local-infile=0 or --local-infile=1 to explicitly disable or enable LOCAL. Enabling local data loading also requires that the server permits it; see Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

• --max-allowed-packet=value
  The maximum size of the buffer for client/server communication. The default is 16MB, the maximum is 1GB.

• --max-join-size=value
  The automatic limit for rows in a join when using --safe-updates. (Default value is 1,000,000.)

• --named-commands, -G
  Enable named mysql commands. Long-format commands are permitted, not just short-format commands. For example, quit and \q both are recognized. Use --skip-named-commands to disable named commands. See Section 4.5.1.2, “mysql Client Commands”.

• --net-buffer-length=value
  The buffer size for TCP/IP and socket communication. (Default value is 16KB.)

• --no-auto-rehash, -A
  This has the same effect as --skip-auto-rehash. See the description for --auto-rehash.

• --no-beep, -b
  Do not beep when errors occur.

• --no-defaults
  Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --one-database, -o
  Ignore statements except those that occur while the default database is the one named on the command line. This option is rudimentary and should be used with care. Statement filtering is based only on USE statements.

  Initially, mysql executes statements in the input because specifying a database db_name on the command line is equivalent to inserting USE db_name at the beginning of the input. Then, for each USE statement encountered, mysql accepts or rejects following statements depending on whether the database named is the one on the command line. The content of the statements is immaterial.

  Suppose that mysql is invoked to process this set of statements:

  ```sql
  DELETE FROM db2.t2;
  USE db2;
  DROP TABLE db1.t1;
  CREATE TABLE db1.t1 (i INT);
  USE db1;
  INSERT INTO t1 (i) VALUES(1);
  ```
CREATE TABLE db2.t1 (j INT);

If the command line is `mysql --force --one-database db1`, `mysql` handles the input as follows:

- The DELETE statement is executed because the default database is `db1`, even though the statement names a table in a different database.
- The DROP TABLE and CREATE TABLE statements are not executed because the default database is not `db1`, even though the statements name a table in `db1`.
- The INSERT and CREATE TABLE statements are executed because the default database is `db1`, even though the CREATE TABLE statement names a table in a different database.

- **--pager[=command]**

  Use the given command for paging query output. If the command is omitted, the default pager is the value of your `PAGER` environment variable. Valid pagers are `less`, `more`, `cat [> filename]`, and so forth. This option works only on Unix and only in interactive mode. To disable paging, use **--skip-pager**. Section 4.5.1.2, “mysql Client Commands”, discusses output paging further.

- **--password[=password], -p[password]**

  The password of the MySQL account used for connecting to the server. The password value is optional. If not given, `mysql` prompts for one. If given, there must be no space between --password= or -p and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that `mysql` should not prompt for one, use the **--skip-password** option.

- **--pipe, -W**

  On Windows, connect to the server using a named pipe. This option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- **--plugin-dir=dir_name**

  The directory in which to look for plugins. Specify this option if the **--default-auth** option is used to specify an authentication plugin but `mysql` does not find it. See Section 6.2.10, “Pluggable Authentication”.

- **--port=port_num, -P port_num**

  For TCP/IP connections, the port number to use.

- **--print-defaults**

  Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.
• **--prompt=format_str**

Set the prompt to the specified format. The default is `mysql>`. The special sequences that the prompt can contain are described in Section 4.5.1.2, "mysql Client Commands".

• **--protocol={TCP|SOCKET|PIPE|MEMORY}**

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, "Connecting to the MySQL Server Using Command Options".

• **--quick,-q**

Do not cache each query result, print each row as it is received. This may slow down the server if the output is suspended. With this option, `mysql` does not use the history file.

• **--raw,-r**

For tabular output, the “boxing” around columns enables one column value to be distinguished from another. For nontabular output (such as is produced in batch mode or when the `--batch` or `--silent` option is given), special characters are escaped in the output so they can be identified easily. Newline, tab, NUL, and backslash are written as \n, \t, \0, and \. The `--raw` option disables this character escaping.

The following example demonstrates tabular versus nontabular output and the use of raw mode to disable escaping:

```sql
% mysql
mysql> SELECT CHAR(92);
+----------+
| CHAR(92) |
+----------+
| \        |
+----------+
%
mysql -s
mysql> SELECT CHAR(92);
CHAR(92)
\\
%
mysql -s -r
mysql> SELECT CHAR(92);
CHAR(92)
\
```

• **--reconnect**

If the connection to the server is lost, automatically try to reconnect. A single reconnect attempt is made each time the connection is lost. To suppress reconnection behavior, use `--skip-reconnect`.

• **--safe-updates,--i-am-a-dummy,-U**

If this option is enabled, `UPDATE` and `DELETE` statements that do not use a key in the `WHERE` clause or a `LIMIT` clause produce an error. In addition, restrictions are placed on `SELECT` statements that produce (or are estimated to produce) very large result sets. If you have set this option in an option file, you can use `--skip-safe-updates` on the command line to override it. For more information about this option, see Using Safe-Updates Mode (`--safe-updates`).
• **--secure-auth**

Do not send passwords to the server in old (pre-4.1) format. This prevents connections except for servers that use the newer password format.

**Note**

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

• **--select-limit=value**

The automatic limit for `SELECT` statements when using `--safe-updates`. (Default value is 1,000.)

• **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.

This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

• **--show-warnings**

Cause warnings to be shown after each statement if there are any. This option applies to interactive and batch mode.

• **--sigint-ignore**

Ignore `SIGINT` signals (typically the result of typing `Control+C`).

Without this option, typing `Control+C` interrupts the current statement if there is one, or cancels any partial input line otherwise.

• **--silent, -s**

Silent mode. Produce less output. This option can be given multiple times to produce less and less output.

This option results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the `--raw` option.

• **--skip-column-names, -N**

Do not write column names in results.

• **--skip-line-numbers, -L**

Do not write line numbers for errors. Useful when you want to compare result files that include error messages.

• **--socket=path, -S path**

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.
• **--ssl***

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

• **--table, -t**

Display output in table format. This is the default for interactive use, but can be used to produce table output in batch mode.

• **--tee=file_name**

Append a copy of output to the given file. This option works only in interactive mode. Section 4.5.1.2, “mysql Client Commands”, discusses tee files further.

• **--unbuffered, -n**

Flush the buffer after each query.

• **--user=user_name, -u user_name**

The user name of the MySQL account to use for connecting to the server.

• **--verbose, -v**

Verbose mode. Produce more output about what the program does. This option can be given multiple times to produce more and more output. (For example, `--v --v --v` produces table output format even in batch mode.)

• **--version, -V**

Display version information and exit.

• **--vertical, -E**

Print query output rows vertically (one line per column value). Without this option, you can specify vertical output for individual statements by terminating them with `\G`.

• **--wait, -w**

If the connection cannot be established, wait and retry instead of aborting.

• **--xml, -X**

Produce XML output.

```xml
<field name="column_name">NULL</field>
```

The output when `--xml` is used with mysql matches that of mysqldump `--xml`. See Section 4.5.4, “mysqldump — A Database Backup Program”, for details.

The XML output also uses an XML namespace, as shown here:

```sql
shell> mysql --xml -uroot -e "SHOW VARIABLES LIKE 'version%';"

<resultset statement="SHOW VARIABLES LIKE 'version%'">
  <row>
    <field name="Variable_name">version</field>
    <field name="Value">5.0.40-debug</field>
  </row>
</resultset>
```
4.5.1.2 mysql Client Commands

mysql sends each SQL statement that you issue to the server to be executed. There is also a set of commands that mysql itself interprets. For a list of these commands, type help or \h at the mysql> prompt:

mysql> help

List of all MySQL commands:
Note that all text commands must be first on line and end with ';
?
\?
Synonym for 'help'.
clear \c
Clear the current input statement.
connect \r
Reconnect to the server. Optional arguments are db and host.
delimiter \d
Set statement delimiter.
edit \e
Edit command with $EDITOR.
ego \G
Send command to mysql server, display result vertically.
ext \q
Exit mysql. Same as quit.
go \g
Send command to mysql server.
help \h
Display this help.
nopager \n
Disables pager, print to stdout.
notee \t
Don't write into outfile.
pager \P
Set PAGER [to_pager]. Print the query results via PAGER.
print \p
Print current command.
prompt \R
Change your mysql prompt.
quit \q
Quit mysql.
rehash \#
Rebuild completion hash.
source \.
Execute an SQL script file. Takes a file name as an argument.
status \s
Get status information from the server.
system \!
Execute a system shell command.
tee \T
Set outfile [to_outfile]. Append everything into given outfile.
use \u
Use another database. Takes database name as argument.
charset \C
Switch to another charset. Might be needed for processing
binlog with multi-byte charsets.
warnings \W
Show warnings after every statement.
nowarning \w
Don't show warnings after every statement.

For server side help, type 'help contents'

Each command has both a long and short form. The long form is not case-sensitive; the short form is. The long form can be followed by an optional semicolon terminator, but the short form should not.

The use of short-form commands within multiple-line /* ... */ comments is not supported.

- help [arg], \h [arg], \? [arg], ? [arg]
  Display a help message listing the available mysql commands.
If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. For more information, see Section 4.5.1.4, “mysql Client Server-Side Help”.

- `charset charset_name, \C charset_name`

  Change the default character set and issue a `SET NAMES` statement. This enables the character set to remain synchronized on the client and server if `mysql` is run with auto-reconnect enabled (which is not recommended), because the specified character set is used for reconnects.

- `clear, \c`

  Clear the current input. Use this if you change your mind about executing the statement that you are entering.

- `connect [db_name host_name], \r [db_name host_name]`

  Reconnect to the server. The optional database name and host name arguments may be given to specify the default database or the host where the server is running. If omitted, the current values are used.

- `delimiter str, \d str`

  Change the string that `mysql` interprets as the separator between SQL statements. The default is the semicolon character (`;`).

  The delimiter string can be specified as an unquoted or quoted argument on the `delimiter` command line. Quoting can be done with either single quote (`'`), double quote (`"`), or backtick (`'`) characters. To include a quote within a quoted string, either quote the string with a different quote character or escape the quote with a backslash (`\`) character. Backslash should be avoided outside of quoted strings because it is the escape character for MySQL. For an unquoted argument, the delimiter is read up to the first space or end of line. For a quoted argument, the delimiter is read up to the matching quote on the line.

  `mysql` interprets instances of the delimiter string as a statement delimiter anywhere it occurs, except within quoted strings. Be careful about defining a delimiter that might occur within other words. For example, if you define the delimiter as `X`, you will be unable to use the word `INDEX` in statements. `mysql` interprets this as `INDE` followed by the delimiter `X`.

  When the delimiter recognized by `mysql` is set to something other than the default of `;`, instances of that character are sent to the server without interpretation. However, the server itself still interprets `;` as a statement delimiter and processes statements accordingly. This behavior on the server side comes into play for multiple-statement execution (see Section 23.7.15, “C API Multiple Statement Execution Support”), and for parsing the body of stored procedures and functions, triggers, and events (see Section 20.1, “Defining Stored Programs”).

- `edit, \e`

  Edit the current input statement. `mysql` checks the values of the `EDITOR` and `VISUAL` environment variables to determine which editor to use. The default editor is `vi` if neither variable is set.

  The `edit` command works only in Unix.

- `ego, \G`

  Send the current statement to the server to be executed and display the result using vertical format.
mysql — The MySQL Command-Line Client

• exit, \q
Exit mysql.

• go, \g
Send the current statement to the server to be executed.

• nopager, \n
Disable output paging. See the description for pager.
The nopager command works only in Unix.

• notee, \t
Disable output copying to the tee file. See the description for tee.

• nowarning, \w
Disable display of warnings after each statement.

• pager [command], \P [command]
Enable output paging. By using the --pager option when you invoke mysql, it is possible to browse or search query results in interactive mode with Unix programs such as less, more, or any other similar program. If you specify no value for the option, mysql checks the value of the PAGER environment variable and sets the pager to that. Pager functionality works only in interactive mode.

Output paging can be enabled interactively with the pager command and disabled with nopager. The command takes an optional argument; if given, the paging program is set to that. With no argument, the pager is set to the pager that was set on the command line, or stdout if no pager was specified.

Output paging works only in Unix because it uses the popen() function, which does not exist on Windows. For Windows, the tee option can be used instead to save query output, although it is not as convenient as pager for browsing output in some situations.

• print, \p
Print the current input statement without executing it.

• prompt [str], \R [str]
Reconfigure the mysql prompt to the given string. The special character sequences that can be used in the prompt are described later in this section.

If you specify the prompt command with no argument, mysql resets the prompt to the default of mysql>.

• quit, \q
Exit mysql.

• rehash, \#
Rebuild the completion hash that enables database, table, and column name completion while you are entering statements. (See the description for the --auto-rehash option.)

• source file_name, \ file_name
Read the named file and executes the statements contained therein. On Windows, specify path name separators as / or \.

Quote characters are taken as part of the file name itself. For best results, the name should not include space characters.

* status, \s

Provide status information about the connection and the server you are using. If you are running with --safe-updates enabled, status also prints the values for the mysql variables that affect your queries.

* system command, \! command

Execute the given command using your default command interpreter.

The system command works only in Unix.

* tee [file_name], \T [file_name]

By using the --tee option when you invoke mysql, you can log statements and their output. All the data displayed on the screen is appended into a given file. This can be very useful for debugging purposes also. mysql flushes results to the file after each statement, just before it prints its next prompt. Tee functionality works only in interactive mode.

You can enable this feature interactively with the tee command. Without a parameter, the previous file is used. The tee file can be disabled with the notee command. Executing tee again re-enables logging.

* use db_name, \u db_name

Use db_name as the default database.

* warnings, \W

Enable display of warnings after each statement (if there are any).

Here are a few tips about the pager command:

* You can use it to write to a file and the results go only to the file:

```
mysql> pager cat > /tmp/log.txt
```

You can also pass any options for the program that you want to use as your pager:

```
mysql> pager less -n -i -S
```

* In the preceding example, note the -S option. You may find it very useful for browsing wide query results. Sometimes a very wide result set is difficult to read on the screen. The -S option to less can make the result set much more readable because you can scroll it horizontally using the left-arrow and right-arrow keys. You can also use -S interactively within less to switch the horizontal-browse mode on and off. For more information, read the less manual page:

```
shell> man less
```

* The -F and -X options may be used with less to cause it to exit if output fits on one screen, which is convenient when no scrolling is necessary:

```
mysql> pager less -n -i -S -F -X
```

* You can specify very complex pager commands for handling query output:
In this example, the command would send query results to two files in two different directories on two different file systems mounted on /dr1 and /dr2, yet still display the results onscreen using less.

You can also combine the tee and pager functions. Have a tee file enabled and pager set to less, and you are able to browse the results using the less program and still have everything appended into a file the same time. The difference between the Unix tee used with the pager command and the mysql built-in tee command is that the built-in tee works even if you do not have the Unix tee available. The built-in tee also logs everything that is printed on the screen, whereas the Unix tee used with pager does not log quite that much. Additionally, tee file logging can be turned on and off interactively from within mysql. This is useful when you want to log some queries to a file, but not others.

The prompt command reconfigures the default mysql> prompt. The string for defining the prompt can contain the following special sequences.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\c</td>
<td>A counter that increments for each statement you issue</td>
</tr>
<tr>
<td>\D</td>
<td>The full current date</td>
</tr>
<tr>
<td>\d</td>
<td>The default database</td>
</tr>
<tr>
<td>\h</td>
<td>The server host</td>
</tr>
<tr>
<td>\l</td>
<td>The current delimiter</td>
</tr>
<tr>
<td>\m</td>
<td>Minutes of the current time</td>
</tr>
<tr>
<td>\n</td>
<td>A newline character</td>
</tr>
<tr>
<td>\o</td>
<td>The current month in three-letter format (Jan, Feb, …)</td>
</tr>
<tr>
<td>\o</td>
<td>The current month in numeric format</td>
</tr>
<tr>
<td>\P</td>
<td>am/pm</td>
</tr>
<tr>
<td>\p</td>
<td>The current TCP/IP port or socket file</td>
</tr>
<tr>
<td>\R</td>
<td>The current time, in 24-hour military time (0–23)</td>
</tr>
<tr>
<td>\r</td>
<td>The current time, standard 12-hour time (1–12)</td>
</tr>
<tr>
<td>\S</td>
<td>Semicolon</td>
</tr>
<tr>
<td>\s</td>
<td>Seconds of the current time</td>
</tr>
<tr>
<td>\t</td>
<td>A tab character</td>
</tr>
<tr>
<td>\U</td>
<td>Your full user_name@host_name account name</td>
</tr>
<tr>
<td>\u</td>
<td>Your user name</td>
</tr>
<tr>
<td>\v</td>
<td>The server version</td>
</tr>
<tr>
<td>\w</td>
<td>The current day of the week in three-letter format (Mon, Tue, …)</td>
</tr>
<tr>
<td>\Y</td>
<td>The current year, four digits</td>
</tr>
<tr>
<td>\y</td>
<td>The current year, two digits</td>
</tr>
<tr>
<td>_</td>
<td>A space</td>
</tr>
<tr>
<td>\</td>
<td>A space (a space follows the backslash)</td>
</tr>
<tr>
<td>'</td>
<td>Single quote</td>
</tr>
<tr>
<td>&quot;</td>
<td>Double quote</td>
</tr>
</tbody>
</table>
### Option Description

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>\</code></td>
<td>A literal \ backslash character</td>
</tr>
<tr>
<td><code>\x</code></td>
<td><code>x</code>, for any “x” not listed above</td>
</tr>
</tbody>
</table>

You can set the prompt in several ways:

- **Use an environment variable.** You can set the `MYSQL_PS1` environment variable to a prompt string. For example:

  ```shell
  export MYSQL_PS1="(\u@\h) [\d]> "
  ```

- **Use a command-line option.** You can set the `--prompt` option on the command line to `mysql`. For example:

  ```shell
  mysql --prompt="(\u@\h) [\d]> "
  ```

- **Use an option file.** You can set the `prompt` option in the `[mysql]` group of any MySQL option file, such as `/etc/my.cnf` or the `.my.cnf` file in your home directory. For example:

  ```ini
  [mysql]
  prompt="(\u@\h) [\d]> \\_
  ```

In this example, note that the backslashes are doubled. If you set the prompt using the `prompt` option in an option file, it is advisable to double the backslashes when using the special prompt options. There is some overlap in the set of permissible prompt options and the set of special escape sequences that are recognized in option files. (The rules for escape sequences in option files are listed in Section 4.2.2.2, “Using Option Files”.) The overlap may cause you problems if you use single backslashes. For example, `\s` is interpreted as a space rather than as the current seconds value. The following example shows how to define a prompt within an option file to include the current time in `hh:mm:ss>` format:

```ini
[mysql]
prompt="\r:\m:\s> "
```

- **Set the prompt interactively.** You can change your prompt interactively by using the `prompt` (or `\R`) command. For example:

  ```sql
  mysql> prompt (\u@\h) [\d]\_
  PROMPT set to ' (\u@\h) [\d]\_'
  (user@host) [database]>
  (user@host) [database]> prompt
  Returning to default PROMPT of mysql>
  mysql>
  ```

### 4.5.1.3 mysql Client Logging

On Unix, the `mysql` client logs statements executed interactively to a history file. By default, this file is named `.mysql_history` in your home directory. To specify a different file, set the value of the `MYSQL_HISTFILE` environment variable.

- **How Logging Occurs**
- **Controlling the History File**

#### How Logging Occurs

Statement logging occurs as follows:
• Statements are logged only when executed interactively. Statements are noninteractive, for example, when read from a file or a pipe. It is also possible to suppress statement logging by using the --batch or --execute option.

• `mysql` logs each nonempty statement line individually.

• If a statement spans multiple lines (not including the terminating delimiter), `mysql` concatenates the lines to form the complete statement, maps newlines to spaces, and logs the result, plus a delimiter.

Consequently, an input statement that spans multiple lines can be logged twice. Consider this input:

```
mysql> SELECT
       -> 'Today is'
       -> ,
       -> CURDATE()
       -> ;
```

In this case, `mysql` logs the “SELECT”, “Today is”, “,”, “CURDATE()”, and “;” lines as it reads them. It also logs the complete statement, after mapping `SELECT
'Today is'
,\nCURDATE()` to `SELECT 'Today is' , CURDATE()`, plus a delimiter. Thus, these lines appear in logged output:

```
SELECT
'Today is'
, CURDATE()
;
SELECT 'Today is' , CURDATE();
```

## Controlling the History File

The `.mysql_history` file should be protected with a restrictive access mode because sensitive information might be written to it, such as the text of SQL statements that contain passwords. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

If you do not want to maintain a history file, first remove `.mysql_history` if it exists. Then use either of the following techniques to prevent it from being created again:

• Set the `MYSQL_HISTFILE` environment variable to `/dev/null`. To cause this setting to take effect each time you log in, put it in one of your shell's startup files.

• Create `.mysql_history` as a symbolic link to `/dev/null`; this need be done only once:

```
shell> ln -s /dev/null $HOME/.mysql_history
```

### 4.5.1.4 mysql Client Server-Side Help

If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. The proper operation of this command requires that the help tables in the `mysql` database be initialized with help topic information (see Section 5.1.13, “Server-Side Help Support”).

If there is no match for the search string, the search fails:

```
mysql> help me
Nothing found
Please try to run 'help contents' for a list of all accessible topics
```
Use `help contents` to see a list of the help categories:

```
mysql> help contents
You asked for help about help category: "Contents"
For more information, type 'help <item>', where <item> is one of the
following categories:
  Account Management
  Administration
  Data Definition
  Data Manipulation
  Data Types
  Functions
  Functions and Modifiers for Use with GROUP BY
  Geographic Features
  Language Structure
  Plugins
  Storage Engines
  Stored Routines
  Table Maintenance
  Transactions
  Triggers
```

If the search string matches multiple items, `mysql` shows a list of matching topics:

```
mysql> help logs
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following topics:
  SHOW
  SHOW BINARY LOGS
  SHOW ENGINE
  SHOW LOGS
```

Use a topic as the search string to see the help entry for that topic:

```
mysql> help show binary logs
Name: 'SHOW BINARY LOGS'
Description:
Syntax:
SHOW BINARY LOGS
SHOW MASTER LOGS
Lists the binary log files on the server. This statement is used as
part of the procedure described in [purge-binary-logs], that shows how
to determine which logs can be purged.
mysql> SHOW BINARY LOGS;
+---------------+-----------+
| Log_name      | File_size |
|---------------+-----------|
| binlog.000015 |    724935 |
| binlog.000016 |    733481 |
+---------------+-----------+
```

The search string can contain the wildcard characters `%` and `_`. These have the same meaning as for
pattern-matching operations performed with the `LIKE` operator. For example, `HELP rep%` returns a list of
topics that begin with `rep`:

```
mysql> HELP rep%
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following
topics:
  REPAIR TABLE
  REPEAT FUNCTION
```
4.5.1.5 Executing SQL Statements from a Text File

The mysql client typically is used interactively, like this:

shell> mysql db_name

However, it is also possible to put your SQL statements in a file and then tell mysql to read its input from that file. To do so, create a text file text_file that contains the statements you wish to execute. Then invoke mysql as shown here:

shell> mysql db_name < text_file

If you place a USE db_name statement as the first statement in the file, it is unnecessary to specify the database name on the command line:

shell> mysql < text_file

If you are already running mysql, you can execute an SQL script file using the source command or \ command:

mysql> source file_name
mysql> \ file_name

Sometimes you may want your script to display progress information to the user. For this you can insert statements like this:

SELECT '<info_to_display>' AS ' ';

The statement shown outputs <info_to_display>.

You can also invoke mysql with the --verbose option, which causes each statement to be displayed before the result that it produces.

mysql ignores Unicode byte order mark (BOM) characters at the beginning of input files. Previously, it read them and sent them to the server, resulting in a syntax error. Presence of a BOM does not cause mysql to change its default character set. To do that, invoke mysql with an option such as --default-character-set=utf8.

For more information about batch mode, see Section 3.5, “Using mysql in Batch Mode”.

4.5.1.6 mysql Client Tips

This section provides information about techniques for more effective use of mysql and about mysql operational behavior.

- Input-Line Editing
- Displaying Query Results Vertically
- Using Safe-Updates Mode (--safe-updates)
- Disabling mysql Auto-Reconnect
- mysql Client Parser Versus Server Parser
**Input-Line Editing**

`mysql` supports input-line editing, which enables you to modify the current input line in place or recall previous input lines. For example, the **left-arrow** and **right-arrow** keys move horizontally within the current input line, and the **up-arrow** and **down-arrow** keys move up and down through the set of previously entered lines. **Backspace** deletes the character before the cursor and typing new characters enters them at the cursor position. To enter the line, press **Enter**.

On Windows, the editing key sequences are the same as supported for command editing in console windows. On Unix, the key sequences depend on the input library used to build `mysql` (for example, the **libedit** or **readline** library).

Documentation for the **libedit** and **readline** libraries is available online. To change the set of key sequences permitted by a given input library, define key bindings in the library startup file. This is a file in your home directory: `.editrc` for **libedit** and `.inputrc` for **readline**.

For example, in **libedit**, **Control+W** deletes everything before the current cursor position and **Control+U** deletes the entire line. In **readline**, **Control+W** deletes the word before the cursor and **Control+U** deletes everything before the current cursor position. If `mysql` was built using **libedit**, a user who prefers the **readline** behavior for these two keys can put the following lines in the `.editrc` file (creating the file if necessary):

```
bind "^W" ed-delete-prev-word
bind "^U" vi-kill-line-prev
```

To see the current set of key bindings, temporarily put a line that says only `bind` at the end of `.editrc`. `mysql` will show the bindings when it starts.

**Displaying Query Results Vertically**

Some query results are much more readable when displayed vertically, instead of in the usual horizontal table format. Queries can be displayed vertically by terminating the query with `\G` instead of a semicolon. For example, longer text values that include newlines often are much easier to read with vertical output:

```
mysql> SELECT * FROM mails WHERE LENGTH(txt) < 300 LIMIT 300,1\G
*************************** 1. row ***************************
  msg_nro: 3068
  date: 2000-03-01 23:29:50
  time_zone: +0200
  mail_from: Jones
  reply: jones@no.spam.com
  mail_to: "John Smith" <smith@example.com>
  subj: UTF-8
  txt: >>>>> "John" == John Smith writes:
        John> Hi.  I think this is a good idea.  Is anyone familiar
        John> with UTF-8 or Unicode? Otherwise, I'll put this on my
        John> TODO list and see what happens.
        Yes, please do that.
        Regards,
        Jones
  file: inbox-jani-1
  hash: 190402944
1 row in set (0.09 sec)
```

**Using Safe-Updates Mode (--safe-updates)**

For beginners, a useful startup option is **--safe-updates** (or **--i-am-a-dummy**, which has the same effect). Safe-updates mode is helpful for cases when you might have issued an **UPDATE** or **DELETE**
statement but forgotten the **WHERE** clause indicating which rows to modify. Normally, such statements update or delete all rows in the table. With **--safe-updates**, you can modify rows only by specifying the key values that identify them, or a **LIMIT** clause, or both. This helps prevent accidents. Safe-updates mode also restricts **SELECT** statements that produce (or are estimated to produce) very large result sets.

The **--safe-updates** option causes **mysql** to execute the following statement when it connects to the MySQL server, to set the session values of the **sql_safe_updates**, **sql_select_limit**, and **max_join_size** system variables:

```
SET sql_safe_updates=1, sql_select_limit=1000, sql_max_join_size=1000000;
```

The **SET** statement affects statement processing as follows:

- **Enabling** **sql_safe_updates** causes **UPDATE** and **DELETE** statements to produce an error if they do not specify a key constraint in the **WHERE** clause, or provide a **LIMIT** clause, or both. For example:

  ```
  UPDATE tbl_name SET not_key_column=val WHERE key_column=val;
  UPDATE tbl_name SET not_key_column=val LIMIT 1;
  ```

- **Setting** **sql_select_limit** to 1,000 causes the server to limit all **SELECT** result sets to 1,000 rows unless the statement includes a **LIMIT** clause.

- **Setting** **max_join_size** to 1,000,000 causes multiple-table **SELECT** statements to produce an error if the server estimates it must examine more than 1,000,000 row combinations.

To specify result set limits different from 1,000 and 1,000,000, you can override the defaults by using the **--select-limit** and **--max-join-size** options when you invoke **mysql**:

```
mysql --safe-updates --select-limit=500 --max-join-size=10000
```

It is possible for **UPDATE** and **DELETE** statements to produce an error in safe-updates mode even with a key specified in the **WHERE** clause, if the optimizer decides not to use the index on the key column. For example, if key comparisons require type conversion, the index may not be used (see Section 8.3.1, “How MySQL Uses Indexes”). Suppose that an indexed string column **c1** is compared to a numeric value using **WHERE c1 = 2222**. For such comparisons, the string value is converted to a number and the operands are compared numerically (see Section 12.2, “Type Conversion in Expression Evaluation”), preventing use of the index. If safe-updates mode is enabled, an error occurs.

### Disabling mysql Auto-Reconnect

If the **mysql** client loses its connection to the server while sending a statement, it immediately and automatically tries to reconnect once to the server and send the statement again. However, even if **mysql** succeeds in reconnecting, your first connection has ended and all your previous session objects and settings are lost: temporary tables, the autocommit mode, and user-defined and session variables. Also, any current transaction rolls back. This behavior may be dangerous for you, as in the following example where the server was shut down and restarted between the first and second statements without you knowing it:

```
mysql> SET @a=1;
Query OK, 0 rows affected (0.05 sec)
mysql> INSERT INTO t VALUES(@a);
ERROR 2006: MySQL server has gone away
No connection. Trying to reconnect...
Connection id:    1
Current database: test
```
Query OK, 1 row affected (1.30 sec)

mysql> SELECT * FROM t;
+------+
| a    |
+------+
| NULL |
+------+
1 row in set (0.05 sec)

The `@a` user variable has been lost with the connection, and after the reconnection it is undefined. If it is important to have `mysql` terminate with an error if the connection has been lost, you can start the `mysql` client with the `--skip-reconnect` option.

For more information about auto-reconnect and its effect on state information when a reconnection occurs, see Section 23.7.19, “C API Automatic Reconnection Control”.

**mysql Client Parser Versus Server Parser**

The `mysql` client uses a parser on the client side that is not a duplicate of the complete parser used by the `mysqld` server on the server side. This can lead to differences in treatment of certain constructs. Examples:

- The server parser treats strings delimited by " characters as identifiers rather than as plain strings if the `ANSI_QUOTES` SQL mode is enabled.

  The `mysql` client parser does not take the `ANSI_QUOTES` SQL mode into account. It treats strings delimited by "", ' and ` characters the same, regardless of whether `ANSI_QUOTES` is enabled.

- Within `/*! ... */` comments, the `mysql` client parser interprets short-form `mysql` commands. The server parser does not interpret them because these commands have no meaning on the server side.

  If it is desirable for `mysql` not to interpret short-form commands within comments, a partial workaround is to use the `--binary-mode` option, which causes all `mysql` commands to be disabled except `\C` and `\d` in noninteractive mode (for input piped to `mysql` or loaded using the `source` command).

**4.5.2 mysqladmin — Client for Administering a MySQL Server**

`mysqladmin` is a client for performing administrative operations. You can use it to check the server’s configuration and current status, to create and drop databases, and more.

Invoke `mysqladmin` like this:

```
shell> mysqladmin [options] command [command-arg] [command [command-arg]] ...
```

`mysqladmin` supports the following commands. Some of the commands take an argument following the command name.

- `create db_name`

  Create a new database named `db_name`.

- `debug`

  Tell the server to write debug information to the error log. The connected user must have the `SUPER` privilege. Format and content of this information is subject to change.

  This includes information about the Event Scheduler. See Section 20.4.5, “Event Scheduler Status”.
• **drop db_name**
  Delete the database named *db_name* and all its tables.

• **extended-status**
  Display the server status variables and their values.

• **flush-hosts**
  Flush all information in the host cache. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

• **flush-logs**
  Flush all logs.

• **flush-privileges**
  Reload the grant tables (same as *reload*).

• **flush-status**
  Clear status variables.

• **flush-tables**
  Flush all tables.

• **flush-threads**
  Flush the thread cache.

• **kill id,id,...**
  Kill server threads. If multiple thread ID values are given, there must be no spaces in the list.
  To kill threads belonging to other users, the connected user must have the **SUPER** privilege.

• **old-password new_password**
  This is like the *password* command but stores the password using the old (pre-4.1) password-hashing format. (See Section 6.1.2.4, “Password Hashing in MySQL”.)

• **password new_password**
  Set a new password. This changes the password to *new_password* for the account that you use with *mysqladmin* for connecting to the server. Thus, the next time you invoke *mysqladmin* (or any other client program) using the same account, you will need to specify the new password.

---

**Warning**

Setting a password using *mysqladmin* should be considered **insecure**. On some systems, your password becomes visible to system status programs such as *ps* that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and
mysqladmin — Client for Administering a MySQL Server

the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If the `new_password` value contains spaces or other characters that are special to your command interpreter, you need to enclose it within quotation marks. On Windows, be sure to use double quotation marks rather than single quotation marks; single quotation marks are not stripped from the password, but rather are interpreted as part of the password. For example:

```
shell> mysqladmin password "my new password"
```

The new password can be omitted following the `password` command. In this case, `mysqladmin` prompts for the password value, which enables you to avoid specifying the password on the command line. Omitting the password value should be done only if `password` is the final command on the `mysqladmin` command line. Otherwise, the next argument is taken as the password.

**Caution**

Do not use this command used if the server was started with the `--skip-grant-tables` option. No password change will be applied. This is true even if you precede the `password` command with `flush-privileges` on the same command line to re-enable the grant tables because the flush operation occurs after you connect. However, you can use `mysqladmin flush-privileges` to re-enable the grant table and then use a separate `mysqladmin password` command to change the password.

- **ping**

  Check whether the server is available. The return status from `mysqladmin` is 0 if the server is running, 1 if it is not. This is 0 even in case of an error such as `Access denied`, because this means that the server is running but refused the connection, which is different from the server not running.

- **processlist**

  Show a list of active server threads. This is like the output of the `SHOW PROCESSLIST` statement. If the `--verbose` option is given, the output is like that of `SHOW FULL PROCESSLIST`. (See Section 13.7.5.30, "SHOW PROCESSLIST Statement").

- **reload**

  Reload the grant tables.

- **refresh**

  Flush all tables and close and open log files.

- **shutdown**

  Stop the server.

- **start-slave**

  Start replication on a slave server.

- **status**

  Display a short server status message.

- **stop-slave**
Stop replication on a slave server.

- **variables**
  
  Display the server system variables and their values.

- **version**
  
  Display version information from the server.

All commands can be shortened to any unique prefix. For example:

```
shell> mysqladmin proc stat
```

```
+----+-------+-----------+----+---------+------+-------+------------------+
| Id | User  | Host      | db | Command | Time | State | Info             |
+----+-------+-----------+----+---------+------+-------+------------------+
| 51 | jones | localhost |    | Query   | 0    |       | show processlist |
+----+-------+-----------+----+---------+------+-------+------------------+
```

Uptime: 1473624  Threads: 1  Questions: 39487
Slow queries: 0  Opens: 541  Flush tables: 1
Open tables: 19  Queries per second avg: 0.0268

The `mysqladmin status` command result displays the following values:

- **Uptime**
  
  The number of seconds the MySQL server has been running.

- **Threads**
  
  The number of active threads (clients).

- **Questions**
  
  The number of questions (queries) from clients since the server was started.

- **Slow queries**
  
  The number of queries that have taken more than `long_query_time` seconds. See Section 5.4.5, “The Slow Query Log”.

- **Opens**
  
  The number of tables the server has opened.

- **Flush tables**
  
  The number of `flush-*`, `refresh`, and `reload` commands the server has executed.

- **Open tables**
  
  The number of tables that currently are open.

If you execute `mysqladmin shutdown` when connecting to a local server using a Unix socket file, `mysqladmin` waits until the server's process ID file has been removed, to ensure that the server has stopped properly.

`mysqladmin` supports the following options, which can be specified on the command line or in the `[mysqladmin]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

340
Table 4.11 mysqladmin Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--compress</td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td>--connect_timeout</td>
<td>Number of seconds before connection timeout</td>
<td></td>
</tr>
<tr>
<td>--count</td>
<td>Number of iterations to make for repeated command execution</td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td>--debug-check</td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td>--debug-info</td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td>--default-auth</td>
<td>Authentication plugin to use</td>
<td>5.5.9</td>
</tr>
<tr>
<td>--default-character-set</td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--enable-cleartext-plugin</td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.27</td>
</tr>
<tr>
<td>--force</td>
<td>Continue even if an SQL error occurs</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--no-beep</td>
<td>Do not beep when errors occur</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.9</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--relative</td>
<td>Show the difference between the current and previous values when used with the --sleep option</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--shutdown_timeout</td>
<td>The maximum number of seconds to wait for server shutdown</td>
<td></td>
</tr>
<tr>
<td>--silent</td>
<td>Silent mode</td>
<td></td>
</tr>
<tr>
<td>--sleep</td>
<td>Execute commands repeatedly, sleeping for delay seconds in between</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
</tbody>
</table>
### mysqladmin — Client for Administering a MySQL Server

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verboses mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
<tr>
<td>--vertical</td>
<td>Print query output rows vertically (one line per column value)</td>
<td></td>
</tr>
<tr>
<td>--wait</td>
<td>If the connection cannot be established, wait and retry instead of aborting</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**
  Display a help message and exit.

- **--bind-address=ip_address**
  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.
  This option is supported only in the version of mysqladmin that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- **--character-sets-dir=dir_name**
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--compress, -C**
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- **--count=N, -c N**
  The number of iterations to make for repeated command execution if the --sleep option is given.

- **--debug[=debug_options], -# [debug_options]**
  Write a debugging log. A typical debug_options string is d:t:o, file_name. The default is d:t:o,/ tmp/mysqladmin.trace.

- **--debug-check**
  Print some debugging information when the program exits.

- **--debug-info**
  Print debugging information and memory and CPU usage statistics when the program exits.

- **--default-auth=plugin**
A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.9.

- **--default-character-set=charset_name**

  Use `charset_name` as the default character set. See Section 10.15, “Character Set Configuration”.

- **--defaults-extra-file=file_name**

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--defaults-file=file_name**

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name.

- **--defaults-group-suffix=str**

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqladmin` normally reads the `[client]` and `[mysqladmin]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqladmin` also reads the `[client_other]` and `[mysqladmin_other]` groups.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--enable-cleartext-plugin**

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

- **--force, -f**

  Do not ask for confirmation for the `drop db_name` command. With multiple commands, continue even if an error occurs.

- **--host=host_name, -h host_name**

  Connect to the MySQL server on the given host.

- **--no-beep, -b**

  Suppress the warning beep that is emitted by default for errors such as a failure to connect to the server.

- **--no-defaults**

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.


• **--password[=password], -p [password]**

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, `mysqladmin` prompts for one. If given, there must be no space between `--password=` or `-p` and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that `mysqladmin` should not prompt for one, use the `--skip-password` option.

• **--pipe, -W**

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

• **--plugin-dir=dir_name**

The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqladmin` does not find it. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.9.

• **--port=port_num, -P port_num**

For TCP/IP connections, the port number to use.

• **--print-defaults**

Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--protocol={TCP|SOCKET|PIPE|MEMORY}**

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

• **--relative, -r**

Show the difference between the current and previous values when used with the `--sleep` option. This option works only with the `extended-status` command.

• **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.

This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

• **--silent, -s**

Exit silently if a connection to the server cannot be established.
mysqlcheck — A Table Maintenance Program

- **--sleep=delay, -i delay**
  Execute commands repeatedly, sleeping for delay seconds in between. The **--count** option determines the number of iterations. If **--count** is not given, mysqladmin executes commands indefinitely until interrupted.

- **--socket=path, -S path**
  For connections to localhost, the Unix socket file to use, or, on Windows, the name of the named pipe to use. On Windows, this option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.

- **--ssl**
  Options that begin with **--ssl** specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

- **--user=user_name, -u user_name**
  The user name of the MySQL account to use for connecting to the server.

- **--verbose, -v**
  Verbose mode. Print more information about what the program does.

- **--version, -V**
  Display version information and exit.

- **--vertical, -E**
  Print output vertically. This is similar to **--relative**, but prints output vertically.

- **--wait=[count], -w[count]**
  If the connection cannot be established, wait and retry instead of aborting. If a **count** value is given, it indicates the number of times to retry. The default is one time.

You can also set the following variables by using **--var_name=value**

- **connect_timeout**
  The maximum number of seconds before connection timeout. The default value is 43200 (12 hours).

- **shutdown_timeout**
  The maximum number of seconds to wait for server shutdown. The default value is 3600 (1 hour).

### 4.5.3 mysqlcheck — A Table Maintenance Program

The mysqlcheck client performs table maintenance: It checks, repairs, optimizes, or analyzes tables.

Each table is locked and therefore unavailable to other sessions while it is being processed, although for check operations, the table is locked with a **READ** lock only (see Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”, for more information about **READ** and **WRITE** locks). Table maintenance operations can be time-consuming, particularly for large tables. If you use the **--databases** or **--all-databases** option to process all tables in one or more databases, an invocation of mysqlcheck might
mysqlcheck — A Table Maintenance Program

take a long time. (This is also true for the MySQL upgrade procedure if it determines that table checking is needed because it processes tables the same way.)

mysqlcheck is similar in function to myisamchk, but works differently. The main operational difference is that mysqlcheck must be used when the mysqld server is running, whereas myisamchk should be used when it is not. The benefit of using mysqlcheck is that you do not have to stop the server to perform table maintenance.

mysqlcheck uses the SQL statements CHECK TABLE, REPAIR TABLE, ANALYZE TABLE, and OPTIMIZE TABLE in a convenient way for the user. It determines which statements to use for the operation you want to perform, and then sends the statements to the server to be executed. For details about which storage engines each statement works with, see the descriptions for those statements in Section 13.7.2, “Table Maintenance Statements”.

The MyISAM storage engine supports all four maintenance operations, so mysqlcheck can be used to perform any of them on MyISAM tables. Other storage engines do not necessarily support all operations. In such cases, an error message is displayed. For example, if test.t is a MEMORY table, an attempt to check it produces this result:

shell> mysqlcheck test t
  test.t
  note     : The storage engine for the table doesn't support check

If mysqlcheck is unable to repair a table, see Section 2.11.7, “Rebuilding or Repairing Tables or Indexes” for manual table repair strategies. This will be the case, for example, for InnoDB tables, which can be checked with CHECK TABLE, but not repaired with REPAIR TABLE.

Caution

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

There are three general ways to invoke mysqlcheck:

shell> mysqlcheck [options] db_name [tbl_name ...]
shell> mysqlcheck [options] --databases db_name ...
shell> mysqlcheck [options] --all-databases

If you do not name any tables following db_name or if you use the --databases or --all-databases option, entire databases are checked.

mysqlcheck has a special feature compared to other client programs. The default behavior of checking tables (--check) can be changed by renaming the binary. If you want to have a tool that repairs tables by default, you should just make a copy of mysqlcheck named mysqlrepair, or make a symbolic link to mysqlcheck named mysqlrepair. If you invoke mysqlrepair, it repairs tables.

The names shown in the following table can be used to change mysqlcheck default behavior.

<table>
<thead>
<tr>
<th>Command</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>mysqlrepair</td>
<td>The default option is --repair</td>
</tr>
<tr>
<td>mysqlanalyze</td>
<td>The default option is --analyze</td>
</tr>
<tr>
<td>mysqloptimize</td>
<td>The default option is --optimize</td>
</tr>
</tbody>
</table>

mysqlcheck supports the following options, which can be specified on the command line or in the [mysqlcheck] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

### Table 4.12 mysqlcheck Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--all-databases</td>
<td>Check all tables in all databases</td>
<td></td>
</tr>
<tr>
<td>--all-in-1</td>
<td>Execute a single statement for each database that names all the tables from that database</td>
<td></td>
</tr>
<tr>
<td>--analyze</td>
<td>Analyze the tables</td>
<td></td>
</tr>
<tr>
<td>--auto-repair</td>
<td>If a checked table is corrupted, automatically fix it</td>
<td></td>
</tr>
<tr>
<td>--character-sets-dir</td>
<td>Directory where character sets are installed</td>
<td></td>
</tr>
<tr>
<td>--check</td>
<td>Check the tables for errors</td>
<td></td>
</tr>
<tr>
<td>--check-only-changed</td>
<td>Check only tables that have changed since the last check</td>
<td></td>
</tr>
<tr>
<td>--check-upgrade</td>
<td>Invoke CHECK TABLE with the FOR UPGRADE option</td>
<td></td>
</tr>
<tr>
<td>--compress</td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td>--databases</td>
<td>Interpret all arguments as database names</td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td>--debug-check</td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td>--debug-info</td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td>--default-auth</td>
<td>Authentication plugin to use</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--default-character-set</td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--enable-cleartext-plugin</td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.47</td>
</tr>
<tr>
<td>--extended</td>
<td>Check and repair tables</td>
<td></td>
</tr>
<tr>
<td>--fast</td>
<td>Check only tables that have not been closed properly</td>
<td></td>
</tr>
<tr>
<td>--fix-db-names</td>
<td>Convert database names to 5.1 format</td>
<td></td>
</tr>
<tr>
<td>--fix-table-names</td>
<td>Convert table names to 5.1 format</td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Continue even if an SQL error occurs</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--medium-check</td>
<td>Do a check that is faster than an --extended operation</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--optimize</td>
<td>Optimize the tables</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
</tbody>
</table>
### mysqlcheck — A Table Maintenance Program

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--quick</td>
<td>The fastest method of checking</td>
<td></td>
</tr>
<tr>
<td>--repair</td>
<td>Perform a repair that can fix almost anything except unique keys that are not unique</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--silent</td>
<td>Silent mode</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--tables</td>
<td>Overrides the --databases or -B option</td>
<td></td>
</tr>
<tr>
<td>--use frm</td>
<td>For repair operations on MyISAM tables</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
<tr>
<td>--write-binlog</td>
<td>Log ANALYZE, OPTIMIZE, REPAIR statements to binary log. --skip-write-binlog adds NO_WRITE_TO_BINLOG to these statements</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**

Display a help message and exit.

- **--all-databases, -A**

Check all tables in all databases. This is the same as using the --databases option and naming all the databases on the command line, except that the INFORMATION_SCHEMA and performance_schema databases are not checked. They can be checked by explicitly naming them with the --databases option.

- **--all-in-1, -1**

Instead of issuing a statement for each table, execute a single statement for each database that names all the tables from that database to be processed.

- **--analyze, -a**

Analyze the tables.

- **--auto-repair**
If a checked table is corrupted, automatically fix it. Any necessary repairs are done after all tables have been checked.

- **--bind-address=ip_address**

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of `mysqlcheck` that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- **--character-sets-dir=dir_name**

The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--check, -c**

Check the tables for errors. This is the default operation.

- **--check-only-changed, -C**

Check only tables that have changed since the last check or that have not been closed properly.

- **--check-upgrade, -g**

Invoke `CHECK TABLE` with the FOR UPGRADE option to check tables for incompatibilities with the current version of the server. This option automatically enables the `--fix-db-names` and `--fix-table-names` options.

- **--compress**

Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- **--databases, -B**

Process all tables in the named databases. Normally, `mysqlcheck` treats the first name argument on the command line as a database name and any following names as table names. With this option, it treats all name arguments as database names.

- **--debug[=debug_options], -# [debug_options]**

Write a debugging log. A typical `debug_options` string is `d:t:o, file_name`. The default is `d:t:o`.

- **--debug-check**

Print some debugging information when the program exits.

- **--debug-info**

Print debugging information and memory and CPU usage statistics when the program exits.

- **--default-character-set=charset_name**

Use `charset_name` as the default character set. See Section 10.15, “Character Set Configuration”.
mysqlcheck — A Table Maintenance Program

- **--defaults-extra-file=file_name**
  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name.

  For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

- **--defaults-file=file_name**
  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name.

- **--defaults-group-suffix=str**
  Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, mysqlcheck normally reads the [client] and [mysqlcheck] groups. If the **--defaults-group-suffix=_other** option is given, mysqlcheck also reads the [client_other] and [mysqlcheck_other] groups.

  For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

- **--extended, -e**
  If you are using this option to check tables, it ensures that they are 100% consistent but takes a long time.

  If you are using this option to repair tables, it runs an extended repair that may not only take a long time to execute, but may produce a lot of garbage rows also!

- **--default-auth=plugin**
  A hint about which client-side authentication plugin to use. See Section 6.2.10, "Pluggable Authentication".

  This option was added in MySQL 5.5.10.

- **--enable-cleartext-plugin**
  Enable the mysql_clear_password cleartext authentication plugin. (See Section 6.4.1.3, "Client-Side Cleartext Pluggable Authentication".)

  This option was added in MySQL 5.5.47.

- **--fast, -F**
  Check only tables that have not been closed properly.

- **--fix-db-names**
  Convert database names to 5.1 format. Only database names that contain special characters are affected.

- **--fix-table-names**
  Convert table names to 5.1 format. Only table names that contain special characters are affected. This option also applies to views.
• **--force**, `-f`
  Continue even if an SQL error occurs.

• **--host=host_name**, `-h host_name`
  Connect to the MySQL server on the given host.

• **--medium-check**, `-m`
  Do a check that is faster than an **--extended** operation. This finds only 99.99% of all errors, which should be good enough in most cases.

• **--no-defaults**
  Do not read any option files. If program startup fails due to reading unknown options from an option file, **--no-defaults** can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--optimize**, `-o`
  Optimize the tables.

• **--password[=password]**, `-p[password]`
  The password of the MySQL account used for connecting to the server. The password value is optional. If not given, mysqlcheck prompts for one. If given, there must be no space between **--password=** or `-p` and the password following it. If no password option is specified, the default is to send no password.

  Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

  To explicitly specify that there is no password and that mysqlcheck should not prompt for one, use the **--skip-password** option.

• **--pipe**, `-W`
  On Windows, connect to the server using a named pipe. This option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

• **--plugin-dir=dir_name**
  The directory in which to look for plugins. Specify this option if the **--default-auth** option is used to specify an authentication plugin but mysqlcheck does not find it. See Section 6.2.10, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

• **--port=port_num**, `-P port_num`
  For TCP/IP connections, the port number to use.

• **--print-defaults**
  Print the program name and all options that it gets from option files.
For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--protocol={TCP|SOCKET|PIPE|MEMORY}**
  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

- **--quick, -q**
  If you are using this option to check tables, it prevents the check from scanning the rows to check for incorrect links. This is the fastest check method.
  If you are using this option to repair tables, it tries to repair only the index tree. This is the fastest repair method.

- **--repair, -r**
  Perform a repair that can fix almost anything except unique keys that are not unique.

- **--shared-memory-base-name=name**
  On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.
  This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

- **--silent, -s**
  Silent mode. Print only error messages.

- **--socket=path, -S path**
  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.
  On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- **--ssl**
  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

- **--tables**
  Override the `--databases` or `-B` option. All name arguments following the option are regarded as table names.

- **--use-frm**
  For repair operations on `MyISAM` tables, get the table structure from the `.frm` file so that the table can be repaired even if the `.MYI` header is corrupted.

- **--user=user_name, -u user_name**
The user name of the MySQL account to use for connecting to the server.

- **--verbose, -v**
  Verbose mode. Print information about the various stages of program operation.

- **--version, -V**
  Display version information and exit.

- **--write-binlog**
  This option is enabled by default, so that ANALYZE TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements generated by mysqlcheck are written to the binary log. Use **--skip-write-binlog** to cause NO_WRITE_TO_BINLOG to be added to the statements so that they are not logged. Use the **--skip-write-binlog** when these statements should not be sent to replication slaves or run when using the binary logs for recovery from backup.

### 4.5.4 mysqldump — A Database Backup Program

#### Performance and Scalability Considerations

#### Invocation Syntax

#### Option Syntax - Alphabetical Summary

The **mysqldump** client utility performs logical backups, producing a set of SQL statements that can be executed to reproduce the original database object definitions and table data. It dumps one or more MySQL databases for backup or transfer to another SQL server. The **mysqldump** command can also generate output in CSV, other delimited text, or XML format.

**mysqldump** requires at least the **SELECT** privilege for dumped tables, **SHOW VIEW** for dumped views, **TRIGGER** for dumped triggers, and **LOCK TABLES** if the **--single-transaction** option is not used. Certain options might require other privileges as noted in the option descriptions.

To reload a dump file, you must have the privileges required to execute the statements that it contains, such as the appropriate **CREATE** privileges for objects created by those statements.

**mysqldump** output can include **ALTER DATABASE** statements that change the database collation. These may be used when dumping stored programs to preserve their character encodings. To reload a dump file containing such statements, the **ALTER** privilege for the affected database is required.

If you are performing a backup on the server and your tables all are **MyISAM** tables, you can also use **mysqlhotcopy** for this purpose.

---

**Note**

A dump made using PowerShell on Windows with output redirection creates a file that has UTF-16 encoding:

```
shell> mysqldump [options] > dump.sql
```

However, UTF-16 is not permitted as a connection character set (see Impermissible Client Character Sets), so the dump file will not load correctly. To work around this issue, use the **--result-file** option, which creates the output in ASCII format:

```
shell> mysqldump [options] --result-file=dump.sql
```
Performance and Scalability Considerations

`mysqldump` advantages include the convenience and flexibility of viewing or even editing the output before restoring. You can clone databases for development and DBA work, or produce slight variations of an existing database for testing. It is not intended as a fast or scalable solution for backing up substantial amounts of data. With large data sizes, even if the backup step takes a reasonable time, restoring the data can be very slow because replaying the SQL statements involves disk I/O for insertion, index creation, and so on.

For large-scale backup and restore, a physical backup is more appropriate, to copy the data files in their original format that can be restored quickly:

- If your tables are primarily InnoDB tables, or if you have a mix of InnoDB and MyISAM tables, consider using the `mysqlbackup` command of the MySQL Enterprise Backup product. (Available as part of the Enterprise subscription.) It provides the best performance for InnoDB backups with minimal disruption; it can also back up tables from MyISAM and other storage engines; and it provides a number of convenient options to accommodate different backup scenarios. See Section 25.2, "MySQL Enterprise Backup Overview".

- If your tables are primarily MyISAM tables, consider using the `mysqlhotcopy` instead, for better performance than `mysqldump` of backup and restore operations. See Section 4.6.9, "mysqlhotcopy — A Database Backup Program".

`mysqldump` can retrieve and dump table contents row by row, or it can retrieve the entire content from a table and buffer it in memory before dumping it. Buffering in memory can be a problem if you are dumping large tables. To dump tables row by row, use the `--quick` option (or `--opt`, which enables `--quick`). The `--opt` option (and hence `--quick`) is enabled by default, so to enable memory buffering, use `--skip-quick`.

If you are using a recent version of `mysqldump` to generate a dump to be reloaded into a very old MySQL server, use the `--skip-opt` option instead of the `--opt` or `--extended-insert` option.

For additional information about `mysqldump`, see Section 7.4, "Using mysqldump for Backups".

Invocation Syntax

There are in general three ways to use `mysqldump`—in order to dump a set of one or more tables, a set of one or more complete databases, or an entire MySQL server—as shown here:

```
shell> mysqldump [options] db_name [tbl_name ...]
shell> mysqldump [options] --databases db_name ...
shell> mysqldump [options] --all-databases
```

To dump entire databases, do not name any tables following `db_name`, or use the `--databases` or `--all-databases` option.

`mysqldump` does not dump the INFORMATION_SCHEMA or performance_schema database by default. To dump either of these, name it explicitly on the command line and also use the `--skip-lock-tables` option. You can also name them with the `--databases` option. Before MySQL 5.5, `mysqldump` silently ignores INFORMATION_SCHEMA even if you name it explicitly on the command line.

`mysqldump` does not dump the performance_schema database.

Before MySQL 5.5.25, `mysqldump` does not dump the general_log or slow_query_log tables for dumps of the mysql database. As of 5.5.25, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

`mysqldump` also does not dump the NDB Cluster ndbinfo information database.
To see a list of the options your version of `mysqldump` supports, execute `mysqldump --help`.

Some `mysqldump` options are shorthand for groups of other options:

- **Use of `--opt`** is the same as specifying `--add-drop-table`, `--add-locks`, `--create-options`, `--disable-keys`, `--extended-insert`, `--lock-tables`, `--quick`, and `--set-charset`. All of the options that `--opt` stands for also are on by default because `--opt` is on by default.

- **Use of `--compact`** is the same as specifying `--skip-add-drop-table`, `--skip-add-locks`, `--skip-comments`, `--skip-disable-keys`, and `--skip-set-charset` options.

To reverse the effect of a group option, uses its `--skip-xxx` form (`--skip-opt` or `--skip-compact`). It is also possible to select only part of the effect of a group option by following it with options that enable or disable specific features. Here are some examples:

- To select the effect of `--opt` except for some features, use the `--skip` option for each feature. To disable extended inserts and memory buffering, use `--opt --skip-extended-insert --skip-quick`. (Actually, `--skip-extended-insert --skip-quick` is sufficient because `--opt` is on by default.)

- To reverse `--opt` for all features except index disabling and table locking, use `--skip-opt --disable-keys --lock-tables`.

When you selectively enable or disable the effect of a group option, order is important because options are processed first to last. For example, `--disable-keys --lock-tables --skip-opt` would not have the intended effect; it is the same as `--skip-opt` by itself.

`mysqldump` can retrieve and dump table contents row by row, or it can retrieve the entire content from a table and buffer it in memory before dumping it. Buffering in memory can be a problem if you are dumping large tables. To dump tables row by row, use the `--quick` option (or `--opt`, which enables `--quick`). The `--opt` option (and hence `--quick`) is enabled by default, so to enable memory buffering, use `--skip-quick`.

If you are using a recent version of `mysqldump` to generate a dump to be reloaded into a very old MySQL server, you should not use the `--opt` or `--extended-insert` option. Use `--skip-opt` instead.

For additional information about `mysqldump`, see Section 7.4, “Using mysqldump for Backups”.

### Option Syntax - Alphabetical Summary

`mysqldump` supports the following options, which can be specified on the command line or in the `[mysqldump]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

#### Table 4.13 mysqldump Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--add-drop-database</code></td>
<td>Add DROP DATABASE statement before each CREATE DATABASE statement</td>
<td></td>
</tr>
<tr>
<td><code>--add-drop-table</code></td>
<td>Add DROP TABLE statement before each CREATE TABLE statement</td>
<td></td>
</tr>
<tr>
<td><code>--add-locks</code></td>
<td>Surround each table dump with LOCK TABLES and UNLOCK TABLES statements</td>
<td></td>
</tr>
<tr>
<td><code>--all-databases</code></td>
<td>Dump all tables in all databases</td>
<td></td>
</tr>
<tr>
<td><code>--allow-keywords</code></td>
<td>Allow creation of column names that are keywords</td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td><code>--apply-slave-statements</code></td>
<td>Include STOP SLAVE prior to CHANGE MASTER statement and START SLAVE at end of output</td>
<td></td>
</tr>
<tr>
<td><code>--bind-address</code></td>
<td>Use specified network interface to connect to MySQL Server</td>
<td></td>
</tr>
<tr>
<td><code>--character-sets-dir</code></td>
<td>Directory where character sets are installed</td>
<td></td>
</tr>
<tr>
<td><code>--comments</code></td>
<td>Add comments to dump file</td>
<td></td>
</tr>
<tr>
<td><code>--compact</code></td>
<td>Produce more compact output</td>
<td></td>
</tr>
<tr>
<td><code>--compatible</code></td>
<td>Produce output that is more compatible with other database systems or with older MySQL servers</td>
<td></td>
</tr>
<tr>
<td><code>--complete-insert</code></td>
<td>Use complete INSERT statements that include column names</td>
<td></td>
</tr>
<tr>
<td><code>--compress</code></td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td><code>--create-options</code></td>
<td>Include all MySQL-specific table options in CREATE TABLE statements</td>
<td></td>
</tr>
<tr>
<td><code>--databases</code></td>
<td>Interpret all name arguments as database names</td>
<td></td>
</tr>
<tr>
<td><code>--debug</code></td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td><code>--debug-check</code></td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--debug-info</code></td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--default-auth</code></td>
<td>Authentication plugin to use</td>
<td>5.5.9</td>
</tr>
<tr>
<td><code>--default-character-set</code></td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-extra-file</code></td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-file</code></td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-group-suffix</code></td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td><code>--delayed-insert</code></td>
<td>Write INSERT DELAYED statements rather than INSERT statements</td>
<td></td>
</tr>
<tr>
<td><code>--delete-master-logs</code></td>
<td>On a master replication server, delete the binary logs after performing the dump operation</td>
<td></td>
</tr>
<tr>
<td><code>--disable-keys</code></td>
<td>For each table, surround INSERT statements with statements to disable and enable keys</td>
<td></td>
</tr>
<tr>
<td><code>--dump-date</code></td>
<td>Include dump date as &quot;Dump completed on&quot; comment if --comments is given</td>
<td></td>
</tr>
<tr>
<td><code>--dump-slave</code></td>
<td>Include CHANGE MASTER statement that lists binary log coordinates of slave's master</td>
<td></td>
</tr>
<tr>
<td><code>--enable-cleartext-plugin</code></td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.47</td>
</tr>
<tr>
<td><code>--events</code></td>
<td>Dump events from dumped databases</td>
<td></td>
</tr>
<tr>
<td><code>--extended-insert</code></td>
<td>Use multiple-row INSERT syntax</td>
<td></td>
</tr>
<tr>
<td><code>--fields-enclosed-by</code></td>
<td>This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td><code>--fields-escaped-by</code></td>
<td>This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>--fields-optionally-enclosed-by</td>
<td>This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--fields-terminated-by</td>
<td>This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--flush-logs</td>
<td>Flush MySQL server log files before starting dump</td>
<td></td>
</tr>
<tr>
<td>--flush-privileges</td>
<td>Emit a FLUSH PRIVILEGES statement after dumping mysql database</td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Continue even if an SQL error occurs during a table dump</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--hex-blob</td>
<td>Dump binary columns using hexadecimal notation</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--ignore-table</td>
<td>Do not dump given table</td>
<td></td>
</tr>
<tr>
<td>--include-master-host-port</td>
<td>Include MASTER_HOST/MASTER_PORT options in CHANGE MASTER statement produced with --dump-slave</td>
<td></td>
</tr>
<tr>
<td>--insert-ignore</td>
<td>Write INSERT IGNORE rather than INSERT statements</td>
<td></td>
</tr>
<tr>
<td>--lines-terminated-by</td>
<td>This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--lock-all-tables</td>
<td>Lock all tables across all databases</td>
<td></td>
</tr>
<tr>
<td>--lock-tables</td>
<td>Lock all tables before dumping them</td>
<td></td>
</tr>
<tr>
<td>--log-error</td>
<td>Append warnings and errors to named file</td>
<td></td>
</tr>
<tr>
<td>--master-data</td>
<td>Write the binary log file name and position to the output</td>
<td></td>
</tr>
<tr>
<td>--max-allowed-packet</td>
<td>Maximum packet length to send to or receive from server</td>
<td></td>
</tr>
<tr>
<td>--net-buffer-length</td>
<td>Buffer size for TCP/IP and socket communication</td>
<td></td>
</tr>
<tr>
<td>--no-autocommit</td>
<td>Enclose the INSERT statements for each dumped table within SET autocommit = 0 and COMMIT statements</td>
<td></td>
</tr>
<tr>
<td>--no-create-db</td>
<td>Do not write CREATE DATABASE statements</td>
<td></td>
</tr>
<tr>
<td>--no-create-info</td>
<td>Do not write CREATE TABLE statements that re-create each dumped table</td>
<td></td>
</tr>
<tr>
<td>--no-data</td>
<td>Do not dump table contents</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--no-set-names</td>
<td>Same as --skip-set-charset</td>
<td></td>
</tr>
<tr>
<td>--no-tablespaces</td>
<td>Do not write any CREATE LOGFILE GROUP or CREATE TABLESPACE statements in output</td>
<td></td>
</tr>
<tr>
<td>--opt</td>
<td>Shorthand for --add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset</td>
<td></td>
</tr>
<tr>
<td>--order-by-primary</td>
<td>Dump each table’s rows sorted by its primary key, or by its first unique index</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.9</td>
</tr>
</tbody>
</table>
## mysqldump — A Database Backup Program

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--port</code></td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td><code>--print-defaults</code></td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td><code>--protocol</code></td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td><code>--quick</code></td>
<td>Retrieve rows for a table from the server a row at a time</td>
<td></td>
</tr>
<tr>
<td><code>--quote-names</code></td>
<td>Quote identifiers within backtick characters</td>
<td></td>
</tr>
<tr>
<td><code>--replace</code></td>
<td>Write REPLACE statements rather than INSERT statements</td>
<td></td>
</tr>
<tr>
<td><code>--result-file</code></td>
<td>Direct output to a given file</td>
<td></td>
</tr>
<tr>
<td><code>--routines</code></td>
<td>Dump stored routines (procedures and functions) from dumped databases</td>
<td></td>
</tr>
<tr>
<td><code>--set-charset</code></td>
<td>Add SET NAMES default_character_set to output</td>
<td></td>
</tr>
<tr>
<td><code>--shared-memory-base-name</code></td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td><code>--single-transaction</code></td>
<td>Issue a BEGIN SQL statement before dumping data from server</td>
<td></td>
</tr>
<tr>
<td><code>--skip-add-drop-table</code></td>
<td>Do not add a DROP TABLE statement before each CREATE TABLE statement</td>
<td></td>
</tr>
<tr>
<td><code>--skip-add-locks</code></td>
<td>Do not add locks</td>
<td></td>
</tr>
<tr>
<td><code>--skip-comments</code></td>
<td>Do not add comments to dump file</td>
<td></td>
</tr>
<tr>
<td><code>--skip-compact</code></td>
<td>Do not produce more compact output</td>
<td></td>
</tr>
<tr>
<td><code>--skip-disable-keys</code></td>
<td>Do not disable keys</td>
<td></td>
</tr>
<tr>
<td><code>--skip-extended-insert</code></td>
<td>Turn off extended-insert</td>
<td></td>
</tr>
<tr>
<td><code>--skip-opt</code></td>
<td>Turn off options set by --opt</td>
<td></td>
</tr>
<tr>
<td><code>--skip-quick</code></td>
<td>Do not retrieve rows for a table from the server a row at a time</td>
<td></td>
</tr>
<tr>
<td><code>--skip-quote-names</code></td>
<td>Do not quote identifiers</td>
<td></td>
</tr>
<tr>
<td><code>--skip-set-charset</code></td>
<td>Do not write SET NAMES statement</td>
<td></td>
</tr>
<tr>
<td><code>--skip-triggers</code></td>
<td>Do not dump triggers</td>
<td></td>
</tr>
<tr>
<td><code>--skip-tz-utc</code></td>
<td>Turn off tz-utc</td>
<td></td>
</tr>
<tr>
<td><code>--socket</code></td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td><code>--ssl</code></td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-ca</code></td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-capath</code></td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-cert</code></td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-cipher</code></td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-key</code></td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td><code>--ssl-mode</code></td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td><code>--ssl-verify-server-cert</code></td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
</tbody>
</table>
mysqldump — A Database Backup Program

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--tab</td>
<td>Produce tab-separated data files</td>
<td></td>
</tr>
<tr>
<td>--tables</td>
<td>Override --databases or -B option</td>
<td></td>
</tr>
<tr>
<td>--triggers</td>
<td>Dump triggers for each dumped table</td>
<td></td>
</tr>
<tr>
<td>--tz-utc</td>
<td>Add SET TIME_ZONE='+00:00' to dump file</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
<tr>
<td>--where</td>
<td>Dump only rows selected by given WHERE condition</td>
<td></td>
</tr>
<tr>
<td>--xml</td>
<td>Produce XML output</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**
  Display a help message and exit.

- **--add-drop-database**
  Write a DROP DATABASE statement before each CREATE DATABASE statement. This option is typically used in conjunction with the --all-databases or --databases option because no CREATE DATABASE statements are written unless one of those options is specified.

- **--add-drop-table**
  Write a DROP TABLE statement before each CREATE TABLE statement.

- **--add-drop-trigger**
  Write a DROP TRIGGER statement before each CREATE TRIGGER statement.

  **Note**
  This option is supported only by mysqldump as supplied with NDB Cluster. It is not available when using MySQL Server 5.5.

- **--add-locks**
  Surround each table dump with LOCK TABLES and UNLOCK TABLES statements. This results in faster inserts when the dump file is reloaded. See Section 8.2.4.1, “Optimizing INSERT Statements”.

- **--all-databases, -A**
  Dump all tables in all databases. This is the same as using the --databases option and naming all the databases on the command line.

- **--all-tablespaces, -Y**
  Adds to a table dump all SQL statements needed to create any tablespaces used by an NDBCLUSTER table. This information is not otherwise included in the output from mysqldump. This option is currently relevant only to NDB Cluster tables.

- **--allow-keywords**
  Permit creation of column names that are keywords. This works by prefixing each column name with the table name.
• **--apply-slave-statements**

For a slave dump produced with the `--dump-slave` option, add a `STOP SLAVE` statement before the `CHANGE MASTER TO` statement and a `START SLAVE` statement at the end of the output.

• **--bind-address=ip_address**

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of `mysqldump` that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

• **--character-sets-dir=dir_name**

The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

• **--comments, -i**

Write additional information in the dump file such as program version, server version, and host. This option is enabled by default. To suppress this additional information, use `--skip-comments`.

• **--compact**

Produce more compact output. This option enables the `--skip-add-drop-table`, `--skip-add-locks`, `--skip-comments`, `--skip-disable-keys`, and `--skip-set-charset` options.

• **--compatible=name**

Produce output that is more compatible with other database systems or with older MySQL servers. The value of `name` can be `ansi`, `mysql323`, `mysql40`, `postgresql`, `oracle`, `mssql`, `maxdb`, `no_key_options`, `no_table_options`, or `no_field_options`. To use several values, separate them by commas. These values have the same meaning as the corresponding options for setting the server SQL mode. See Section 5.1.10, “Server SQL Modes”.

This option does not guarantee compatibility with other servers. It only enables those SQL mode values that are currently available for making dump output more compatible. For example, `--compatible=oracle` does not map data types to Oracle types or use Oracle comment syntax.

• **--complete-insert, -c**

Use complete `INSERT` statements that include column names.

• **--compress, -C**

Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

• **--create-options**

Include all MySQL-specific table options in the `CREATE TABLE` statements.

• **--databases, -B**

Dump several databases. Normally, `mysqldump` treats the first name argument on the command line as a database name and following names as table names. With this option, it treats all name arguments as database names. `CREATE DATABASE` and `USE` statements are included in the output before each new database.
This option may be used to dump the `INFORMATION_SCHEMA` and `performance_schema` databases, which normally are not dumped even with the `--all-databases` option. (Also use the `--skip-lock-tables` option.)

- `--debug[=debug_options],-# [debug_options]`
  Write a debugging log. A typical `debug_options` string is `d:t:o, file_name`. The default value is `d:t:o,/tmp/mysqldump.trace`.

- `--debug-check`
  Print some debugging information when the program exits.

- `--debug-info`
  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-auth=plugin`
  A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.
  This option was added in MySQL 5.5.9.

- `--default-character-set=charset_name`
  Use `charset_name` as the default character set. See Section 10.15, “Character Set Configuration”. If no character set is specified, `mysqldump` uses `utf8`.

- `--defaults-extra-file=file_name`
  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name.
  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- `--defaults-file=file_name`
  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`
  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqldump` normally reads the `[client]` and `[mysqldump]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqldump` also reads the `[client_other]` and `[mysqldump_other]` groups.
  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- `--delayed-insert`
  Write `INSERT DELAYED` statements rather than `INSERT` statements.

- `--delete-master-logs`
On a master replication server, delete the binary logs by sending a `PURGE BINARY LOGS` statement to the server after performing the dump operation. This option automatically enables `--master-data`.

- `--disable-keys,-K`

For each table, surround the `INSERT` statements with `/*!40000 ALTER TABLE tbl_name DISABLE KEYS */;` and `/*!40000 ALTER TABLE tbl_name ENABLE KEYS */;` statements. This makes loading the dump file faster because the indexes are created after all rows are inserted. This option is effective only for nonunique indexes of `MyISAM` tables. It has no effect for other tables.

- `--dump-date`

If the `--comments` option is given, `mysqldump` produces a comment at the end of the dump of the following form:

```
-- Dump completed on DATE
```

However, the date causes dump files taken at different times to appear to be different, even if the data are otherwise identical. `--dump-date` and `--skip-dump-date` control whether the date is added to the comment. The default is `--dump-date` (include the date in the comment). `--skip-dump-date` suppresses date printing.

- `--dump-slave[=value]`

This option is similar to `--master-data` except that it is used to dump a replication slave server to produce a dump file that can be used to set up another server as a slave that has the same master as the dumped server. It causes the dump output to include a `CHANGE MASTER TO` statement that indicates the binary log coordinates (file name and position) of the dumped slave's master. These are the master server coordinates from which the slave should start replicating.

`--dump-slave` causes the coordinates from the master to be used rather than those of the dumped server, as is done by the `--master-data` option. In addition, specifying this option causes the `--master-data` option to be overridden, if used, and effectively ignored.

The option value is handled the same way as for `--master-data` (setting no value or 1 causes a `CHANGE MASTER TO` statement to be written to the dump, setting 2 causes the statement to be written but encased in SQL comments) and has the same effect as `--master-data` in terms of enabling or disabling other options and in how locking is handled.

This option causes `mysqldump` to stop the slave SQL thread before the dump and restart it again after.

In conjunction with `--dump-slave`, the `--apply-slave-statements` and `--include-master-host-port` options can also be used.

- `--events,-E`

Include Event Scheduler events for the dumped databases in the output. This option requires the `EVENT` privileges for those databases.

- `--extended-insert,-e`

Write `INSERT` statements using multiple-row syntax that includes several `VALUES` lists. This results in a smaller dump file and speeds up inserts when the file is reloaded.
• **--fields-terminated-by=...**, **--fields-enclosed-by=...**, **--fields-optionally-enclosed-by=...**, **--fields-escaped-by=...**

These options are used with the **--tab** option and have the same meaning as the corresponding **FIELDS** clauses for **LOAD DATA**. See Section 13.2.6, “LOAD DATA Statement”.

• **--flush-logs, -F**

Flush the MySQL server log files before starting the dump. This option requires the **RELOAD** privilege. If you use this option in combination with the **--all-databases** option, the logs are flushed for each database dumped. The exception is when using **--lock-all-tables, --master-data, or (as of MySQL 5.5.21) --single-transaction**: In this case, the logs are flushed only once, corresponding to the moment that all tables are locked by **FLUSH TABLES WITH READ LOCK**. If you want your dump and the log flush to happen at exactly the same moment, you should use **--flush-logs** together with **--lock-all-tables, --master-data, or --single-transaction**.

• **--flush-privileges**

Add a **FLUSH PRIVILEGES** statement to the dump output after dumping the mysql database. This option should be used any time the dump contains the mysql database and any other database that depends on the data in the mysql database for proper restoration.

• **--force, -f**

Continue even if an SQL error occurs during a table dump.

One use for this option is to cause **mysqldump** to continue executing even when it encounters a view that has become invalid because the definition refers to a table that has been dropped. Without **--force**, **mysqldump** exits with an error message. With **--force**, **mysqldump** prints the error message, but it also writes an SQL comment containing the view definition to the dump output and continues executing.

• **--enable-cleartext-plugin**

Enable the **mysql_clear_password** cleartext authentication plugin. (See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.)

This option was added in MySQL 5.5.47.

• **--host=host_name, -h host_name**

Dump data from the MySQL server on the given host. The default host is **localhost**.

• **--hex-blob**

Dump binary columns using hexadecimal notation (for example, "abc" becomes 0x616263). The affected data types are **BINARY, VARBINARY, BLOB** types, **BIT**, all spatial data types, and other non-binary data types when used with the binary **character set**.

• **--include-master-host-port**

For the **CHANGE MASTER TO** statement in a slave dump produced with the **--dump-slave** option, add **MASTER_HOST** and **MASTER_PORT** options for the host name and TCP/IP port number of the slave’s master.
• **--ignore-table=db_name.tbl_name**

Do not dump the given table, which must be specified using both the database and table names. To ignore multiple tables, use this option multiple times. This option also can be used to ignore views.

• **--insert-ignore**

Write **INSERT IGNORE** statements rather than **INSERT** statements.

• **--lines-terminated-by=...**

This option is used with the **--tab** option and has the same meaning as the corresponding **LINES** clause for **LOAD DATA**. See Section 13.2.6, “LOAD DATA Statement”.

• **--lock-all-tables, -x**

Lock all tables across all databases. This is achieved by acquiring a global read lock for the duration of the whole dump. This option automatically turns off **--single-transaction** and **--lock-tables**.

• **--lock-tables, -l**

For each dumped database, lock all tables to be dumped before dumping them. The tables are locked with **READ LOCAL** to permit concurrent inserts in the case of **MyISAM** tables. For transactional tables such as **InnoDB**, **--single-transaction** is a much better option than **--lock-tables** because it does not need to lock the tables at all.

Because **--lock-tables** locks tables for each database separately, this option does not guarantee that the tables in the dump file are logically consistent between databases. Tables in different databases may be dumped in completely different states.

Some options, such as **--opt**, automatically enable **--lock-tables**. If you want to override this, use **--skip-lock-tables** at the end of the option list.

• **--log-error=file_name**

Log warnings and errors by appending them to the named file. The default is to do no logging.

• **--master-data[=value]**

Use this option to dump a master replication server to produce a dump file that can be used to set up another server as a slave of the master. It causes the dump output to include a **CHANGE MASTER TO** statement that indicates the binary log coordinates (file name and position) of the dumped server. These are the master server coordinates from which the slave should start replicating after you load the dump file into the slave.

If the option value is 2, the **CHANGE MASTER TO** statement is written as an SQL comment, and thus is informative only; it has no effect when the dump file is reloaded. If the option value is 1, the statement is not written as a comment and takes effect when the dump file is reloaded. If no option value is specified, the default value is 1.

This option requires the **RELOAD** privilege and the binary log must be enabled.

The **--master-data** option automatically turns off **--lock-tables**. It also turns on **--lock-all-tables**, unless **--single-transaction** also is specified, in which case, a global read lock...
is acquired only for a short time at the beginning of the dump (see the description for `--single-transaction`). In all cases, any action on logs happens at the exact moment of the dump.

It is also possible to set up a slave by dumping an existing slave of the master, using the `--dump-slave` option, which overrides `--master-data` and causes it to be ignored if both options are used.

- `--max-allowed-packet=value`

  The maximum size of the buffer for client/server communication. The default is 24MB, the maximum is 1GB.

- `--net-buffer-length=value`

  The initial size of the buffer for client/server communication. When creating multiple-row INSERT statements (as with the `--extended-insert` or `--opt` option), `mysqldump` creates rows up to `--net-buffer-length` bytes long. If you increase this variable, ensure that the MySQL server `net_buffer_length` system variable has a value at least this large.

- `--no-autocommit`

  Enclose the INSERT statements for each dumped table within `SET autocommit = 0` and COMMIT statements.

- `--no-create-db, -n`

  Suppress the CREATE DATABASE statements that are otherwise included in the output if the `--databases` or `--all-databases` option is given.

- `--no-create-info, -t`

  Do not write CREATE TABLE statements that create each dumped table.

  **Note**
  
  This option does *not* exclude statements creating log file groups or tablespaces from `mysqldump` output; however, you can use the `--no-tablespaces` option for this purpose.

- `--no-data, -d`

  Do not write any table row information (that is, do not dump table contents). This is useful if you want to dump only the CREATE TABLE statement for the table (for example, to create an empty copy of the table by loading the dump file).

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- `--no-set-names, -N`

  This has the same effect as `--skip-set-charset`. 
• --no-tablespaces, -y

This option suppresses all CREATE LOGFILE GROUP and CREATE TABLESPACE statements in the output of mysqldump.

• --opt

This option is shorthand. It is the same as specifying --add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset. It should give you a fast dump operation and produce a dump file that can be reloaded into a MySQL server quickly.

The --opt option is enabled by default. Use --skip-opt to disable it. See the discussion at the beginning of this section for information about selectively enabling or disabling a subset of the options affected by --opt.

• --order-by-primary

Dump each table's rows sorted by its primary key, or by its first unique index, if such an index exists. This is useful when dumping a MyISAM table to be loaded into an InnoDB table, but will make the dump operation take considerably longer.

• --password[=password], -p[password]

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, mysqldump prompts for one. If given, there must be no space between --password= or -p and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, "End-User Guidelines for Password Security".

To explicitly specify that there is no password and that mysqldump should not prompt for one, use the --skip-password option.

• --pipe, -W

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.

• --plugin-dir=dir_name

The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but mysqldump does not find it. See Section 6.2.10, "Pluggable Authentication".

This option was added in MySQL 5.5.9.

• --port=port_num, -P port_num

For TCP/IP connections, the port number to use.

• --print-defaults

Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".
mysqldump — A Database Backup Program

- **--protocol={TCP|SOCKET|PIPE|MEMORY}**

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, "Connecting to the MySQL Server Using Command Options".

- **--quick,-q**

  This option is useful for dumping large tables. It forces mysqldump to retrieve rows for a table from the server a row at a time rather than retrieving the entire row set and buffering it in memory before writing it out.

- **--quote-names,-Q**

  Quote identifiers (such as database, table, and column names) within ` ` characters. If the ANSI_QUOTES SQL mode is enabled, identifiers are quoted within " " characters. This option is enabled by default. It can be disabled with --skip-quote-names, but this option should be given after any option such as --compatible that may enable --quote-names.

- **--replace**

  Write REPLACE statements rather than INSERT statements.

- **--result-file=file_name,-r file_name**

  Direct output to the named file. The result file is created and its previous contents overwritten, even if an error occurs while generating the dump.

  This option should be used on Windows to prevent newline \n characters from being converted to \r\n carriage return/newline sequences.

- **--routines,-R**

  Include stored routines (procedures and functions) for the dumped databases in the output. This option requires the SELECT privilege for the mysql.proc table.

  The output generated by using --routines contains CREATE PROCEDURE and CREATE FUNCTION statements to create the routines. However, these statements do not include attributes such as the routine creation and modification timestamps, so when the routines are reloaded, they are created with timestamps equal to the reload time.

  If you require routines to be created with their original timestamp attributes, do not use --routines. Instead, dump and reload the contents of the mysql.proc table directly, using a MySQL account that has appropriate privileges for the mysql database.

  Prior to MySQL 5.5.21, this option had no effect when used together with the --xml option. (Bug #11760384, Bug #52792)

- **--set-charset**

  Write SET NAMES default_character_set to the output. This option is enabled by default. To suppress the SET NAMES statement, use --skip-set-charset.
• **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.

This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

• **--single-transaction**

This option sets the transaction isolation mode to `REPEATABLE READ` and sends a `START TRANSACTION` SQL statement to the server before dumping data. It is useful only with transactional tables such as `InnoDB`, because then it dumps the consistent state of the database at the time when `START TRANSACTION` was issued without blocking any applications.

When using this option, you should keep in mind that only `InnoDB` tables are dumped in a consistent state. For example, any `MyISAM` or `MEMORY` tables dumped while using this option may still change state.

While a `--single-transaction` dump is in process, to ensure a valid dump file (correct table contents and binary log coordinates), no other connection should use the following statements: `ALTER TABLE`, `CREATE TABLE`, `DROP TABLE`, `RENAME TABLE`, `TRUNCATE TABLE`. A consistent read is not isolated from those statements, so use of them on a table to be dumped can cause the `SELECT` that is performed by `mysqldump` to retrieve the table contents to obtain incorrect contents or fail.

The `--single-transaction` option and the `--lock-tables` option are mutually exclusive because `LOCK TABLES` causes any pending transactions to be committed implicitly.

This option is not supported for NDB Cluster tables; the results cannot be guaranteed to be consistent due to the fact that the `NDBCLUSTER` storage engine supports only the `READ_COMMITTED` transaction isolation level. You should always use `NDB` backup and restore instead.

To dump large tables, combine the `--single-transaction` option with the `--quick` option.

• **--skip-comments**

See the description for the `--comments` option.

• **--skip-opt**

See the description for the `--opt` option.

• **--socket=path, -S path**

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

• **--ssl***

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See [Command Options for Encrypted Connections](#).
• **--tab=dir_name, -T dir_name**

Produce tab-separated text-format data files. For each dumped table, `mysqldump` creates a `tbl_name.sql` file that contains the `CREATE TABLE` statement that creates the table, and the server writes a `tbl_name.txt` file that contains its data. The option value is the directory in which to write the files.

**Note**

This option should be used only when `mysqldump` is run on the same machine as the `mysqld` server. Because the server creates `*.txt` files in the directory that you specify, the directory must be writable by the server and the MySQL account that you use must have the `FILE` privilege. Because `mysqldump` creates `*.sql` in the same directory, it must be writable by your system login account.

By default, the `.txt` data files are formatted using tab characters between column values and a newline at the end of each line. The format can be specified explicitly using the `--fields-xxx` and `--lines-terminated-by` options.

Column values are converted to the character set specified by the `--default-character-set` option.

• **--tables**

Override the `--databases` or `-B` option. `mysqldump` regards all name arguments following the option as table names.

• **--triggers**

Include triggers for each dumped table in the output. This option is enabled by default; disable it with `--skip-triggers`.

To be able to dump a table's triggers, you must have the `TRIGGER` privilege for the table.

• **--tz-utc**

This option enables `TIMESTAMP` columns to be dumped and reloaded between servers in different time zones. `mysqldump` sets its connection time zone to UTC and adds `SET TIME_ZONE='+00:00'` to the dump file. Without this option, `TIMESTAMP` columns are dumped and reloaded in the time zones local to the source and destination servers, which can cause the values to change if the servers are in different time zones. `--tz-utc` also protects against changes due to daylight saving time. `--tz-utc` is enabled by default. To disable it, use `--skip-tz-utc`.

• **--user=user_name, -u user_name**

The user name of the MySQL account to use for connecting to the server.

• **--verbose, -v**

Verbose mode. Print more information about what the program does.

• **--version, -V**

Display version information and exit.
mysqldump — A Database Backup Program

• **--where=’where_condition’, --w ’where_condition’**

  Dump only rows selected by the given WHERE condition. Quotes around the condition are mandatory if it contains spaces or other characters that are special to your command interpreter.

  **Examples:**

  ```
  --where="user='jimf'"
  -w"userid>1"
  -w"userid<1"
  ```

• **--xml, -X**

  Write dump output as well-formed XML.

  **NULL, 'NULL', and Empty Values:** For a column named `column_name`, the NULL value, an empty string, and the string value ‘NULL’ are distinguished from one another in the output generated by this option as follows.

<table>
<thead>
<tr>
<th>Value:</th>
<th>XML Representation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL (unknown value)</td>
<td><code>&lt;field name=&quot;column_name&quot; xsi:nil=&quot;true&quot; /&gt;</code></td>
</tr>
<tr>
<td>'' (empty string)</td>
<td><code>&lt;field name=&quot;column_name&quot;&gt;&lt;/field&gt;</code></td>
</tr>
<tr>
<td>'NULL' (string value)</td>
<td><code>&lt;field name=&quot;column_name&quot;&gt;NULL&lt;/field&gt;</code></td>
</tr>
</tbody>
</table>

  The output from the mysql client when run using the --xml option also follows the preceding rules. (See Section 4.5.1.1, “mysql Client Options”.)

  XML output from mysqldump includes the XML namespace, as shown here:

  ```
  shell> mysqldump --xml -u root world City
  <?xml version="1.0"?>
  <mysqldump xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <database name="world">
  <table_structure name="City">
    <field Field="ID" Type="int(11)" Null="NO" Key="PRI" Extra="auto_increment" />
    <field Field="Name" Type="char(35)" Null="NO" Key="" Default="" Extra="" />
    <field Field="CountryCode" Type="char(3)" Null="NO" Key="" Default="" Extra="" />
    <field Field="District" Type="char(20)" Null="NO" Key="" Default="" Extra="" />
    <key Table="City" Non_unique="0" Key_name="PRIMARY" Seq_in_index="1" Column_name="ID" Collation="A" Cardinality="4079" Null="" Index_type="BTREE" Comment="" />
    <options Name="City" Engine="MyISAM" Version="10" Row_format="Fixed" Rows="4079" Avg_row_length="67" Data_length="273293" Max_data_length="18858823439613951" Index_length="43008" Data_free="0" Auto_increment="4080" Create_time="2007-03-31 01:47:01" Update_time="2007-03-31 01:47:02" Collation="latin1_swedish_ci" Create_options="" Comment="" />
  </table_structure>
  <table_data name="City">
  <row>
    <field name="ID">1</field>
    <field name="Name">Kabul</field>
    <field name="CountryCode">AFG</field>
    <field name="District">Kabol</field>
    <field name="Population">1780000</field>
  </row>
  ...
  <row>
  ```
Prior to MySQL 5.5.21, this option prevented the `--routines` option from working correctly—that is, no stored routines, triggers, or events could be dumped in XML format. (Bug #11760384, Bug #52792)

A common use of `mysqldump` is for making a backup of an entire database:

```
shell> mysqldump db_name > backup-file.sql
```

You can load the dump file back into the server like this:

```
shell> mysql db_name < backup-file.sql
```

Or like this:

```
shell> mysql -e "source /path-to-backup/backup-file.sql" db_name
```

`mysqldump` is also very useful for populating databases by copying data from one MySQL server to another:

```
shell> mysqldump --opt db_name | mysql --host=remote_host -C db_name
```

It is possible to dump several databases with one command:

```
shell> mysqldump --databases db_name1 [db_name2 ...] > my_databases.sql
```

To dump all databases, use the `--all-databases` option:

```
shell> mysqldump --all-databases > all_databases.sql
```

For InnoDB tables, `mysqldump` provides a way of making an online backup:

```
shell> mysqldump --all-databases --master-data --single-transaction > all_databases.sql
```

This backup acquires a global read lock on all tables (using `FLUSH TABLES WITH READ LOCK`) at the beginning of the dump. As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the `FLUSH` statement is issued, the MySQL server may get stalled until those statements finish. After that, the dump becomes lock free and does not disturb reads and writes on the tables. If the update statements that the MySQL server receives are short (in terms of execution time), the initial lock period should not be noticeable, even with many updates.

For point-in-time recovery (also known as “roll-forward,” when you need to restore an old backup and replay the changes that happened since that backup), it is often useful to rotate the binary log (see Section 5.4.4, “The Binary Log”) or at least know the binary log coordinates to which the dump corresponds:

```
shell> mysqldump --all-databases --master-data=2 > all_databases.sql
```

Or:

```
shell> mysqldump --all-databases --flush-logs --master-data=2 > all_databases.sql
```
The `--master-data` and `--single-transaction` options can be used simultaneously, which provides a convenient way to make an online backup suitable for use prior to point-in-time recovery if tables are stored using the InnoDB storage engine.

For more information on making backups, see Section 7.2, “Database Backup Methods”, and Section 7.3, “Example Backup and Recovery Strategy”.

If you encounter problems backing up views, please read the section that covers restrictions on views which describes a workaround for backing up views when this fails due to insufficient privileges. See Section 20.9, “Restrictions on Views”.

### 4.5.5 `mysqlimport` — A Data Import Program

The `mysqlimport` client provides a command-line interface to the `LOAD DATA` SQL statement. Most options to `mysqlimport` correspond directly to clauses of `LOAD DATA` syntax. See Section 13.2.6, “LOAD DATA Statement”.

Invoke `mysqlimport` like this:

```
shell> mysqlimport [options] db_name textfile1 [textfile2 ...]
```

For each text file named on the command line, `mysqlimport` strips any extension from the file name and uses the result to determine the name of the table into which to import the file’s contents. For example, files named `patient.txt`, `patient.text`, and `patient` all would be imported into a table named `patient`.

`mysqlimport` supports the following options, which can be specified on the command line or in the `[mysqlimport]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

#### Table 4.14 `mysqlimport` Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--columns</code></td>
<td>This option takes a comma-separated list of column names as its value</td>
<td></td>
</tr>
<tr>
<td><code>--compress</code></td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td><code>--debug</code></td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td><code>--debug-check</code></td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--debug-info</code></td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--default-auth</code></td>
<td>Authentication plugin to use</td>
<td>5.5.10</td>
</tr>
<tr>
<td><code>--default-character-set</code></td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-extra-file</code></td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-file</code></td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-group-suffix</code></td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td><code>--delete</code></td>
<td>Empty the table before importing the text file</td>
<td></td>
</tr>
<tr>
<td><code>--enable-cleartext-plugin</code></td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.47</td>
</tr>
<tr>
<td><code>--fields-enclosed-by</code></td>
<td>This option has the same meaning as the corresponding clause for <code>LOAD DATA</code></td>
<td></td>
</tr>
<tr>
<td><code>--fields-escaped-by</code></td>
<td>This option has the same meaning as the corresponding clause for <code>LOAD DATA</code></td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>--fields-optionally-enclosed-by</td>
<td>This option has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--fields-terminated-by</td>
<td>This option has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Continue even if an SQL error occurs</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--ignore</td>
<td>See the description for the --replace option</td>
<td></td>
</tr>
<tr>
<td>--ignore-lines</td>
<td>Ignore the first N lines of the data file</td>
<td></td>
</tr>
<tr>
<td>--lines-terminated-by</td>
<td>This option has the same meaning as the corresponding clause for LOAD DATA</td>
<td></td>
</tr>
<tr>
<td>--local</td>
<td>Read input files locally from the client host</td>
<td></td>
</tr>
<tr>
<td>--lock-tables</td>
<td>Lock all tables for writing before processing any text files</td>
<td></td>
</tr>
<tr>
<td>--low-priority</td>
<td>Use LOW_PRIORITY when loading the table</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--replace</td>
<td>The --replace and --ignore options control handling of input rows that duplicate existing rows on unique key values</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--silent</td>
<td>Produce output only when errors occur</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--use-threads</td>
<td>Number of threads for parallel file-loading</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, --?**
  Display a help message and exit.

  The output generated by using **--events** contains **CREATE EVENT** statements to create the events. However, these statements do not include attributes such as the event creation and modification timestamps, so when the events are reloaded, they are created with timestamps equal to the reload time.

  If you require events to be created with their original timestamp attributes, do not use **--events**. Instead, dump and reload the contents of the **mysql.event** table directly, using a MySQL account that has appropriate privileges for the **mysql** database.

- **--bind-address=ip_address**
  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of **mysqlimport** that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- **--character-sets-dir=dir_name**
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--columns=column_list, -c column_list**
  This option takes a list of comma-separated column names as its value. The order of the column names indicates how to match data file columns with table columns.

- **--compress, --C**
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- **--debug=[debug_options], --# [debug_options]**
  Write a debugging log. A typical **debug_options** string is **d:t:o, file_name**. The default is **d:t:o**.

- **--debug-check**
  Print some debugging information when the program exits.

- **--debug-info**
  Print debugging information and memory and CPU usage statistics when the program exits.

- **--default-character-set=charset_name**
  Use **charset_name** as the default character set. See Section 10.15, “Character Set Configuration”.

- **--default-auth=plugin**
  A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.
This option was added in MySQL 5.5.10.

- **--defaults-extra-file=file_name**

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

- **--defaults-file=file_name**

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.

- **--defaults-group-suffix=str**

Read not only the usual option groups, but also groups with the usual names and a suffix of str. For example, mysqlimport normally reads the [client] and [mysqlimport] groups. If the --defaults-group-suffix=_other option is given, mysqlimport also reads the [client_other] and [mysqlimport_other] groups.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

- **--delete,-D**

Empty the table before importing the text file.

- **--enable-cleartext-plugin**

Enable the mysql_clear_password cleartext authentication plugin. (See Section 6.4.1.3, "Client-Side Cleartext Pluggable Authentication".)

This option was added in MySQL 5.5.47.

- **--fields-terminated-by=..., --fields-enclosed-by=..., --fields-optionally-enclosed-by=..., --fields-escaped-by=...**

These options have the same meaning as the corresponding clauses for \texttt{LOAD DATA}. See Section 13.2.6, "LOAD DATA Statement".

- **--force,-f**

Ignore errors. For example, if a table for a text file does not exist, continue processing any remaining files. Without --force, mysqlimport exits if a table does not exist.

- **--host=host_name,-h host_name**

Import data to the MySQL server on the given host. The default host is localhost.

- **--ignore,-i**

See the description for the **--replace** option.

- **--ignore-lines=N**


mysqlimport — A Data Import Program

Ignore the first \( N \) lines of the data file.

- \(--\text{lines-terminated-by}=\ldots\)

This option has the same meaning as the corresponding clause for \texttt{LOAD DATA}. For example, to import Windows files that have lines terminated with carriage return/linefeed pairs, use \(--\text{lines-terminated-by}=\"\r\n\"\). (You might have to double the backslashes, depending on the escaping conventions of your command interpreter.) See Section 13.2.6, “LOAD DATA Statement”.

- \(--\text{local},-\mathbf{L}\)

By default, files are read by the server on the server host. With this option, \texttt{mysqlimport} reads input files locally on the client host. Enabling local data loading also requires that the server permits it; see Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

- \(--\text{lock-tables},-\mathbf{l}\)

Lock all tables for writing before processing any text files. This ensures that all tables are synchronized on the server.

- \(--\text{low-priority}\)

Use \texttt{LOW\_PRIORITY} when loading the table. This affects only storage engines that use only table-level locking (such as \texttt{MyISAM}, \texttt{MEMORY}, and \texttt{MERGE}).

- \(--\text{no-defaults}\)

Do not read any option files. If program startup fails due to reading unknown options from an option file, \(--\text{no-defaults}\) can be used to prevent them from being read.

For additional information about this and other option-file options, see Section 4.2.3, “Command-Line Options that Affect Option-File Handling”.

- \(--\text{password}=[\text{password}],-\mathbf{p}[\text{password}]\)

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, \texttt{mysqlimport} prompts for one. If given, there must be no space between \(--\text{password}=\) or \(--\text{p}\) and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that \texttt{mysqlimport} should not prompt for one, use the \(--\text{skip-password}\) option.

- \(--\text{pipe},-\mathbf{W}\)

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the \texttt{named\_pipe} system variable enabled to support named-pipe connections.
• **--plugin-dir=dir_name**

The directory in which to look for plugins. Specify this option if the **--default-auth** option is used to specify an authentication plugin but **mysqlimport** does not find it. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

• **--port=port_num, -P port_num**

For TCP/IP connections, the port number to use.

• **--print-defaults**

Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--protocol={TCP|SOCKET|PIPE|MEMORY}**

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

• **--replace, -r**

The **--replace** and **--ignore** options control handling of input rows that duplicate existing rows on unique key values. If you specify **--replace**, new rows replace existing rows that have the same unique key value. If you specify **--ignore**, input rows that duplicate an existing row on a unique key value are skipped. If you do not specify either option, an error occurs when a duplicate key value is found, and the rest of the text file is ignored.

• **--shared-memory-base-name=name**

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is **MYSQL**. The shared-memory name is case-sensitive.

This option applies only if the server was started with the **shared_memory** system variable enabled to support shared-memory connections.

• **--silent, -s**

Silent mode. Produce output only when errors occur.

• **--socket=path, -S path**

For connections to **localhost**, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the **named_pipe** system variable enabled to support named-pipe connections.

• **--ssl**

Options that begin with **--ssl** specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

• **--user=user_name, -u user_name**
The user name of the MySQL account to use for connecting to the server.

- **--use-threads=N**
  Load files in parallel using \(N\) threads.

- **--verbose, -v**
  Verbose mode. Print more information about what the program does.

- **--version, -V**
  Display version information and exit.

Here is a sample session that demonstrates use of `mysqlimport`:

```bash
shell> mysql -e 'CREATE TABLE imptest(id INT, n VARCHAR(30))' test
shell> ed
a
100   Max Sydow
101   Count Dracula
.w imptest.txt
32
q
shell> od -c imptest.txt
0000000  1  0  0   \t   M   a   x   S   y   d   o   w  
   1   0
0000020   1  \t   C   o   u   n   t   D   r   a   c   u   l   a  

shell> mysqlimport --local test imptest.txt
test.imptest: Records: 2  Deleted: 0  Skipped: 0  Warnings: 0
shell> mysql -e 'SELECT * FROM imptest' test
+------+---------------+
<table>
<thead>
<tr>
<th>id</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Max Sydow</td>
</tr>
<tr>
<td>101</td>
<td>Count Dracula</td>
</tr>
</tbody>
</table>
+------+---------------+
```

## 4.5.6 `mysqlshow` — Display Database, Table, and Column Information

The `mysqlshow` client can be used to quickly see which databases exist, their tables, or a table's columns or indexes.

`mysqlshow` provides a command-line interface to several SQL `SHOW` statements. See Section 13.7.5, “SHOW Statements”. The same information can be obtained by using those statements directly. For example, you can issue them from the `mysql` client program.

Invoke `mysqlshow` like this:

```bash
shell> mysqlshow [options] [db_name [tbl_name [col_name]]]
```

- If no database is given, a list of database names is shown.
- If no table is given, all matching tables in the database are shown.
- If no column is given, all matching columns and column types in the table are shown.

The output displays only the names of those databases, tables, or columns for which you have some privileges.
mysqlshow — Display Database, Table, and Column Information

If the last argument contains shell or SQL wildcard characters (*, ?, %, or _), only those names that are matched by the wildcard are shown. If a database name contains any underscores, those should be escaped with a backslash (some Unix shells require two) to get a list of the proper tables or columns. * and ? characters are converted into SQL % and _ wildcard characters. This might cause some confusion when you try to display the columns for a table with a _ in the name, because in this case, mysqlshow shows you only the table names that match the pattern. This is easily fixed by adding an extra % last on the command line as a separate argument.

mysqlshow supports the following options, which can be specified on the command line or in the [mysqlshow] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, "Using Option Files".

Table 4.15 mysqlshow Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--bind-address</td>
<td>Use specified network interface to connect to MySQL Server</td>
<td></td>
</tr>
<tr>
<td>--compress</td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td>--count</td>
<td>Show the number of rows per table</td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td>--debug-check</td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td>--debug-info</td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td>--default-auth</td>
<td>Authentication plugin to use</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--default-character-set</td>
<td>Specify default character set</td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--enable-cleartext-plugin</td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.47</td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--keys</td>
<td>Show table indexes</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--show-table-type</td>
<td>Show a column indicating the table type</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
</tbody>
</table>
mysqlshow — Display Database, Table, and Column Information

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--status</td>
<td>Display extra information about each table</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**
  Display a help message and exit.

- **--bind-address=ip_address**
  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.
  This option is supported only in the version of mysqlshow that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- **--character-sets-dir=dir_name**
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--compress,-C**
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- **--count**
  Show the number of rows per table. This can be slow for non-MyISAM tables.

- **--debug[=debug_options],-# [debug_options]**
  Write a debugging log. A typical debug_options string is d:t:o, file_name. The default is d:t:o.

- **--debug-check**
  Print some debugging information when the program exits.

- **--debug-info**
  Print debugging information and memory and CPU usage statistics when the program exits.

- **--default-character-set=charset_name**
  Use charset_name as the default character set. See Section 10.15, “Character Set Configuration”. 

• **--default-auth=plugin**

A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

• **--defaults-extra-file=file_name**

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--defaults-file=file_name**

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name.

• **--defaults-group-suffix=str**

Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, *mysqlshow* normally reads the [client] and [mysqlshow] groups. If the **--defaults-group-suffix=_other** option is given, *mysqlshow* also reads the [client_other] and [mysqlshow_other] groups.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--enable-cleartext-plugin**

Enable the *mysql_clear_password* cleartext authentication plugin. (See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.)

This option was added in MySQL 5.5.47.

• **--host=host_name, -h host_name**

Connect to the MySQL server on the given host.

• **--keys, -k**

Show table indexes.

• **--no-defaults**

Do not read any option files. If program startup fails due to reading unknown options from an option file, **--no-defaults** can be used to prevent them from being read.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• **--password[=password], -p[password]**

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, *mysqlshow* prompts for one. If given, there must be no space between **--password=** or **-p** and the password following it. If no password option is specified, the default is to send no password.
Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that mysqlshow should not prompt for one, use the --skip-password option.

- --pipe, -W

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.

- --plugin-dir=dir_name

The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but mysqlshow does not find it. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

- --port=port_num, -P port_num

For TCP/IP connections, the port number to use.

- --print-defaults

Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- --protocol={TCP|SOCKET|PIPE|MEMORY}

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

- --shared-memory-base-name=name

On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is MYSQL. The shared-memory name is case-sensitive.

This option applies only if the server was started with the shared_memory system variable enabled to support shared-memory connections.

- --show-table-type, -t

Show a column indicating the table type, as in SHOW FULL TABLES. The type is BASE TABLE or VIEW.

- --socket=path, -S path

For connections to localhost, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.

- --ssl*
mysqlslap — Load Emulation Client

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

- `--status`, `-i`
  Display extra information about each table.

- `--user=user_name`, `-u user_name`
  The user name of the MySQL account to use for connecting to the server.

- `--verbose`, `-v`
  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version`, `-V`
  Display version information and exit.

4.5.7 mysqlslap — Load Emulation Client

mysqlslap is a diagnostic program designed to emulate client load for a MySQL server and to report the timing of each stage. It works as if multiple clients are accessing the server.

Invoke mysqlslap like this:

```
shell> mysqlslap [options]
```

Some options such as `--create` or `--query` enable you to specify a string containing an SQL statement or a file containing statements. If you specify a file, by default it must contain one statement per line. (That is, the implicit statement delimiter is the newline character.) Use the `--delimiter` option to specify a different delimiter, which enables you to specify statements that span multiple lines or place multiple statements on a single line. You cannot include comments in a file; mysqlslap does not understand them.

mysqlslap runs in three stages:

1. Create schema, table, and optionally any stored programs or data to use for the test. This stage uses a single client connection.

2. Run the load test. This stage can use many client connections.

3. Clean up (disconnect, drop table if specified). This stage uses a single client connection.

Examples:

Supply your own create and query SQL statements, with 50 clients querying and 200 selects for each (enter the command on a single line):

```
mysqlslap --delimiter=";";
   --create="CREATE TABLE a (b int);INSERT INTO a VALUES (23)"
   --query="SELECT * FROM a" --concurrency=50 --iterations=200
```

Let mysqlslap build the query SQL statement with a table of two `INT` columns and three `VARCHAR` columns. Use five clients querying 20 times each. Do not create the table or insert the data (that is, use the previous test's schema and data):

```
mysqlslap --concurrency=5 --iterations=20
   --number-int-cols=2 --number-char-cols=3
   --auto-generate-sql
```
Tell the program to load the create, insert, and query SQL statements from the specified files, where the `create.sql` file has multiple table creation statements delimited by `';'` and multiple insert statements delimited by `'.'`. The `--query` file will have multiple queries delimited by `';'`. Run all the load statements, then run all the queries in the query file with five clients (five times each):

```
mysqlslap --concurrency=5
    --iterations=5 --query=query.sql --create=create.sql
    --delimiter=";"*
```

`mysqlslap` supports the following options, which can be specified on the command line or in the `[mysqlslap]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

### Table 4.16 `mysqlslap` Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--auto-generate-sql</code></td>
<td>Generate SQL statements automatically when they are not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>supplied in files or using command options</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-add-autoincrement</code></td>
<td>Add AUTO_INCREMENT column to automatically</td>
<td></td>
</tr>
<tr>
<td></td>
<td>generated tables</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-execute-number</code></td>
<td>Specify how many queries to generate automatically</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-g guid-primary</code></td>
<td>Add a GUID-based primary key to automatically generated tables</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-load-type</code></td>
<td>Specify the test load type</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-secondary-indexes</code></td>
<td>Specify how many secondary indexes to add to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>automatically generated tables</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-unique-query-number</code></td>
<td>How many different queries to generate for automatic tests</td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-unique-write-number</code></td>
<td>How many different queries to generate for <code>--auto-</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>generate-sql-write-number</code></td>
<td></td>
</tr>
<tr>
<td><code>--auto-generate-sql-write-number</code></td>
<td>How many row inserts to perform on each thread</td>
<td></td>
</tr>
<tr>
<td><code>--commit</code></td>
<td>How many statements to execute before committing</td>
<td></td>
</tr>
<tr>
<td><code>--compress</code></td>
<td>Compress all information sent between client and server</td>
<td></td>
</tr>
<tr>
<td><code>--concurrency</code></td>
<td>Number of clients to simulate when issuing the SELECT statement</td>
<td></td>
</tr>
<tr>
<td><code>--create</code></td>
<td>File or string containing the statement to use for creating the table</td>
<td></td>
</tr>
<tr>
<td><code>--create-schema</code></td>
<td>Schema in which to run the tests</td>
<td></td>
</tr>
<tr>
<td><code>--csv</code></td>
<td>Generate output in comma-separated values format</td>
<td></td>
</tr>
<tr>
<td><code>--debug</code></td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td><code>--debug-check</code></td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--debug-info</code></td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td><code>--default-auth</code></td>
<td>Authentication plugin to use</td>
<td>5.5.10</td>
</tr>
<tr>
<td><code>--defaults-extra-file</code></td>
<td>Read named option file in addition to usual option files</td>
<td></td>
</tr>
<tr>
<td><code>--defaults-file</code></td>
<td>Read only named option file</td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
</tr>
<tr>
<td>--delimiter</td>
<td>Delimiter to use in SQL statements</td>
<td></td>
</tr>
<tr>
<td>--detach</td>
<td>Detach (close and reopen) each connection after each N statements</td>
<td></td>
</tr>
<tr>
<td>--enable-cleartext-plugin</td>
<td>Enable cleartext authentication plugin</td>
<td>5.5.27</td>
</tr>
<tr>
<td>--engine</td>
<td>Storage engine to use for creating the table</td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
<td></td>
</tr>
<tr>
<td>--iterations</td>
<td>Number of times to run the tests</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
</tr>
<tr>
<td>--no-drop</td>
<td>Do not drop any schema created during the test run</td>
<td>5.5.12</td>
</tr>
<tr>
<td>--number-char-cols</td>
<td>Number of VARCHAR columns to use if --auto-generate-sql is specified</td>
<td></td>
</tr>
<tr>
<td>--number-int-cols</td>
<td>Number of INT columns to use if --auto-generate-sql is specified</td>
<td></td>
</tr>
<tr>
<td>--number-of-queries</td>
<td>Limit each client to approximately this number of queries</td>
<td></td>
</tr>
<tr>
<td>--only-print</td>
<td>Do not connect to databases. mysqlslap only prints what it would have done</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--pipe</td>
<td>Connect to server using named pipe (Windows only)</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--post-query</td>
<td>File or string containing the statement to execute after the tests have completed</td>
<td></td>
</tr>
<tr>
<td>--post-system</td>
<td>String to execute using system() after the tests have completed</td>
<td></td>
</tr>
<tr>
<td>--pre-query</td>
<td>File or string containing the statement to execute before running the tests</td>
<td></td>
</tr>
<tr>
<td>--pre-system</td>
<td>String to execute using system() before running the tests</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--query</td>
<td>File or string containing the SELECT statement to use for retrieving data</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--silent</td>
<td>Silent mode</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl</td>
<td>Enable connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-ca</td>
<td>File that contains list of trusted SSL Certificate Authorities</td>
<td></td>
</tr>
<tr>
<td>--ssl-capath</td>
<td>Directory that contains trusted SSL Certificate Authority certificate files</td>
<td></td>
</tr>
</tbody>
</table>
## mysqlslap — Load Emulation Client

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ssl-cert</td>
<td>File that contains X.509 certificate</td>
<td></td>
</tr>
<tr>
<td>--ssl-cipher</td>
<td>Permissible ciphers for connection encryption</td>
<td></td>
</tr>
<tr>
<td>--ssl-key</td>
<td>File that contains X.509 key</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--ssl-verify-server-cert</td>
<td>Verify host name against server certificate Common Name identity</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
</tbody>
</table>

- **--help, -?**
  Display a help message and exit.

- **--auto-generate-sql, -a**
  Generate SQL statements automatically when they are not supplied in files or using command options.

- **--auto-generate-sql-add-autoincrement**
  Add an `AUTO_INCREMENT` column to automatically generated tables.

- **--auto-generate-sql-execute-number=N**
  Specify how many queries to generate automatically.

- **--auto-generate-sql-guid-primary**
  Add a GUID-based primary key to automatically generated tables.

- **--auto-generate-sql-load-type=type**
  Specify the test load type. The permissible values are `read` (scan tables), `write` (insert into tables), `key` (read primary keys), `update` (update primary keys), or `mixed` (half inserts, half scanning selects). The default is `mixed`.

- **--auto-generate-sql-secondary-indexes=N**
  Specify how many secondary indexes to add to automatically generated tables. By default, none are added.

- **--auto-generate-sql-unique-query-number=N**
  How many different queries to generate for automatic tests. For example, if you run a `key` test that performs 1000 selects, you can use this option with a value of 1000 to run 1000 unique queries, or with a value of 50 to perform 50 different selects. The default is 10.

- **--auto-generate-sql-unique-write-number=N**
  How many different queries to generate for `--auto-generate-sql-write-number`. The default is 10.

- **--auto-generate-sql-write-number=N**
How many row inserts to perform. The default is 100.

•  **--commit=N**
  How many statements to execute before committing. The default is 0 (no commits are done).

•  **--compress, -C**
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

•  **--concurrency=N, -c N**
  The number of parallel clients to simulate.

•  **--create=value**
  The file or string containing the statement to use for creating the table.

•  **--create-schema=value**
  The schema in which to run the tests.

  **Note**
  If the **--auto-generate-sql** option is also given, mysqlslap drops the schema at the end of the test run. To avoid this, use the **--no-drop** option as well.

•  **--csv=file_name**
  Generate output in comma-separated values format. The output goes to the named file, or to the standard output if no file is given.

•  **--debug=[debug_options], -# [debug_options]**
  Write a debugging log. A typical **debug_options** string is **d:t:o, file_name**. The default is **d:t:o, /tmp/mysqlslap.trace**.

•  **--debug-check**
  Print some debugging information when the program exits.

•  **--debug-info, -T**
  Print debugging information and memory and CPU usage statistics when the program exits.

•  **--default-auth=plugin**
  A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

•  **--defaults-extra-file=file_name**
  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. **file_name** is interpreted relative to the current directory if given as a relative path name.
mysqlslap — Load Emulation Client

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --defaults-file=file_name

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. 
  file_name is interpreted relative to the current directory if given as a relative path name.

• --defaults-group-suffix=str

  Read not only the usual option groups, but also groups with the usual names and a suffix of str. 
  For example, mysqlslap normally reads the [client] and [mysqlslap] groups. If the -- 
  defaults-group-suffix=_other option is given, mysqlslap also reads the [client_other] 
  and [mysqlslap_other] groups.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --delimiter=str, -F str

  The delimiter to use in SQL statements supplied in files or using command options.

• --detach=N

  Detach (close and reopen) each connection after each N statements. The default is 0 (connections are 
  not detached).

• --enable-cleartext-plugin

  Enable the mysql_clear_password cleartext authentication plugin. (See Section 6.4.1.3, “Client-Side 
  Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

• --engine=engine_name, -e engine_name

  The storage engine to use for creating tables.

• --host=host_name, -h host_name

  Connect to the MySQL server on the given host.

• --iterations=N, -i N

  The number of times to run the tests.

• --no-drop

  Prevent mysqlslap from dropping any schema it creates during the test run. This option was added in 
  MySQL 5.5.12.

• --no-defaults

  Do not read any option files. If program startup fails due to reading unknown options from an option file, 
  --no-defaults can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --number-char-cols=N, -x N
The number of VARCHAR columns to use if `--auto-generate-sql` is specified.

- `--number-int-cols=N, -y N`

The number of INT columns to use if `--auto-generate-sql` is specified.

- `--number-of-queries=N`

Limit each client to approximately this many queries. Query counting takes into account the statement delimiter. For example, if you invoke `mysqlslap` as follows, the ; delimiter is recognized so that each instance of the query string counts as two queries. As a result, 5 rows (not 10) are inserted.

```shell
shell> mysqlslap --delimiter=";" --number-of-queries=10
--query="use test;insert into t values(null)"
```

- `--only-print`

Do not connect to databases. `mysqlslap` only prints what it would have done.

- `--password[=password], -p[password]`

The password of the MySQL account used for connecting to the server. The password value is optional. If not given, `mysqlslap` prompts for one. If given, there must be no space between `--password=` or `-p` and the password following it. If no password option is specified, the default is to send no password.

Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

To explicitly specify that there is no password and that `mysqlslap` should not prompt for one, use the `--skip-password` option.

- `--pipe, -W`

On Windows, connect to the server using a named pipe. This option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- `--plugin-dir=dir_name`

The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlslap` does not find it. See Section 6.2.10, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

- `--port=port_num, -P port_num`

For TCP/IP connections, the port number to use.

- `--post-query=value`

The file or string containing the statement to execute after the tests have completed. This execution is not counted for timing purposes.

- `--post-system=string`

The string to execute using `system()` after the tests have completed. This execution is not counted for timing purposes.
mysqlslap — Load Emulation Client

- **--pre-query=value**
  The file or string containing the statement to execute before running the tests. This execution is not counted for timing purposes.

- **--pre-system=str**
  The string to execute using `system()` before running the tests. This execution is not counted for timing purposes.

- **--print-defaults**
  Print the program name and all options that it gets from option files.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--protocol={TCP|SOCKET|PIPE|MEMORY}**
  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

- **--query=value, -q value**
  The file or string containing the `SELECT` statement to use for retrieving data.

- **--shared-memory-base-name=name**
  On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case-sensitive.

  This option applies only if the server was started with the `shared_memory` system variable enabled to support shared-memory connections.

- **--silent, -s**
  Silent mode. No output.

- **--socket=path, -S path**
  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

  On Windows, this option applies only if the server was started with the `named_pipe` system variable enabled to support named-pipe connections.

- **--ssl**
  Options that begin with **--ssl** specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

- **--user=user_name, -u user_name**
  The user name of the MySQL account to use for connecting to the server.
• --verbose, -v
   Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

• --version, -V
   Display version information and exit.

4.6 Administrative and Utility Programs

This section describes administrative programs and programs that perform miscellaneous utility operations.

4.6.1 innochecksum — Offline InnoDB File Checksum Utility

innochecksum prints checksums for InnoDB files. This tool reads an InnoDB tablespace file, calculates the checksum for each page, compares the calculated checksum to the stored checksum, and reports mismatches, which indicate damaged pages. It was originally developed to speed up verifying the integrity of tablespace files after power outages but can also be used after file copies. Because checksum mismatches cause InnoDB to deliberately shut down a running server, it may be preferable to use this tool rather than waiting for an in-production server to encounter the damaged pages. innochecksum supports files up to 2GB in size.

innochecksum does not support tablespaces that contain compressed pages.

innochecksum cannot be used on tablespace files that the server already has open. For such files, you should use CHECK TABLE to check tables within the tablespace.

If checksum mismatches are found, you would normally restore the tablespace from backup or start the server and attempt to use mysqldump to make a backup of the tables within the tablespace.

Invoke innochecksum like this:

shell> innochecksum [options] file_name

innochecksum supports the following options. For options that refer to page numbers, the numbers are zero-based.

• -c
   Print a count of the number of pages in the file.

• -d
   Debug mode; prints checksums for each page.

• -e num
   End at this page number.

• -p num
   Check only this page number.

• -s num
   Start at this page number.

• -v
myisam_ftdump — Display Full-Text Index information

Verbose mode; print a progress indicator every five seconds.

4.6.2 myisam_ftdump — Display Full-Text Index information

myisam_ftdump displays information about FULLTEXT indexes in MyISAM tables. It reads the MyISAM index file directly, so it must be run on the server host where the table is located. Before using myisam_ftdump, be sure to issue a FLUSH TABLES statement first if the server is running.

myisam_ftdump scans and dumps the entire index, which is not particularly fast. On the other hand, the distribution of words changes infrequently, so it need not be run often.

Invoke myisam_ftdump like this:

```
shell> myisam_ftdump [options] tbl_name index_num
```

The tbl_name argument should be the name of a MyISAM table. You can also specify a table by naming its index file (the file with the .MYI suffix). If you do not invoke myisam_ftdump in the directory where the table files are located, the table or index file name must be preceded by the path name to the table's database directory. Index numbers begin with 0.

Example: Suppose that the test database contains a table named mytexttable that has the following definition:

```sql
CREATE TABLE mytexttable
(    id INT NOT NULL,
    txt TEXT NOT NULL,
    PRIMARY KEY (id),
    FULLTEXT (txt)
) ENGINE=MyISAM;
```

The index on id is index 0 and the FULLTEXT index on txt is index 1. If your working directory is the test database directory, invoke myisam_ftdump as follows:

```
shell> myisam_ftdump mytexttable 1
```

If the path name to the test database directory is /usr/local/mysql/data/test, you can also specify the table name argument using that path name. This is useful if you do not invoke myisam_ftdump in the database directory:

```
shell> myisam_ftdump /usr/local/mysql/data/test/mytexttable 1
```

You can use myisam_ftdump to generate a list of index entries in order of frequency of occurrence like this on Unix-like systems:

```
shell> myisam_ftdump -c mytexttable 1 | sort -r
```

On Windows, use:

```
shell> myisam_ftdump -c mytexttable 1 | sort /R
```

myisam_ftdump supports the following options:

- `--help, -h, -?`
  Display a help message and exit.

- `--count, -c`
  Calculate per-word statistics (counts and global weights).
myisamchk — MyISAM Table-Maintenance Utility

- **--dump, -d**
  Dump the index, including data offsets and word weights.
- **--length, -l**
  Report the length distribution.
- **--stats, -s**
  Report global index statistics. This is the default operation if no other operation is specified.
- **--verbose, -v**
  Verbose mode. Print more output about what the program does.

4.6.3 **myisamchk** — MyISAM Table-Maintenance Utility

The **myisamchk** utility gets information about your database tables or checks, repairs, or optimizes them. **myisamchk** works with **MyISAM** tables (tables that have .MYD and .MYI files for storing data and indexes).

You can also use the **CHECK TABLE** and **REPAIR TABLE** statements to check and repair **MyISAM** tables. See Section 13.7.2.2, “CHECK TABLE Statement”, and Section 13.7.2.5, “REPAIR TABLE Statement”.

The use of **myisamchk** with partitioned tables is not supported.

**Caution**

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

Invoke **myisamchk** like this:

```bash
shell> myisamchk [options] tbl_name ...
```

The **options** specify what you want **myisamchk** to do. They are described in the following sections. You can also get a list of options by invoking **myisamchk --help**.

With no options, **myisamchk** simply checks your table as the default operation. To get more information or to tell **myisamchk** to take corrective action, specify options as described in the following discussion.

**tbl_name** is the database table you want to check or repair. If you run **myisamchk** somewhere other than in the database directory, you must specify the path to the database directory, because **myisamchk** has no idea where the database is located. In fact, **myisamchk** does not actually care whether the files you are working on are located in a database directory. You can copy the files that correspond to a database table into some other location and perform recovery operations on them there.

You can name several tables on the **myisamchk** command line if you wish. You can also specify a table by naming its index file (the file with the .MYI suffix). This enables you to specify all tables in a directory by using the pattern *.MYI. For example, if you are in a database directory, you can check all the **MyISAM** tables in that directory like this:

```bash
shell> myisamchk *.MYI
```

If you are not in the database directory, you can check all the tables there by specifying the path to the directory:

```bash
shell> myisamchk /path/to/database_dir/* .MYI
```
You can even check all tables in all databases by specifying a wildcard with the path to the MySQL data directory:

```
shell> myisamchk /path/to/datadir/*/*.MYI
```

The recommended way to quickly check all MyISAM tables is:

```
shell> myisamchk --silent --fast /path/to/datadir/*/*.MYI
```

If you want to check all MyISAM tables and repair any that are corrupted, you can use the following command:

```
shell> myisamchk --silent --force --fast --update-state --key_buffer_size=64M --myisam_sort_buffer_size=64M --read_buffer_size=1M --write_buffer_size=1M /path/to/datadir/*/*.MYI
```

This command assumes that you have more than 64MB free. For more information about memory allocation with myisamchk, see Section 4.6.3.6, “myisamchk Memory Usage”.

For additional information about using myisamchk, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

### Important

You must ensure that no other program is using the tables while you are running myisamchk. The most effective means of doing so is to shut down the MySQL server while running myisamchk, or to lock all tables that myisamchk is being used on.

Otherwise, when you run myisamchk, it may display the following error message:

```
warning: clients are using or haven't closed the table properly
```

This means that you are trying to check a table that has been updated by another program (such as the mysqld server) that hasn't yet closed the file or that has died without closing the file properly, which can sometimes lead to the corruption of one or more MyISAM tables.

If mysqld is running, you must force it to flush any table modifications that are still buffered in memory by using `FLUSH TABLES`. You should then ensure that no one is using the tables while you are running myisamchk.

However, the easiest way to avoid this problem is to use `CHECK TABLE` instead of myisamchk to check tables. See Section 13.7.2.2, “CHECK TABLE Statement”.

myisamchk supports the following options, which can be specified on the command line or in the [myisamchk] group of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
<th>Deprecated</th>
</tr>
</thead>
<tbody>
<tr>
<td>--analyze</td>
<td>Analyze the distribution of key values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--backup</td>
<td>Make a backup of the .MYD file as file_name-time.BAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--block-search</td>
<td>Find the record that a block at the given offset belongs to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
<td>Deprecated</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>--check</td>
<td>Check the table for errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--check-only-changed</td>
<td>Check only tables that have changed since the last check</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--correct-checksum</td>
<td>Correct the checksum information for the table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--data-file-length</td>
<td>Maximum length of the data file (when re-creating data file when it is full)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--decode_bits</td>
<td>Decode_bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--defaults-extra-file</td>
<td>Read named option file in addition to usual option files</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--defaults-file</td>
<td>Read only named option file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--defaults-group-suffix</td>
<td>Option group suffix value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--description</td>
<td>Print some descriptive information about the table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--extend-check</td>
<td>Do very thorough table check or repair that tries to recover every possible row from the data file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--fast</td>
<td>Check only tables that haven't been closed properly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Do a repair operation automatically if myisamchk finds any errors in the table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--force</td>
<td>Overwrite old temporary files. For use with the -r or -o option</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--ft_max_word_len</td>
<td>Maximum word length for FULLTEXT indexes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--ft_min_word_len</td>
<td>Minimum word length for FULLTEXT indexes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--ft_stopword_file</td>
<td>Use stopwords from this file instead of built-in list</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--HELP</td>
<td>Display help message and exit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--information</td>
<td>Print informational statistics about the table that is checked</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--key_buffer_size</td>
<td>Size of buffer used for index blocks for MyISAM tables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--keys-used</td>
<td>A bit-value that indicates which indexes to update</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--max-record-length</td>
<td>Skip rows larger than the given length if myisamchk cannot allocate memory to hold them</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--medium-check</td>
<td>Do a check that is faster than an --extend-check operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--myisam_block_size</td>
<td>Block size to be used for MyISAM index pages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--myisam_sort_buffer_size</td>
<td>The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE</td>
<td>5.5.29</td>
<td></td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Read no option files</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--parallel-recover</td>
<td>Uses the same technique as -r and -n, but creates all the keys in parallel, using different threads (beta)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Option Name | Description | Introduced | Deprecated
--- | --- | --- | ---
`--print-defaults` | Print default options | | |
`--quick` | Achieve a faster repair by not modifying the data file | | |
`--read_buffer_size` | Each thread that does a sequential scan allocates a buffer of this size for each table it scans | | |
`--read-only` | Do not mark the table as checked | | |
`--recover` | Do a repair that can fix almost any problem except unique keys that aren't unique | | |
`--safe-recover` | Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found | | |
`--set-auto-increment` | Force AUTO_INCREMENT numbering for new records to start at the given value | | |
`--set-collation` | Specify the collation to use for sorting table indexes | | |
`--silent` | Silent mode | | |
`--sort_buffer_size` | The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE | 5.5.29 |
`--sort-index` | Sort the index tree blocks in high-low order | | |
`--sort_key_blocks` | `sort_key_blocks` | | |
`--sort-records` | Sort records according to a particular index | | |
`--sort-recover` | Force myisamchk to use sorting to resolve the keys even if the temporary files would be very large | | |
`--stats_method` | Specifies how MyISAM index statistics collection code should treat NULLs | | |
`--tmpdir` | Directory to be used for storing temporary files | | |
`--unpack` | Unpack a table that was packed with myisampack | | |
`--update-state` | Store information in the .MYI file to indicate when the table was checked and whether the table crashed | | |
`--verbose` | Verbose mode | | |
`--version` | Display version information and exit | | |
`--write_buffer_size` | Write buffer size | | |

### 4.6.3.1 myisamchk General Options

The options described in this section can be used for any type of table maintenance operation performed by `myisamchk`. The sections following this one describe options that pertain only to specific operations, such as table checking or repairing.

- `--help, -?`
  Display a help message and exit. Options are grouped by type of operation.

- `--HELP, -H`
  Display a help message and exit. Options are presented in a single list.
--debug=debug_options, -# debug_options
Write a debugging log. A typical debug_options string is d:t:o, file_name. The default is d:t:o, / tmp/myisamchk.trace.

--defaults-extra-file=file_name
Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

--defaults-file=file_name
Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

--defaults-group-suffix=str
Read not only the usual option groups, but also groups with the usual names and a suffix of str.
For example, myisamchk normally reads the [myisamchk] group. If the --defaults-group-suffix=_other option is given, myisamchk also reads the [myisamchk_other] group.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

--no-defaults
Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

--print-defaults
Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

--silent, -s
Silent mode. Write output only when errors occur. You can use -s twice (-ss) to make myisamchk very silent.

--verbose, -v
Verbose mode. Print more information about what the program does. This can be used with -d and -e. Use -v multiple times (-vv, -vvv) for even more output.

--version, -V
Display version information and exit.
**myisamchk** — MyISAM Table-Maintenance Utility

- **--wait, -w**

  Instead of terminating with an error if the table is locked, wait until the table is unlocked before continuing. If you are running **mysqld** with external locking disabled, the table can be locked only by another **myisamchk** command.

You can also set the following variables by using **--var_name=value** syntax:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>decode_bits</td>
<td>9</td>
</tr>
<tr>
<td>ft_max_word_len</td>
<td>version-dependent</td>
</tr>
<tr>
<td>ft_min_word_len</td>
<td>4</td>
</tr>
<tr>
<td>ft_stopword_file</td>
<td>built-in list</td>
</tr>
<tr>
<td>key_buffer_size</td>
<td>523264</td>
</tr>
<tr>
<td>myisam_block_size</td>
<td>1024</td>
</tr>
<tr>
<td>myisam_sort_key_blocks</td>
<td>16</td>
</tr>
<tr>
<td>read_buffer_size</td>
<td>262136</td>
</tr>
<tr>
<td>sort_buffer_size</td>
<td>2097144</td>
</tr>
<tr>
<td>sort_key_blocks</td>
<td>16</td>
</tr>
<tr>
<td>stats_method</td>
<td>nulls_unequal</td>
</tr>
<tr>
<td>write_buffer_size</td>
<td>262136</td>
</tr>
</tbody>
</table>

The possible **myisamchk** variables and their default values can be examined with **myisamchk --help**:

- **sort_buffer_size** is used when the keys are repaired by sorting keys, which is the normal case when you use **--recover**. As of MySQL 5.5.29, **myisam_sort_buffer_size** is available as an alternative name to **sort_buffer_size**. **myisam_sort_buffer_size** is preferable to **sort_buffer_size** because its name corresponds to the **myisam_sort_buffer_size** server system variable that has a similar meaning. **sort_buffer_size** should be considered deprecated.

- **key_buffer_size** is used when you are checking the table with **--extend-check** or when the keys are repaired by inserting keys row by row into the table (like when doing normal inserts). Repairing through the key buffer is used in the following cases:
  - You use **--safe-recover**.
  - The temporary files needed to sort the keys would be more than twice as big as when creating the key file directly. This is often the case when you have large key values for **CHAR**, **VARCHAR**, or **TEXT** columns, because the sort operation needs to store the complete key values as it proceeds. If you have lots of temporary space and you can force **myisamchk** to repair by sorting, you can use the **--sort-recover** option.

  Repairing through the key buffer takes much less disk space than using sorting, but is also much slower.

If you want a faster repair, set the **key_buffer_size** and **myisam_sort_buffer_size** variables to about 25% of your available memory. You can set both variables to large values, because only one of them is used at a time.

- **myisam_block_size** is the size used for index blocks.

  **stats_method** influences how **NULL** values are treated for index statistics collection when the **--analyze** option is given. It acts like the **myisam_stats_method** system variable. For more information,
myisamchk — MyISAM Table-Maintenance Utility

see the description of `myisam_stats_method` in Section 5.1.7, “Server System Variables”, and Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

`ft_min_word_len` and `ft_max_word_len` indicate the minimum and maximum word length for `FULLTEXT` indexes. `ft_stopword_file` names the stopword file. These need to be set under the following circumstances.

If you use `myisamchk` to perform an operation that modifies table indexes (such as repair or analyze), the `FULLTEXT` indexes are rebuilt using the default full-text parameter values for minimum and maximum word length and the stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in MyISAM index files. To avoid the problem if you have modified the minimum or maximum word length or the stopword file in the server, specify the same `ft_min_word_len`, `ft_max_word_len`, and `ft_stopword_file` values to `myisamchk` that you use for `mysqld`. For example, if you have set the minimum word length to 3, you can repair a table with `myisamchk` like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```

To ensure that `myisamchk` and the server use the same values for full-text parameters, you can place each one in both the `[mysqld]` and `[myisamchk]` sections of an option file:

```
[mysqld]
ft_min_word_len=3

[myisamchk]
ft_min_word_len=3
```

An alternative to using `myisamchk` is to use the `REPAIR TABLE`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, or `ALTER TABLE`. These statements are performed by the server, which knows the proper full-text parameter values to use.

### 4.6.3.2 myisamchk Check Options

`myisamchk` supports the following options for table checking operations:

- **--check**, `-c`
  
  Check the table for errors. This is the default operation if you specify no option that selects an operation type explicitly.

- **--check-only-changed**, `-C`
  
  Check only tables that have changed since the last check.

- **--extend-check**, `-e`
  
  Check the table very thoroughly. This is quite slow if the table has many indexes. This option should only be used in extreme cases. Normally, `myisamchk` or `myisamchk --medium-check` should be able to determine whether there are any errors in the table.

  If you are using `--extend-check` and have plenty of memory, setting the `key_buffer_size` variable to a large value helps the repair operation run faster.

  See also the description of this option under table repair options.

  For a description of the output format, see Section 4.6.3.5, “Obtaining Table Information with `myisamchk`”.

- **--fast**, `-F`
Check only tables that haven't been closed properly.

- **--force, -f**
  Do a repair operation automatically if myisamchk finds any errors in the table. The repair type is the same as that specified with the **--recover** or **-r** option.

- **--information, -i**
  Print informational statistics about the table that is checked.

- **--medium-check, -m**
  Do a check that is faster than an **--extend-check** operation. This finds only 99.99% of all errors, which should be good enough in most cases.

- **--read-only, -T**
  Do not mark the table as checked. This is useful if you use myisamchk to check a table that is in use by some other application that does not use locking, such as mysql when run with external locking disabled.

- **--update-state, -U**
  Store information in the .MYI file to indicate when the table was checked and whether the table crashed. This should be used to get full benefit of the **--check-only-changed** option, but you shouldn’t use this option if the mysql server is using the table and you are running it with external locking disabled.

### 4.6.3.3 myisamchk Repair Options

myisamchk supports the following options for table repair operations (operations performed when an option such as **--recover** or **--safe-recover** is given):

- **--backup, -B**
  Make a backup of the .MYD file as *file_name-time.BAK*

- **--character-sets-dir=dir_name**
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--correct-checksum**
  Correct the checksum information for the table.

- **--data-file-length=len, -D len**
  The maximum length of the data file (when re-creating data file when it is “full”).

- **--extend-check, -e**
  Do a repair that tries to recover every possible row from the data file. Normally, this also finds a lot of garbage rows. Do not use this option unless you are desperate.

  See also the description of this option under table checking options.

  For a description of the output format, see Section 4.6.3.5, “Obtaining Table Information with myisamchk”.
• **--force, -f**

Overwrite old intermediate files (files with names like `tbl_name.TMD`) instead of aborting.

• **--keys-used=val, -k val**

For `myisamchk`, the option value is a bit value that indicates which indexes to update. Each binary bit of the option value corresponds to a table index, where the first index is bit 0. An option value of 0 disables updates to all indexes, which can be used to get faster inserts. Deactivated indexes can be reactivated by using `myisamchk -r`.

• **--no-symlinks, -l**

Do not follow symbolic links. Normally `myisamchk` repairs the table that a symlink points to. This option does not exist as of MySQL 4.0 because versions from 4.0 on do not remove symlinks during repair operations.

• **--max-record-length=len**

Skip rows larger than the given length if `myisamchk` cannot allocate memory to hold them.

• **--parallel-recover, -p**

Use the same technique as `-r` and `-n`, but create all the keys in parallel, using different threads. *This is beta-quality code. Use at your own risk!*

• **--quick, -q**

Achieve a faster repair by modifying only the index file, not the data file. You can specify this option twice to force `myisamchk` to modify the original data file in case of duplicate keys.

• **--recover, -r**

Do a repair that can fix almost any problem except unique keys that are not unique (which is an extremely unlikely error with MyISAM tables). If you want to recover a table, this is the option to try first. You should try **--safe-recover** only if `myisamchk` reports that the table cannot be recovered using **--recover**. (In the unlikely case that **--recover** fails, the data file remains intact.)

If you have lots of memory, you should increase the value of `myisam_sort_buffer_size`.

• **--safe-recover, -o**

Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found. This is an order of magnitude slower than **--recover**, but can handle a couple of very unlikely cases that **--recover** cannot. This recovery method also uses much less disk space than **--recover**. Normally, you should repair first using **--recover**, and then with **--safe-recover** only if **--recover** fails.

If you have lots of memory, you should increase the value of `key_buffer_size`.

• **--set-collation=name**

Specify the collation to use for sorting table indexes. The character set name is implied by the first part of the collation name.

• **--sort-recover, -n**

Force `myisamchk` to use sorting to resolve the keys even if the temporary files would be very large.
• **--tmpdir=dir_name, -t dir_name**

The path of the directory to be used for storing temporary files. If this is not set, `myisamchk` uses the value of the `TMPDIR` environment variable. `--tmpdir` can be set to a list of directory paths that are used successively in round-robin fashion for creating temporary files. The separator character between directory names is the colon (:) on Unix and the semicolon (;) on Windows.

• **--unpack, -u**

Unpack a table that was packed with `myisampack`.

### 4.6.3.4 Other myisamchk Options

`myisamchk` supports the following options for actions other than table checks and repairs:

• **--analyze, -a**

Analyze the distribution of key values. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use. To obtain information about the key distribution, use a `myisamchk --description --verbose tbl_name` command or the `SHOW INDEX FROM tbl_name` statement.

• **--block-search=offset, -b offset**

Find the record that a block at the given offset belongs to.

• **--description, -d**

Print some descriptive information about the table. Specifying the `--verbose` option once or twice produces additional information. See Section 4.6.3.5, "Obtaining Table Information with myisamchk".

• **--set-auto-increment[=value], -A[value]**

Force `AUTO_INCREMENT` numbering for new records to start at the given value (or higher, if there are existing records with `AUTO_INCREMENT` values this large). If `value` is not specified, `AUTO_INCREMENT` numbers for new records begin with the largest value currently in the table, plus one.

• **--sort-index, -S**

Sort the index tree blocks in high-low order. This optimizes seeks and makes table scans that use indexes faster.

• **--sort-records=N, -R N**

Sort records according to a particular index. This makes your data much more localized and may speed up range-based `SELECT` and `ORDER BY` operations that use this index. (The first time you use this option to sort a table, it may be very slow.) To determine a table's index numbers, use `SHOW INDEX`, which displays a table's indexes in the same order that `myisamchk` sees them. Indexes are numbered beginning with 1.

If keys are not packed (`PACK_KEYS=0`), they have the same length, so when `myisamchk` sorts and moves records, it just overwrites record offsets in the index. If keys are packed (`PACK_KEYS=1`), `myisamchk` must unpack key blocks first, then re-create indexes and pack the key blocks again. (In this case, re-creating indexes is faster than updating offsets for each index.)

### 4.6.3.5 Obtaining Table Information with myisamchk

402
To obtain a description of a MyISAM table or statistics about it, use the commands shown here. The output from these commands is explained later in this section.

- **myisamchk -d tbl_name**
  
  Runs `myisamchk` in “describe mode” to produce a description of your table. If you start the MySQL server with external locking disabled, `myisamchk` may report an error for a table that is updated while it runs. However, because `myisamchk` does not change the table in describe mode, there is no risk of destroying data.

- **myisamchk -dv tbl_name**
  
  Adding `-v` runs `myisamchk` in verbose mode so that it produces more information about the table. Adding `-v` a second time produces even more information.

- **myisamchk -eis tbl_name**
  
  Shows only the most important information from a table. This operation is slow because it must read the entire table.

- **myisamchk -eiv tbl_name**
  
  This is like `-eis`, but tells you what is being done.

The `tbl_name` argument can be either the name of a MyISAM table or the name of its index file, as described in Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”. Multiple `tbl_name` arguments can be given.

Suppose that a table named `person` has the following structure. (The `MAX_ROWS` table option is included so that in the example output from `myisamchk` shown later, some values are smaller and fit the output format more easily.)

```sql
CREATE TABLE person
(
    id INT NOT NULL AUTO_INCREMENT,
    last_name VARCHAR(20) NOT NULL,
    first_name VARCHAR(20) NOT NULL,
    birth DATE,
    death DATE,
    PRIMARY KEY (id),
    INDEX (last_name, first_name),
    INDEX (birth)
) MAX_ROWS = 1000000 ENGINE=MYISAM;
```

Suppose also that the table has these data and index file sizes:

```
-rw-rw---- 1 mysql mysql 9347072 Aug 19 11:47 person.MYD
-rw-rw---- 1 mysql mysql 6066176 Aug 19 11:47 person.MYI
```

Example of `myisamchk` `-dvv` output:

```
MyISAM file:         person
Record format:       Packed
Character set:       latin1_swedish_ci (8)
File-version:        1
Creation time:       2009-08-19 16:47:41
Recover time:        2009-08-19 16:47:56
Status:              checked,analyzed,optimized keys
Auto increment key:  1 Last value:                306688
Data records:        306688 Deleted blocks:                 0
Datafile parts:      306688 Deleted data:                   0
Datafile pointer (bytes):  4 Keyfile pointer (bytes): 3
```
myisamchk — MyISAM Table-Maintenance Utility

Datafile length:  9347072  Keyfile length:  6066176
Max datafile length:  4294967294  Max keyfile length:  17179868159
Recordlength:  54

table description:

<table>
<thead>
<tr>
<th>Key Start</th>
<th>Len</th>
<th>Index</th>
<th>Type</th>
<th>Rec/key</th>
<th>Root</th>
<th>Blocksize</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>unique</td>
<td>1</td>
<td>99328</td>
<td>1024</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>20</td>
<td>varchar prefix</td>
<td>512</td>
<td>3563520</td>
<td>1024</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td></td>
<td>varchar</td>
<td>512</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>3</td>
<td>multip. uint24 NULL</td>
<td>306688</td>
<td>6065152</td>
<td>1024</td>
</tr>
</tbody>
</table>

Field Start Length Nullpos Nullbit Type

<table>
<thead>
<tr>
<th>Field Start</th>
<th>Length</th>
<th>Nullpos</th>
<th>Nullbit</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td>no zeros</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>21</td>
<td></td>
<td>varchar</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>21</td>
<td></td>
<td>varchar</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>51</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Explanations for the types of information myisamchk produces are given here. “Keyfile” refers to the index file. “Record” and “row” are synonymous, as are “field” and “column.”

The initial part of the table description contains these values:

• **MyISAM file**
  
  Name of the MyISAM (index) file.

• **Record format**
  
  The format used to store table rows. The preceding examples use Fixed length. Other possible values are Compressed and Packed. (Packed corresponds to what SHOW TABLE STATUS reports as Dynamic.)

• **Chararacter set**
  
  The table default character set.

• **File-version**
  
  Version of MyISAM format. Always 1.

• **Creation time**
  
  When the data file was created.

• **Recover time**
  
  When the index/data file was last reconstructed.

• **Status**
  
  Table status flags. Possible values are crashed, open, changed, analyzed, optimized keys, and sorted index pages.

• **Auto increment key, Last value**
  
  The key number associated the table’s AUTO_INCREMENT column, and the most recently generated value for this column. These fields do not appear if there is no such column.

• **Data records**
The number of rows in the table.

- **Deleted blocks**

  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, “MyISAM Table Optimization”.

- **Datafile parts**

  For dynamic-row format, this indicates how many data blocks there are. For an optimized table without fragmented rows, this is the same as Data records.

- **Deleted data**

  How many bytes of unreclaimed deleted data there are. You can optimize your table to minimize this space. See Section 7.6.4, “MyISAM Table Optimization”.

- **Datafile pointer**

  The size of the data file pointer, in bytes. It is usually 2, 3, 4, or 5 bytes. Most tables manage with 2 bytes, but this cannot be controlled from MySQL yet. For fixed tables, this is a row address. For dynamic tables, this is a byte address.

- **Keyfile pointer**

  The size of the index file pointer, in bytes. It is usually 1, 2, or 3 bytes. Most tables manage with 2 bytes, but this is calculated automatically by MySQL. It is always a block address.

- **Max datafile length**

  How long the table data file can become, in bytes.

- **Max keyfile length**

  How long the table index file can become, in bytes.

- **Recordlength**

  How much space each row takes, in bytes.

The table description part of the output includes a list of all keys in the table. For each key, myisamchk displays some low-level information:

- **Key**

  This key’s number. This value is shown only for the first column of the key. If this value is missing, the line corresponds to the second or later column of a multiple-column key. For the table shown in the example, there are two table description lines for the second index. This indicates that it is a multiple-part index with two parts.

- **Start**

  Where in the row this portion of the index starts.

- **Len**

  How long this portion of the index is. For packed numbers, this should always be the full length of the column. For strings, it may be shorter than the full length of the indexed column, because you can index
a prefix of a string column. The total length of a multiple-part key is the sum of the Len values for all key parts.

- **Index**
  Whether a key value can exist multiple times in the index. Possible values are unique or multip. (multiple).

- **Type**
  What data type this portion of the index has. This is a MyISAM data type with the possible values packed, stripped, or empty.

- **Root**
  Address of the root index block.

- **Blocksize**
  The size of each index block. By default this is 1024, but the value may be changed at compile time when MySQL is built from source.

- **Rec/key**
  This is a statistical value used by the optimizer. It tells how many rows there are per value for this index. A unique index always has a value of 1. This may be updated after a table is loaded (or greatly changed) with myisamchk -a. If this is not updated at all, a default value of 30 is given.

The last part of the output provides information about each column:

- **Field**
  The column number.

- **Start**
  The byte position of the column within table rows.

- **Length**
  The length of the column in bytes.

- **Nullpos, Nullbit**
  For columns that can be NULL, MyISAM stores NULL values as a flag in a byte. Depending on how many nullable columns there are, there can be one or more bytes used for this purpose. The Nullpos and Nullbit values, if nonempty, indicate which byte and bit contains that flag indicating whether the column is NULL.

  The position and number of bytes used to store NULL flags is shown in the line for field 1. This is why there are six Field lines for the person table even though it has only five columns.

- **Type**
  The data type. The value may contain any of the following descriptors:

  - **constant**
    All rows have the same value.
myisamchk — MyISAM Table-Maintenance Utility

- **no endspace**
  Do not store endspace.

- **no endspace, not_always**
  Do not store endspace and do not do endspace compression for all values.

- **no endspace, no empty**
  Do not store endspace. Do not store empty values.

- **table-lookup**
  The column was converted to an **ENUM**.

- **zerofill(N)**
  The most significant \(N\) bytes in the value are always 0 and are not stored.

- **no zeros**
  Do not store zeros.

- **always zero**
  Zero values are stored using one bit.

- **Huff tree**
  The number of the Huffman tree associated with the column.

- **Bits**
  The number of bits used in the Huffman tree.

The **Huff tree** and **Bits** fields are displayed if the table has been compressed with **myisampack**. See **Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"**, for an example of this information.

**Example of myisamchk -eiv output:**

```
Checking MyISAM file: person
Data records: 306688 Deleted blocks: 0
  - check file-size
    - check record delete-chain
    No recordlinks
    - check key delete-chain
    block_size 1024:
      - check index reference
        - check data record references index: 1
          Key: 1: Keyblocks used: 98% Packed: 0% Max levels: 3
          - check data record references index: 2
            Key: 2: Keyblocks used: 99% Packed: 97% Max levels: 3
            - check data record references index: 3
              Key: 3: Keyblocks used: 98% Packed: -14% Max levels: 3
              Total: Keyblocks used: 98% Packed: 89%
            - check records and index references*** LOTS OF ROW NUMBERS DELETED ***
```

407
myisamchk — MyISAM Table-Maintenance Utility

Records: 306688  M.recordlength: 25  Packed: 83%
Recordspace used: 97% Empty space: 2% Blocks/Record: 1.00
Record blocks: 306688  Delete blocks: 0
Record data: 7934464 Deleted data: 0
Lost space: 256512  Linkdata: 1156096

User time 43.08, System time 1.68
Maximum resident set size 0, Integral resident set size 0
Non-physical pagefaults 0, Physical pagefaults 0, Swaps 0
Blocks in 0 out 7, Messages in 0 out 0, Signals 0
Voluntary context switches 0, Involuntary context switches 0
Maximum memory usage: 1046926 bytes (1023k)

myisamchk -eiv output includes the following information:

• **Data records**
  The number of rows in the table.

• **Deleted blocks**
  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, "MyISAM Table Optimization".

• **Key**
  The key number.

• **Keyblocks used**
  What percentage of the keyblocks are used. When a table has just been reorganized with myisamchk, the values are very high (very near theoretical maximum).

• **Packed**
  MySQL tries to pack key values that have a common suffix. This can only be used for indexes on CHAR and VARCHAR columns. For long indexed strings that have similar leftmost parts, this can significantly reduce the space used. In the preceding example, the second key is 40 bytes long and a 97% reduction in space is achieved.

• **Max levels**
  How deep the B-tree for this key is. Large tables with long key values get high values.

• **Records**
  How many rows are in the table.

• **M.recordlength**
  The average row length. This is the exact row length for tables with fixed-length rows, because all rows have the same length.

• **Packed**
  MySQL strips spaces from the end of strings. The Packed value indicates the percentage of savings achieved by doing this.

• **Recordspace used**
  What percentage of the data file is used.
• **Empty space**
  What percentage of the data file is unused.

• **Blocks/Record**
  Average number of blocks per row (that is, how many links a fragmented row is composed of). This is always 1.0 for fixed-format tables. This value should stay as close to 1.0 as possible. If it gets too large, you can reorganize the table. See Section 7.6.4, "MyISAM Table Optimization".

• **Recordblocks**
  How many blocks (links) are used. For fixed-format tables, this is the same as the number of rows.

• **Deleteblocks**
  How many blocks (links) are deleted.

• **Recorddata**
  How many bytes in the data file are used.

• **Deleted data**
  How many bytes in the data file are deleted (unused).

• **Lost space**
  If a row is updated to a shorter length, some space is lost. This is the sum of all such losses, in bytes.

• **Linkdata**
  When the dynamic table format is used, row fragments are linked with pointers (4 to 7 bytes each). **Linkdata** is the sum of the amount of storage used by all such pointers.

### 4.6.3.6 myisamchk Memory Usage

Memory allocation is important when you run **myisamchk**. **myisamchk** uses no more memory than its memory-related variables are set to. If you are going to use **myisamchk** on very large tables, you should first decide how much memory you want it to use. The default is to use only about 3MB to perform repairs. By using larger values, you can get **myisamchk** to operate faster. For example, if you have more than 512MB RAM available, you could use options such as these (in addition to any other options you might specify):

```
shell> myisamchk --myisam_sort_buffer_size=256M \
    --key_buffer_size=512M \ 
    --read_buffer_size=64M \ 
    --write_buffer_size=64M ...
```

Using **--myisam_sort_buffer_size=16M** is probably enough for most cases.

Be aware that **myisamchk** uses temporary files in **TMPDIR**. If **TMPDIR** points to a memory file system, out of memory errors can easily occur. If this happens, run **myisamchk** with the **--tmpdir=dir_name** option to specify a directory located on a file system that has more space.

When performing repair operations, **myisamchk** also needs a lot of disk space:

• Twice the size of the data file (the original file and a copy). This space is not needed if you do a repair with **--quick**; in this case, only the index file is re-created. **This space must be available on the same file system as the original data file**, as the copy is created in the same directory as the original.
myisamlog — Display MyISAM Log File Contents

- Space for the new index file that replaces the old one. The old index file is truncated at the start of the repair operation, so you usually ignore this space. This space must be available on the same file system as the original data file.

- When using --recover or --sort-recover (but not when using --safe-recover), you need space on disk for sorting. This space is allocated in the temporary directory (specified by TMPDIR or --tmpdir=dir_name). The following formula yields the amount of space required:

\[
(largest\_key + row\_pointer\_length) \times number\_of\_rows \times 2
\]

You can check the length of the keys and the row_pointer_length with myisamchk -dv tbl_name (see Section 4.6.3.5, “Obtaining Table Information with myisamchk”). The row_pointer_length and number_of_rows values are the Datafile pointer and Data records values in the table description. To determine the largest_key value, check the Key lines in the table description. The Len column indicates the number of bytes for each key part. For a multiple-column index, the key size is the sum of the Len values for all key parts.

If you have a problem with disk space during repair, you can try --safe-recover instead of --recover.

4.6.4 myisamlog — Display MyISAM Log File Contents

myisamlog processes the contents of a MyISAM log file. To create such a file, start the server with a --log-isam=logfile option.

Invoke myisamlog like this:

```shell
shell> myisamlog [options] [file_name [tbl_name] ...]
```

The default operation is update (-u). If a recovery is done (-r), all writes and possibly updates and deletes are done and errors are only counted. The default log file name is myisam.log if no log_file argument is given. If tables are named on the command line, only those tables are updated.

myisamlog supports the following options:

- `-?`, `-I`
  Display a help message and exit.

- `-c N`
  Execute only N commands.

- `-f N`
  Specify the maximum number of open files.

- `-F filepath/`
  Specify the file path with a trailing slash.

- `-i`
  Display extra information before exiting.

- `-o offset`
  Specify the starting offset.

- `-p N`
Remove N components from path.

- \(-r\)
  Perform a recovery operation.

- \(-R\) record_pos_file record_pos
  Specify record position file and record position.

- \(-u\)
  Perform an update operation.

- \(-v\)
  Verbose mode. Print more output about what the program does. This option can be given multiple times to produce more and more output.

- \(-w\) write_file
  Specify the write file.

- \(-V\)
  Display version information.

### 4.6.5 myisampack — Generate Compressed, Read-Only MyISAM Tables

The **myisampack** utility compresses MyISAM tables. **myisampack** works by compressing each column in the table separately. Usually, **myisampack** packs the data file 40% to 70%.

When the table is used later, the server reads into memory the information needed to decompress columns. This results in much better performance when accessing individual rows, because you only have to uncompress exactly one row.

MySQL uses **mmap()** when possible to perform memory mapping on compressed tables. If **mmap()** does not work, MySQL falls back to normal read/write file operations.

Please note the following:

- If the **mysqld** server was invoked with external locking disabled, it is not a good idea to invoke **myisampack** if the table might be updated by the server during the packing process. It is safest to compress tables with the server stopped.

- After packing a table, it becomes read only. This is generally intended (such as when accessing packed tables on a CD).

- **myisampack** does not support partitioned tables.

Invoke **myisampack** like this:

```bash
shell> myisampack [options] file_name ...
```

Each file name argument should be the name of an index (.MYI) file. If you are not in the database directory, you should specify the path name to the file. It is permissible to omit the .MYI extension.

After you compress a table with **myisampack**, use **myisamchk** \(-rq\) to rebuild its indexes. **Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”**.
myisampack supports the following options. It also reads option files and supports the options for processing them described at Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--help, -?**
  Display a help message and exit.

- **--backup, -b**
  Make a backup of each table’s data file using the name `tbl_name.OLD`.

- **--character-sets-dir=dir_name**
  The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **--debug=[debug_options], -# [debug_options]**
  Write a debugging log. A typical `debug_options` string is `d:t:o`, `file_name`. The default is `d:t:o`.

- **--force, -f**
  Produce a packed table even if it becomes larger than the original or if the intermediate file from an earlier invocation of `myisampack` exists. (`myisampack` creates an intermediate file named `tbl_name.TMD` in the database directory while it compresses the table. If you kill `myisampack`, the `.TMD` file might not be deleted.) Normally, `myisampack` exits with an error if it finds that `tbl_name.TMD` exists. With **--force**, `myisampack` packs the table anyway.

- **--join=big_tbl_name, -j big_tbl_name**
  Join all tables named on the command line into a single packed table `big_tbl_name`. All tables that are to be combined must have identical structure (same column names and types, same indexes, and so forth).

  `big_tbl_name` must not exist prior to the join operation. All source tables named on the command line to be merged into `big_tbl_name` must exist. The source tables are read for the join operation but not modified.

- **--silent, -s**
  Silent mode. Write output only when errors occur.

- **--test, -t**
  Do not actually pack the table, just test packing it.

- **--tmpdir=dir_name, -T dir_name**
  Use the named directory as the location where `myisampack` creates temporary files.

- **--verbose, -v**
  Verbose mode. Write information about the progress of the packing operation and its result.

- **--version, -V**
  Display version information and exit.

- **--wait, -w**
Wait and retry if the table is in use. If the `mysqld` server was invoked with external locking disabled, it is not a good idea to invoke `myisampack` if the table might be updated by the server during the packing process.

The following sequence of commands illustrates a typical table compression session:

```
shell> ls -l station.*
-rw-rw-r-- 1 jones my 994128 Apr 17 19:00 station.MYD
-rw-rw-r-- 1 jones my 53248 Apr 17 19:00 station.MYI
-rw-rw-r-- 1 jones my 5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station
MyISAM file: station
Isam-version: 2
Creation time: 1996-03-13 10:08:58
Recover time: 1997-02-02 3:06:43
Data records: 1192 Deleted blocks: 0
Datafile parts: 1192 Deleted data: 0
Datfile pointer (bytes): 2 Keyfile pointer (bytes): 2
Max datafile length: 54657023 Max keyfile length: 33554431
Recordlength: 834
Record format: Fixed length

table description:
Key Start Len Index Type Root Blocksize Rec/key
1 2 4 unique unsigned long 1024 1024 1
2 32 30 multip. text 10240 1024 1

Field Start Length Type
1 1 1
2 2 4
3 6 4
4 10 1
5 11 20
6 31 1
7 32 30
8 62 35
9 97 35
10 132 35
11 167 4
12 171 16
13 187 35
14 222 4
15 226 16
16 242 20
17 262 20
18 282 20
19 302 30
20 332 4
21 336 4
22 340 1
23 341 8
24 349 8
25 357 8
26 365 2
27 367 2
28 369 4
29 373 4
30 377 1
31 378 2
32 380 8
33 388 4
34 392 4
35 396 4
```
myisampack — Generate Compressed, Read-Only MyISAM Tables

shell> myisampack station.MYI
Compressing station.MYI: (1192 records)
- Calculating statistics
  normal:  20  empty-space:  16  empty-zero:  12  empty-fill:  11
  pre-space:  0  end-space:  12  table-lookups:  5  zero:  7
  Original trees:  57  After join: 17
- Compressing file
87.14%
Remember to run myisamchk -rq on compressed tables

shell> myisamchk -rq station
- check record delete-chain
- recovering (with sort) MyISAM-table 'station'
Data records: 1192
- Fixing index 1
- Fixing index 2

shell> mysqladmin -uroot flush-tables

shell> ls -l station.*
-rw-rw-r--  1 jones my 127874 Apr 17 19:00 station.MYD
-rw-rw-r--  1 jones my  55296 Apr 17 19:04 station.MYI
-rw-rw-r--  1 jones my  6767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station
MyISAM file: station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time: 1997-04-17 19:04:26
Data records: 1192  Deleted blocks: 0
Datafile parts: 1192  Deleted data: 0
Datafile pointer (bytes): 3  Keyfile pointer (bytes): 1
Max datafile length: 16777215  Max keyfile length: 131071
Recordlength: 834
Record format: Compressed

table description:
Key Start Len Index Type    Root  Blocksize  Rec/key
1  2  4  unique  unsigned long 10240  1024  1
2 32 30  multip. text  54272  1024  1
myisampack — Generate Compressed, Read-Only MyISAM Tables

<table>
<thead>
<tr>
<th>Field Start</th>
<th>Length</th>
<th>Type</th>
<th>Huff tree</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>constant</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>no zeros, zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>table-lookup</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>table-lookup</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>no endspace, not_always</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>no endspace, not_always, no empty</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>35</td>
<td>no empty</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>35</td>
<td>no endspace, not_always, no empty</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>16</td>
<td>no endspace, not_always, no empty</td>
<td>5</td>
<td>9</td>
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<td>9</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>no endspace, not_always, no empty</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>no endspace, not_always</td>
<td>8</td>
<td>9</td>
</tr>
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<td>9</td>
</tr>
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<td>19</td>
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<td>9</td>
</tr>
<tr>
<td>21</td>
<td>4</td>
<td>always zero</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>23</td>
<td>8</td>
<td>table-lookup</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>8</td>
<td>table-lookup</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>8</td>
<td>always zero</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>26</td>
<td>2</td>
<td>always zero</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>no zeros, zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>28</td>
<td>4</td>
<td>no zeros, zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>29</td>
<td>4</td>
<td>table-lookup</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>no zeros, zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
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<td>2</td>
<td>no zeros</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>32</td>
<td>8</td>
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<td>9</td>
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<tr>
<td>33</td>
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<td>always zero</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
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<td>table-lookup</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>4</td>
<td>no zeros, zerofill(1)</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>36</td>
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<td>38</td>
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<td>47</td>
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<td>no empty</td>
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<td>9</td>
</tr>
<tr>
<td>53</td>
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<td>no empty</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>54</td>
<td>1</td>
<td>no empty</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>55</td>
<td>20</td>
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<td>3</td>
<td>9</td>
</tr>
<tr>
<td>56</td>
<td>2</td>
<td>no zeros, zerofill(2)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>57</td>
<td>4</td>
<td>no zeros, zerofill(1)</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

myisampack displays the following kinds of information:

- **normal**

  The number of columns for which no extra packing is used.

- **empty-space**
The number of columns containing values that are only spaces. These occupy one bit.

- **empty-zero**
  The number of columns containing values that are only binary zeros. These occupy one bit.

- **empty-fill**
  The number of integer columns that do not occupy the full byte range of their type. These are changed to a smaller type. For example, a `BIGINT` column (eight bytes) can be stored as a `TINYINT` column (one byte) if all its values are in the range from -128 to 127.

- **pre-space**
  The number of decimal columns that are stored with leading spaces. In this case, each value contains a count for the number of leading spaces.

- **end-space**
  The number of columns that have a lot of trailing spaces. In this case, each value contains a count for the number of trailing spaces.

- **table-lookup**
  The column had only a small number of different values, which were converted to an ENUM before Huffman compression.

- **zero**
  The number of columns for which all values are zero.

- **Original trees**
  The initial number of Huffman trees.

- **After join**
  The number of distinct Huffman trees left after joining trees to save some header space.

After a table has been compressed, the Field lines displayed by `myisamchk -dvv` include additional information about each column:

- **Type**
  The data type. The value may contain any of the following descriptors:
    - **constant**
      All rows have the same value.
    - **no endspace**
      Do not store endspace.
    - **no endspace, not_always**
      Do not store endspace and do not do endspace compression for all values.
    - **no endspace, no empty**
Do not store endspace. Do not store empty values.

- **table-lookup**
  
  The column was converted to an **ENUM**.

- **zerofill**(*N*)
  
  The most significant *N* bytes in the value are always 0 and are not stored.

- **no zeros**
  
  Do not store zeros.

- **always zero**
  
  Zero values are stored using one bit.

- **Huff tree**
  
  The number of the Huffman tree associated with the column.

- **Bits**
  
  The number of bits used in the Huffman tree.

After you run `mysampack`, use `myisamchk` to re-create any indexes. At this time, you can also sort the index blocks and create statistics needed for the MySQL optimizer to work more efficiently:

```shell
shell> myisamchk -rq --sort-index --analyze tbl_name.MYI
```

After you have installed the packed table into the MySQL database directory, you should execute `mysqladmin flush-tables` to force `mysqld` to start using the new table.

To unpack a packed table, use the **--unpack** option to `myisamchk`.

### 4.6.6 mysqlaccess — Client for Checking Access Privileges

**mysqlaccess** is a diagnostic tool that Yves Carlier has provided for the MySQL distribution. It checks the access privileges for a host name, user name, and database combination. **mysqlaccess** checks access using only the **user**, **db**, and **host** tables. It does not check table, column, or routine privileges specified in the **tables_priv**, **columns_priv**, or **procs_priv** tables.

Invoke **mysqlaccess** like this:

```shell
shell> mysqlaccess [host_name [user_name [db_name]]] [options]
```

When **mysqlaccess** runs, it loads and executes the contents of its configuration file, `mysqlaccess.conf`. `mysqlaccess` looks for the configuration file in these locations, in order:

- The directory named by the **SYSCONFDIR** option to `CMake` when MySQL was built. By default, this is the **etc** directory located under the compiled-in installation directory.

- The **/etc** directory.

**mysqlaccess** supports the options shown in the following table.
### Table 4.18 mysqlaccess Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--brief</td>
<td>Generate reports in single-line tabular format</td>
</tr>
<tr>
<td>--commit</td>
<td>Copy the new access privileges from the temporary tables to the original grant tables</td>
</tr>
<tr>
<td>--copy</td>
<td>Reload the temporary grant tables from original ones</td>
</tr>
<tr>
<td>--db</td>
<td>Specify the database name</td>
</tr>
<tr>
<td>--debug</td>
<td>Specify the debug level</td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
</tr>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
</tr>
<tr>
<td>--howto</td>
<td>Display some examples that show how to use mysqlaccess</td>
</tr>
<tr>
<td>--old_server</td>
<td>Assume that the server is an old MySQL server (prior to MySQL 3.21)</td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
</tr>
<tr>
<td>--plan</td>
<td>Display suggestions and ideas for future releases</td>
</tr>
<tr>
<td>--preview</td>
<td>Show the privilege differences after making changes to the temporary grant tables</td>
</tr>
<tr>
<td>--relnotes</td>
<td>Display release notes</td>
</tr>
<tr>
<td>--rhost</td>
<td>Host on which MySQL server is located</td>
</tr>
<tr>
<td>--rollback</td>
<td>Undo the most recent changes to the temporary grant tables</td>
</tr>
<tr>
<td>--spassword</td>
<td>Password to use when connecting to server as the superuser</td>
</tr>
<tr>
<td>--superuser</td>
<td>Specify the user name for connecting as the superuser</td>
</tr>
<tr>
<td>--table</td>
<td>Generate reports in table format</td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
</tr>
</tbody>
</table>

- **--help, -?**
  
  Display a help message and exit.

- **--brief, -b**
  
  Generate reports in single-line tabular format.

- **--commit**
  
  Copy the new access privileges from the temporary tables to the original grant tables. The grant tables must be flushed for the new privileges to take effect. (For example, execute a `mysqladmin reload` command.)

- **--copy**
  
  Reload the temporary grant tables from original ones.

- **--db=db_name, -d db_name**
  
  Specify the database name.
- **--debug=N**
  Specify the debug level. \textit{N} can be an integer from 0 to 3.

- **--host=host_name, -h host_name**
  The host name to use in the access privileges.

- **--howto**
  Display some examples that show how to use \texttt{mysqlaccess}.

- **--old_server**
  Assume that the server is an old MySQL server (before MySQL 3.21) that does not yet know how to handle full \texttt{WHERE} clauses.

- **--password[=password], -p[password]**
  The password to use when connecting to the server. If you omit the \texttt{password} value following the \texttt{--password} or \texttt{-p} option on the command line, \texttt{mysqlaccess} prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- **--plan**
  Display suggestions and ideas for future releases.

- **--preview**
  Show the privilege differences after making changes to the temporary grant tables.

- **--relnotes**
  Display the release notes.

- **--rhost=host_name, -H host_name**
  Connect to the MySQL server on the given host.

- **--rollback**
  Undo the most recent changes to the temporary grant tables.

- **--spassword[=password], -P[password]**
  The password to use when connecting to the server as the superuser. If you omit the \texttt{password} value following the \texttt{--spassword} or \texttt{-P} option on the command line, \texttt{mysqlaccess} prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- **--superuser=user_name, -U user_name**
  Specify the user name for connecting as the superuser.

- **--table, -t**
  Generate reports in table format.
mysqlbinlog — Utility for Processing Binary Log Files

• --user=user_name, -u user_name
  The user name to use in the access privileges.

• --version, -v
  Display version information and exit.

If your MySQL distribution is installed in some nonstandard location, you must change the location where mysqlaccess expects to find the mysql client. Edit the mysqlaccess script at approximately line 18. Search for a line that looks like this:

`$MYSQL = '/usr/local/bin/mysql'; # path to mysql executable`

Change the path to reflect the location where mysql actually is stored on your system. If you do not do this, a Broken pipe error will occur when you run mysqlaccess.

4.6.7 mysqlbinlog — Utility for Processing Binary Log Files

The server's binary log consists of files containing "events" that describe modifications to database contents. The server writes these files in binary format. To display their contents in text format, use the mysqlbinlog utility. You can also use mysqlbinlog to display the contents of relay log files written by a slave server in a replication setup because relay logs have the same format as binary logs. The binary log and relay log are discussed further in Section 5.4.4, "The Binary Log", and Section 17.2.2, "Replication Relay and Status Logs".

Invoke mysqlbinlog like this:

```bash
shell> mysqlbinlog [options] log_file ...
```

For example, to display the contents of the binary log file named `binlog.000003`, use this command:

```bash
shell> mysqlbinlog binlog.000003
```

The output includes events contained in `binlog.000003`. For statement-based logging, event information includes the SQL statement, the ID of the server on which it was executed, the timestamp when the statement was executed, how much time it took, and so forth. For row-based logging, the event indicates a row change rather than an SQL statement. See Section 17.1.2, "Replication Formats", for information about logging modes.

Events are preceded by header comments that provide additional information. For example:

```plaintext
# at 141
#100309  9:28:36 server id 123  end_log_pos 245
Query thread_id=3350  exec_time=11  error_code=0
```

In the first line, the number following at indicates the file offset, or starting position, of the event in the binary log file.

The second line starts with a date and time indicating when the statement started on the server where the event originated. For replication, this timestamp is propagated to slave servers. server id is the server_id value of the server where the event originated. end_log_pos indicates where the next event starts (that is, it is the end position of the current event + 1). thread_id indicates which thread executed the event. exec_time is the time spent executing the event, on a master server. On a slave, it is the difference of the end execution time on the slave minus the beginning execution time on the master. The difference serves as an indicator of how much replication lags behind the master. error_code indicates the result from executing the event. Zero means that no error occurred.
mysqlbinlog — Utility for Processing Binary Log Files

Note
When using event groups, the file offsets of events may be grouped together and the comments of events may be grouped together. Do not mistake these grouped events for blank file offsets.

The output from mysqlbinlog can be re-executed (for example, by using it as input to mysql) to redo the statements in the log. This is useful for recovery operations after a server crash. For other usage examples, see the discussion later in this section and in Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

Normally, you use mysqlbinlog to read binary log files directly and apply them to the local MySQL server. It is also possible to read binary logs from a remote server by using the --read-from-remote-server option. To read remote binary logs, the connection parameter options can be given to indicate how to connect to the server. These options are --host, --password, --port, --protocol, --socket, and --user; they are ignored except when you also use the --read-from-remote-server option.

When running mysqlbinlog against a large binary log, be careful that the filesystem has enough space for the resulting files. To configure the directory that mysqlbinlog uses for temporary files, use the TMPDIR environment variable.

mysqlbinlog supports the following options, which can be specified on the command line or in the [mysqlbinlog] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

Table 4.19 mysqlbinlog Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>--base64-output</td>
<td>Print binary log entries using base-64 encoding</td>
<td></td>
</tr>
<tr>
<td>--character-sets-dir</td>
<td>Directory where character sets are installed</td>
<td></td>
</tr>
<tr>
<td>--database</td>
<td>List entries for just this database</td>
<td></td>
</tr>
<tr>
<td>--debug</td>
<td>Write debugging log</td>
<td></td>
</tr>
<tr>
<td>--debug-check</td>
<td>Print debugging information when program exits</td>
<td></td>
</tr>
<tr>
<td>--debug-info</td>
<td>Print debugging information, memory, and CPU statistics when program exits</td>
<td></td>
</tr>
<tr>
<td>Option Name</td>
<td>Description</td>
<td>Introduced</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>--offset</td>
<td>Skip the first N entries in the log</td>
<td></td>
</tr>
<tr>
<td>open_files_limit</td>
<td>Specify the number of open file descriptors to reserve</td>
<td></td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--plugin-dir</td>
<td>Directory where plugins are installed</td>
<td>5.5.10</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
<td></td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print default options</td>
<td></td>
</tr>
<tr>
<td>--protocol</td>
<td>Connection protocol to use</td>
<td></td>
</tr>
<tr>
<td>--read-from-remote-server</td>
<td>Read binary log from MySQL server rather than local log file</td>
<td></td>
</tr>
<tr>
<td>--result-file</td>
<td>Direct output to named file</td>
<td></td>
</tr>
<tr>
<td>--server-id</td>
<td>Extract only those events created by the server having the given server ID</td>
<td></td>
</tr>
<tr>
<td>--server-id-bits</td>
<td>Tell mysqlbinlog how to interpret server IDs in binary log when log was written by a mysqld having its server-id-bits set to less than the maximum; supported only by MySQL Cluster version of mysqlbinlog</td>
<td></td>
</tr>
<tr>
<td>--set-charset</td>
<td>Add a SET NAMES charset_name statement to the output</td>
<td></td>
</tr>
<tr>
<td>--shared-memory-base-name</td>
<td>Name of shared memory to use for shared-memory connections</td>
<td></td>
</tr>
<tr>
<td>--short-form</td>
<td>Display only the statements contained in the log</td>
<td></td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
<td></td>
</tr>
<tr>
<td>--ssl-mode</td>
<td>Desired security state of connection to server</td>
<td>5.5.49</td>
</tr>
<tr>
<td>--start-datetime</td>
<td>Read binary log from first event with timestamp equal to or later than datetime argument</td>
<td></td>
</tr>
<tr>
<td>--start-position</td>
<td>Read binary log from first event with position equal to or greater than argument</td>
<td></td>
</tr>
<tr>
<td>--stop-datetime</td>
<td>Stop reading binary log at first event with timestamp equal to or greater than datetime argument</td>
<td></td>
</tr>
<tr>
<td>--stop-position</td>
<td>Stop reading binary log at first event with position equal to or greater than argument</td>
<td></td>
</tr>
<tr>
<td>--to-last-log</td>
<td>Do not stop at the end of requested binary log from a MySQL server, but rather continue printing to end of last binary log</td>
<td></td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
<td></td>
</tr>
<tr>
<td>--verbose</td>
<td>Reconstruct row events as SQL statements</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Display version information and exit</td>
<td></td>
</tr>
<tr>
<td>--help, -?</td>
<td>Display a help message and exit</td>
<td></td>
</tr>
</tbody>
</table>
**mysqlbinlog** — Utility for Processing Binary Log Files

- **--base64-output [=value]**

  This option determines when events should be displayed encoded as base-64 strings using BINLOG statements. The option has these permissible values (not case-sensitive):

  - **AUTO** ("automatic") or **UNSPEC** ("unspecified") displays BINLOG statements automatically when necessary (that is, for format description events and row events). If no **--base64-output** option is given, the effect is the same as **--base64-output=AUTO**.

  **Note**

  Automatic BINLOG display is the only safe behavior if you intend to use the output of mysqlbinlog to re-execute binary log file contents. The other option values are intended only for debugging or testing purposes because they may produce output that does not include all events in executable form.

  - **ALWAYS** displays BINLOG statements whenever possible. If the **--base64-output** option is given without a value, the effect is the same as **--base64-output=ALWAYS**.

  **Note**

  Changes to replication in MySQL 5.6 make output generated by this option unusable, so **ALWAYS** is deprecated in MySQL 5.5 and will be an invalid value in MySQL 5.6.

  - **NEVER** causes BINLOG statements not to be displayed. mysqlbinlog exits with an error if a row event is found that must be displayed using BINLOG.

  - **DECODE-ROWS** specifies to mysqlbinlog that you intend for row events to be decoded and displayed as commented SQL statements by also specifying the **--verbose** option. Like **NEVER**, **DECODE-ROWS** suppresses display of BINLOG statements, but unlike **NEVER**, it does not exit with an error if a row event is found.

  For examples that show the effect of **--base64-output** and **--verbose** on row event output, see Section 4.6.7.2, "mysqlbinlog Row Event Display".

- **--bind-address=ip_address**

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

- **--character-sets-dir=dir_name**

  The directory where character sets are installed. See Section 10.15, "Character Set Configuration".

- **--database=db_name, -d db_name**

  This option causes mysqlbinlog to output entries from the binary log (local log only) that occur while **db_name** is been selected as the default database by **USE**.

  The **--database** option for mysqlbinlog is similar to the **--binlog-do-db** option for mysql, but can be used to specify only one database. If **--database** is given multiple times, only the last instance is used.

  The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of **--binlog-do-db** depend on whether statement-based or row-based logging is in use.
Statement-based logging. The `--database` option works as follows:

- While `db_name` is the default database, statements are output whether they modify tables in `db_name` or a different database.
- Unless `db_name` is selected as the default database, statements are not output, even if they modify tables in `db_name`.
- There is an exception for `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE`. The database being created, altered, or dropped is considered to be the default database when determining whether to output the statement.

Suppose that the binary log was created by executing these statements using statement-based-logging:

```sql
INSERT INTO test.t1 (i) VALUES(100);
INSERT INTO db2.t2 (j) VALUES(200);
USE test;
INSERT INTO test.t1 (i) VALUES(101);
INSERT INTO t1 (i) VALUES(102);
INSERT INTO db2.t2 (j) VALUES(201);
USE db2;
INSERT INTO test.t1 (i) VALUES(103);
INSERT INTO db2.t2 (j) VALUES(202);
INSERT INTO t2 (j) VALUES(203);
```

`mysqlbinlog --database=test` does not output the first two `INSERT` statements because there is no default database. It outputs the three `INSERT` statements following `USE test`, but not the three `INSERT` statements following `USE db2`.

`mysqlbinlog --database=db2` does not output the first two `INSERT` statements because there is no default database. It does not output the three `INSERT` statements following `USE test`, but does output the three `INSERT` statements following `USE db2`.

Row-based logging. `mysqlbinlog` outputs only entries that change tables belonging to `db_name`. The default database has no effect on this. Suppose that the binary log just described was created using row-based logging rather than statement-based logging. `mysqlbinlog --database=test` outputs only those entries that modify `t1` in the test database, regardless of whether `USE` was issued or what the default database is.

If a server is running with `binlog_format` set to `MIXED` and you want it to be possible to use `mysqlbinlog` with the `--database` option, you must ensure that tables that are modified are in the database selected by `USE`. (In particular, no cross-database updates should be used.)

Note

Prior to MySQL NDB Cluster 7.2.2, this option did not work correctly with NDB Cluster tables unless, unless the binary log was generated using `--log-bin-use-v1-row-events=0`. (Bug #13067813)

- `--debug[=debug_options],-# [debug_options]`

Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysqlbinlog.trace`.

- `--debug-check`

Print some debugging information when the program exits.
mysqlbinlog — Utility for Processing Binary Log Files

• \texttt{--debug-info}

   Print debugging information and memory and CPU usage statistics when the program exits.

• \texttt{--default-auth=plugin}

   A hint about which client-side authentication plugin to use. See Section 6.2.10, “Pluggable Authentication”.

   This option was added in MySQL 5.5.10.

• \texttt{--defaults-extra-file=file_name}

   Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. \textit{file_name} is interpreted relative to the current directory if given as a relative path name.

   For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• \texttt{--defaults-file=file_name}

   Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. \textit{file_name} is interpreted relative to the current directory if given as a relative path name.

   For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• \texttt{--defaults-group-suffix=str}

   Read not only the usual option groups, but also groups with the usual names and a suffix of \textit{str}. For example, \texttt{mysqlbinlog} normally reads the [client] and [mysqlbinlog] groups. If the \texttt{--defaults-group-suffix=_other} option is given, \texttt{mysqlbinlog} also reads the [client\_other] and [mysqlbinlog\_other] groups.

   For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• \texttt{--disable-log-bin, -D}

   Disable binary logging. This is useful for avoiding an endless loop if you use the \texttt{--to-last-log} option and are sending the output to the same MySQL server. This option also is useful when restoring after a crash to avoid duplication of the statements you have logged.

   This option causes \texttt{mysqlbinlog} to include a \texttt{SET sql_log_bin = 0} statement in its output to disable binary logging of the remaining output. Manipulating the session value of the sql\_log\_bin system variable is a restricted operation, so this option requires that you have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

• \texttt{--force-if-open, -F}

   Read binary log files even if they are open or were not closed properly.

• \texttt{--force-read, -f}

   With this option, if \texttt{mysqlbinlog} reads a binary log event that it does not recognize, it prints a warning, ignores the event, and continues. Without this option, \texttt{mysqlbinlog} stops if it reads such an event.
mysqlbinlog — Utility for Processing Binary Log Files

- **--hexdump, -H**
  Display a hex dump of the log in comments, as described in Section 4.6.7.1, “mysqlbinlog Hex Dump Format”. The hex output can be helpful for replication debugging.

- **--host=host_name, -h host_name**
  Get the binary log from the MySQL server on the given host.

- **--local-load=dir_name, -l dir_name**
  Prepare local temporary files for `LOAD DATA` in the specified directory.

  **Important**
  These temporary files are not automatically removed by `mysqlbinlog` or any other MySQL program.

- **--no-defaults**
  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

  For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--offset=N, -o N**
  Skip the first $N$ entries in the log.

- **--open-files-limit=N**
  Specify the number of open file descriptors to reserve.

- **--password[=password], -p[password]**
  The password of the MySQL account used for connecting to the server. The password value is optional. If not given, `mysqlbinlog` prompts for one. If given, there must be no space between `--password=` or `-p` and the password following it. If no password option is specified, the default is to send no password.

  Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

  To explicitly specify that there is no password and that `mysqlbinlog` should not prompt for one, use the `--skip-password` option.

- **--plugin-dir=dir_name**
  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlbinlog` does not find it. See Section 6.2.10, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- **--port=port_num, -P port_num**
  The TCP/IP port number to use for connecting to a remote server.
• --print defaults
Print the program name and all options that it gets from option files.

For additional information about this and other option-file options, see Section 4.2.3, “Command-Line Options that Affect Option-File Handling”.

• --protocol={TCP|SOCKET|PIPE|MEMORY}
The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally result in use of a protocol other than the one you want. For details on the permissible values, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.

• --read-from-remote-server, -R
Read the binary log from a MySQL server rather than reading a local log file. Any connection parameter options are ignored unless this option is given as well. These options are --host, --password, --port, --protocol, --socket, and --user.

This option requires that the remote server be running. It works only for binary log files on the remote server, not relay log files.

• --result-file=name, -r name
Direct output to the given file.

• --server-id=id
Display only those events created by the server having the given server ID.

• --server-id-bits=N
Use only the first N bits of the server_id to identify the server. If the binary log was written by a mysql with server-id-bits set to less than 32 and user data stored in the most significant bit, running mysqlbinlog with --server-id-bits set to 32 enables this data to be seen.

This option is supported only by the versions of mysqlbinlog supplied with the NDB Cluster distribution, or built from the NDB Cluster sources.

• --set-charset=charset_name
Add a SET NAMES charset_name statement to the output to specify the character set to be used for processing log files.

• --shared-memory-base-name=name
On Windows, the shared-memory name to use for connections made using shared memory to a local server. The default value is MYSQL. The shared-memory name is case-sensitive.

This option applies only if the server was started with the shared_memory system variable enabled to support shared-memory connections.

• --short-form, -s
Display only the statements contained in the log, without any extra information or row-based events. This is for testing only, and should not be used in production systems.

• --socket=path, -S path
mysqlbinlog — Utility for Processing Binary Log Files

For connections to localhost, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

On Windows, this option applies only if the server was started with the named_pipe system variable enabled to support named-pipe connections.

• --ssl*

Options that begin with --ssl specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

• --start-datetime=datetime

Start reading the binary log at the first event having a timestamp equal to or later than the datetime argument. The datetime value is relative to the local time zone on the machine where you run mysqlbinlog. The value should be in a format accepted for the DATETIME or TIMESTAMP data types. For example:

```shell
mysqlbinlog --start-datetime="2005-12-25 11:25:56" binlog.000003
```

This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

• --start-position=N, -j N

Start reading the binary log at the first event having a position equal to or greater than N. This option applies to the first log file named on the command line.

This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

• --stop-datetime=datetime

Stop reading the binary log at the first event having a timestamp equal to or later than the datetime argument. This option is useful for point-in-time recovery. See the description of the --start-datetime option for information about the datetime value.

This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

• --stop-position=N

Stop reading the binary log at the first event having a position equal to or greater than N. This option applies to the last log file named on the command line.

This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

• --to-last-log, -t

Do not stop at the end of the requested binary log from a MySQL server, but rather continue printing until the end of the last binary log. If you send the output to the same MySQL server, this may lead to an endless loop. This option requires --read-from-remote-server.

• --user=user_name, -u user_name

The user name of the MySQL account to use when connecting to a remote server.
mysqlbinlog — Utility for Processing Binary Log Files

• **--verbose, -v**

Reconstruct row events and display them as commented SQL statements. If this option is given twice, the output includes comments to indicate column data types and some metadata.

For examples that show the effect of --base64-output and --verbose on row event output, see Section 4.6.7.2, “mysqlbinlog Row Event Display”.

• **--version, -V**

Display version information and exit.

In MySQL 5.5, the version number shown for mysqlbinlog is always 3.3.

You can pipe the output of mysqlbinlog into the mysql client to execute the events contained in the binary log. This technique is used to recover from a crash when you have an old backup (see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”). For example:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p
```

Or:

```
shell> mysqlbinlog binlog.[0-9]* | mysql -u root -p
```

You can also redirect the output of mysqlbinlog to a text file instead, if you need to modify the statement log first (for example, to remove statements that you do not want to execute for some reason). After editing the file, execute the statements that it contains by using it as input to the mysql program:

```
shell> mysqlbinlog binlog.000001 > tmpfile
shell> ... edit tmpfile ...
shell> mysql -u root -p < tmpfile
```

When mysqlbinlog is invoked with the --start-position option, it displays only those events with an offset in the binary log greater than or equal to a given position (the given position must match the start of one event). It also has options to stop and start when it sees an event with a given date and time. This enables you to perform point-in-time recovery using the --stop-datetime option (to be able to say, for example, “roll forward my databases to how they were today at 10:30 a.m.”).

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be unsafe:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
shell> mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using multiple connections to the server causes problems if the first log file contains a CREATE TEMPORARY TABLE statement and the second log contains a statement that uses the temporary table. When the first mysql process terminates, the server drops the temporary table. When the second mysql process attempts to use the table, the server reports “unknown table.”

To avoid problems like this, use a single mysql process to execute the contents of all binary logs that you want to process. Here is one way to do so:

```
shell> mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```

Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 > /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
```
mysqlbinlog — Utility for Processing Binary Log Files

mysqlbinlog can produce output that reproduces a LOAD DATA operation without the original data file. mysqlbinlog copies the data to a temporary file and writes a LOAD DATA LOCAL statement that refers to the file. The default location of the directory where these files are written is system-specific. To specify a directory explicitly, use the --local-load option.

Because mysqlbinlog converts LOAD DATA statements to LOAD DATA LOCAL statements (that is, it adds LOCAL), both the client and the server that you use to process the statements must be configured with the LOCAL capability enabled. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

### Warning

The temporary files created for LOAD DATA LOCAL statements are not automatically deleted because they are needed until you actually execute those statements. You should delete the temporary files yourself after you no longer need the statement log. The files can be found in the temporary file directory and have names like `original_file_name-#-#`.

#### 4.6.7.1 mysqlbinlog Hex Dump Format

The --hexdump option causes mysqlbinlog to produce a hex dump of the binary log contents:

```
shell> mysqlbinlog --hexdump master-bin.000001
```

The hex output consists of comment lines beginning with #, so the output might look like this for the preceding command:

```plaintext
/*!40019 SET @@SESSION.max_insert_delayed_threads=0*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
# at 4
#051024 17:24:13 server id 1  end_log_pos 98
# Position  Timestamp  Type  Master ID        Size  Master Pos  Flags
#  00000004 9d fc 5c 43 0f 01 00 00 00 5e 00 00 00 62 00 00 00 00 00
#  00000017 04 00 35 2e 30 2e 31 35 2d 64 65 62 75 67 2d 6c |...5.0.15.debug.l|
#  00000027 6f 67 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |og..............|
#  00000037 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |................|
#  00000047 00 00 00 00 9d fc 5c 43 13 38 0d 00 08 00 12 00 |....C.8......|
#  00000057 04 04 04 04 12 00 00 4b 00 04 1a |.......K...|
#       Start: binlog v 4, server v 5.0.15-debug-log created 051024 17:24:13
#       at startup
ROLLBACK
```

Hex dump output currently contains the elements in the following list. This format is subject to change. For more information about binary log format, see MySQL Internals: The Binary Log.

- **Position**: The byte position within the log file.
- **Timestamp**: The event timestamp. In the example shown, '9d fc 5c 43' is the representation of '051024 17:24:13' in hexadecimal.
- **Type**: The event type code.
- **Master ID**: The server ID of the master that created the event.
- **Size**: The size in bytes of the event.
- **Master Pos**: The position of the next event in the original master log file.
- **Flags**: Event flag values.
4.6.7.2 mysqlbinlog Row Event Display

The following examples illustrate how `mysqlbinlog` displays row events that specify data modifications. These correspond to events with the `WRITE_ROWS_EVENT`, `UPDATE_ROWS_EVENT`, and `DELETE_ROWS_EVENT` type codes. The `--base64-output=DECODE-ROWS` and `--verbose` options may be used to affect row event output.

Suppose that the server is using row-based binary logging and that you execute the following sequence of statements:

```sql
CREATE TABLE t
    (
        id   INT NOT NULL,
        name VARCHAR(20) NOT NULL,
        date DATE NULL
    ) ENGINE = InnoDB;

START TRANSACTION;
INSERT INTO t VALUES(1, 'apple', NULL);
UPDATE t SET name = 'pear', date = '2009-01-01' WHERE id = 1;
DELETE FROM t WHERE id = 1;
COMMIT;
```

By default, `mysqlbinlog` displays row events encoded as base-64 strings using `BINLOG` statements. Omitting extraneous lines, the output for the row events produced by the preceding statement sequence looks like this:

```
shell> mysqlbinlog log_file ...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F
BINLOG 'fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ=fAS3SBcBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ= //*/';
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F
BINLOG 'fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ=fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ= //*/';
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F
BINLOG 'fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ=fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ= //*/';
```

To see the row events as comments in the form of "pseudo-SQL" statements, run `mysqlbinlog` with the `--verbose` or `-v` option. The output will contain lines beginning with `###`:

```
shell> mysqlbinlog -v log_file ...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F
BINLOG 'fAS3SBMBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ=fAS3SBcBAAAALAAAANoAAAAAABHRlc3QAAwMPCgIUAAQ= //*/';
```
mysqlbinlog — Utility for Processing Binary Log Files

### INSERT INTO test.t
### SET
###   @1=1
###   @2='apple'
###   @3=NULL
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG 'fAS3SBMAAAAALAAAC4BAAAABEAAAAAAABHRLc3QAXQAAwMPCgIUAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEEAAAAAAEA////AEEAAAYFBw5bGX4AQAAMARwZWFyIBIP
'*'!';

### UPDATE test.t
### WHERE
###   @1=1
###   @2='apple'
###   @3=NULL
### SET
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F

BINLOG 'fAS3SBMAAAAALAAAC4BAAAABEAAAAAAABHRLc3QAXQAAwMPCgIUAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEEAAAAAAEA////AEEAAAYFBw5bGX4AQAAMARwZWFyIBIP
'*'!';

### DELETE FROM test.t
### WHERE
###   @1=1
###   @2='pear'
###   @3='2009:01:01'

Specify `--verbose` or `-v` twice to also display data types and some metadata for each column. The output will contain an additional comment following each column change:

shell> mysqlbinlog --vv log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG 'fAS3SBMAAAAALAAAC4BAAAABEAAAAAAABHRLc3QAXQAAwMPCgIUAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEEAAAAAAEA////AEEAAAYFBw5bGx4AQAAMARwZWFyIBIP
'*'!';

### INSERT INTO test.t
### SET
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG 'fAS3SBMAAAAALAAAC4BAAAABEAAAAAAABHRLc3QAXQAAwMPCgIUAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEEAAAAAAEA////AEEAAAYFBw5bGX4AQAAMARwZWFyIBIP
'*'!';

### UPDATE test.t
### WHERE
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
You can tell `mysqlbinlog` to suppress the `BINLOG` statements for row events by using the `--base64-output=DECODE-ROWS` option. This is similar to `--base64-output=NEVER` but does not exit with an error if a row event is found. The combination of `--base64-output=DECODE-ROWS` and `--verbose` provides a convenient way to see row events only as SQL statements:

```
shell> mysqlbinlog -v --base64-output=DECODE-ROWS log_file
```

The SQL statements produced by `--verbose` for row events are much more readable than the corresponding `BINLOG` statements. However, they do not correspond exactly to the original SQL statements that generated the events. The following limitations apply:

- The original column names are lost and replaced by `@N`, where `N` is a column number.
- Character set information is not available in the binary log, which affects string column display.

---

**Note**

You should not suppress `BINLOG` statements if you intend to re-execute `mysqlbinlog` output.
There is no distinction made between corresponding binary and nonbinary string types (BINARY and CHAR, VARBINARY and VARCHAR, BLOB and TEXT). The output uses a data type of STRING for fixed-length strings and VARSTRING for variable-length strings.

For multibyte character sets, the maximum number of bytes per character is not present in the binary log, so the length for string types is displayed in bytes rather than in characters. For example, STRING(4) will be used as the data type for values from either of these column types:

```
CHAR(4) CHARACTER SET latin1
CHAR(2) CHARACTER SET ucs2
```

Due to the storage format for events of type UPDATE_ROWS_EVENT, UPDATE statements are displayed with the WHERE clause preceding the SET clause.

Proper interpretation of row events requires the information from the format description event at the beginning of the binary log. Because mysqlbinlog does not know in advance whether the rest of the log contains row events, by default it displays the format description event using a BINLOG statement in the initial part of the output.

If the binary log is known not to contain any events requiring a BINLOG statement (that is, no row events), the --base64-output=NEVER option can be used to prevent this header from being written.

**4.6.8 mysqldumpslow — Summarize Slow Query Log Files**

The MySQL slow query log contains information about queries that take a long time to execute (see Section 5.4.5, "The Slow Query Log"). mysqldumpslow parses MySQL slow query log files and summarizes their contents.

Normally, mysqldumpslow groups queries that are similar except for the particular values of number and string data values. It "abstracts" these values to N and 'S' when displaying summary output. To modify value abstracting behavior, use the -a and -n options.

Invoke mysqldumpslow like this:

```
shell> mysqldumpslow [options] [log_file ...]
```

Example of usage:

```
shell> mysqldumpslow
Reading mysql slow query log from /usr/local/mysql/data/mysqld55-slow.log
Count: 1  Time=4.32s (4s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
  insert into t2 select * from t1

Count: 3  Time=2.53s (7s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
  insert into t2 select * from t1 limit N

Count: 3  Time=2.13s (6s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
  insert into t1 select * from t1
```

Mysqldumpslow supports the following options.

**Table 4.20 mysqldumpslow Options**

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-a</td>
<td>Do not abstract all numbers to N and strings to 'S'</td>
</tr>
<tr>
<td>-n</td>
<td>Abstract numbers with at least the specified digits</td>
</tr>
</tbody>
</table>
### mysqlslow — Summarize Slow Query Log Files

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--debug</td>
<td>Write debugging information</td>
</tr>
<tr>
<td>-g</td>
<td>Only consider statements that match the pattern</td>
</tr>
<tr>
<td>--help</td>
<td>Display help message and exit</td>
</tr>
<tr>
<td>-h</td>
<td>Host name of the server in the log file name</td>
</tr>
<tr>
<td>-i</td>
<td>Name of the server instance</td>
</tr>
<tr>
<td>-l</td>
<td>Do not subtract lock time from total time</td>
</tr>
<tr>
<td>-r</td>
<td>Reverse the sort order</td>
</tr>
<tr>
<td>-s</td>
<td>How to sort output</td>
</tr>
<tr>
<td>-t</td>
<td>Display only first num queries</td>
</tr>
<tr>
<td>--verbose</td>
<td>Verbose mode</td>
</tr>
</tbody>
</table>

- **--help**
  Display a help message and exit.
- **-a**
  Do not abstract all numbers to N and strings to 'S'.
- **--debug, -d**
  Run in debug mode.
- **-g pattern**
  Consider only queries that match the (grep-style) pattern.
- **-h host_name**
  Host name of MySQL server for *-slow.log file name. The value can contain a wildcard. The default is * (match all).
- **-i name**
  Name of server instance (if using mysql.server startup script).
- **-l**
  Do not subtract lock time from total time.
- **-n N**
  Abstract numbers with at least N digits within names.
- **-r**
  Reverse the sort order.
- **-s sort_type**
  How to sort the output. The value of sort_type should be chosen from the following list:
  - **t, at**: Sort by query time or average query time
mysqlhotcopy — A Database Backup Program

• **l, al**: Sort by lock time or average lock time
• **r, ar**: Sort by rows sent or average rows sent
• **c**: Sort by count

By default, mysqlslow sorts by average query time (equivalent to \(-s\) at).

• **-t N**
  Display only the first \(N\) queries in the output.

• **--verbose, -v**
  Verbose mode. Print more information about what the program does.

4.6.9 mysqlhotcopy — A Database Backup Program

mysqlhotcopy is a Perl script that was originally written and contributed by Tim Bunce. It uses **FLUSH TABLES**, **LOCK TABLES**, and cp or scp to make a database backup. It is a fast way to make a backup of the database or single tables, but it can be run only on the same machine where the database directories are located. mysqlhotcopy works only for backing up **MyISAM** and **ARCHIVE** tables. It runs on Unix.

To use mysqlhotcopy, you must have read access to the files for the tables that you are backing up, the **SELECT** privilege for those tables, the **RELOAD** privilege (to be able to execute **FLUSH TABLES**), and the **LOCK TABLES** privilege (to be able to lock the tables).

`shell> mysqlhotcopy db_name [/path/to/new_directory]`

`shell> mysqlhotcopy db_name_1 ... db_name_n /path/to/new_directory`

Back up tables in the given database that match a regular expression:

`shell> mysqlhotcopy db_name/.regex/`

The regular expression for the table name can be negated by prefixing it with a tilde (~):

`shell> mysqlhotcopy db_name./~regex/`

mysqlhotcopy supports the following options, which can be specified on the command line or in the [mysqlhotcopy] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

<table>
<thead>
<tr>
<th>Table 4.21 mysqlhotcopy Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option Name</strong></td>
</tr>
<tr>
<td>--addtodest</td>
</tr>
<tr>
<td>--allowold</td>
</tr>
<tr>
<td>--checkpoint</td>
</tr>
<tr>
<td>--chroot</td>
</tr>
<tr>
<td>--debug</td>
</tr>
<tr>
<td>--dryrun</td>
</tr>
<tr>
<td>--flushlog</td>
</tr>
<tr>
<td>-h</td>
</tr>
</tbody>
</table>

436
mysqlhotcopy — A Database Backup Program

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--host</td>
<td>Host on which MySQL server is located</td>
</tr>
<tr>
<td>--keepold</td>
<td>Do not delete previous (renamed) target when done</td>
</tr>
<tr>
<td>--method</td>
<td>The method for copying files</td>
</tr>
<tr>
<td>--noindices</td>
<td>Do not include full index files in the backup</td>
</tr>
<tr>
<td>--old_server</td>
<td>Connect to server that does not support FLUSH TABLES tbl_list WITH READ LOCK</td>
</tr>
<tr>
<td>--password</td>
<td>Password to use when connecting to server</td>
</tr>
<tr>
<td>--port</td>
<td>TCP/IP port number for connection</td>
</tr>
<tr>
<td>--quiet</td>
<td>Be silent except for errors</td>
</tr>
<tr>
<td>--regexp</td>
<td>Copy all databases with names that match the given regular expression</td>
</tr>
<tr>
<td>--resetmaster</td>
<td>Reset the binary log after locking all the tables</td>
</tr>
<tr>
<td>--resetslave</td>
<td>Reset the master.info file after locking all the tables</td>
</tr>
<tr>
<td>--socket</td>
<td>Unix socket file or Windows named pipe to use</td>
</tr>
<tr>
<td>--tmpdir</td>
<td>The temporary directory</td>
</tr>
<tr>
<td>--user</td>
<td>MySQL user name to use when connecting to server</td>
</tr>
</tbody>
</table>

- --help, -?
  Display a help message and exit.

- --addtodes
  Do not rename target directory (if it exists); merely add files to it.

- --allowold
  Do not abort if a target exists; rename it by adding an _old suffix.

- --checkpoint=db_name.tbl_name
  Insert checkpoint entries into the specified database db_name and table tbl_name.

- --chroot=dir_name
  Base directory of the chroot jail in which mysqld operates. The dir_name value should match that of the --chroot option given to mysqld.

- --debug
  Enable debug output.

- --dryrun, -n
  Report actions without performing them.

- --flushlog
  Flush logs after all tables are locked.

- --host=host_name, -h host_name

The host name of the local host to use for making a TCP/IP connection to the local server. By default, the connection is made to localhost using a Unix socket file.

- **--keepold**
  Do not delete previous (renamed) target when done.

- **--method=command**
  The method for copying files (cp or scp). The default is cp.

- **--noindices**
  Do not include full index files for MyISAM tables in the backup. This makes the backup smaller and faster. The indexes for reloaded tables can be reconstructed later with myisamchk -rq.

- **--password=password, -ppassword**
  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- **--port=port_num, -P port_num**
  The TCP/IP port number to use when connecting to the local server.

- **--old_server**
  As of MySQL 5.5.3, mysqlhotcopy uses FLUSH TABLES tbl_list WITH READ LOCK to flush and lock tables. Use the --old_server option if the server is older than 5.5.3, which is when that statement was introduced. This option was added in MySQL 5.5.3.

- **--quiet,-q**
  Be silent except for errors.

- **--record_log_pos=db_name.tbl_name**
  Record master and slave status in the specified database db_name and table tbl_name.

- **--regexp=expr**
  Copy all databases with names that match the given regular expression.

- **--resetmaster**
  Reset the binary log after locking all the tables.

- **--resetslave**
  Reset the master.info file after locking all the tables.

- **--socket=path, -S path**
  The Unix socket file to use for connections to localhost.
mysql_convert_table_format — Convert Tables to Use a Given Storage Engine

- **--suffix=str**
  The suffix to use for names of copied databases.

- **--tmpdir=dir_name**
  The temporary directory. The default is /tmp.

- **--user=user_name, -u user_name**
  The MySQL user name to use when connecting to the server.

Use perldoc for additional mysqlhotcopy documentation, including information about the structure of the tables needed for the --checkpoint and --record_log_pos options:

```
shell> perldoc mysqlhotcopy
```

### 4.6.10 mysql_convert_table_format — Convert Tables to Use a Given Storage Engine

mysql_convert_table_format converts the tables in a database to use a particular storage engine (MyISAM by default). mysql_convert_table_format is written in Perl and requires that the DBI and DBD::mysql Perl modules be installed (see Section 2.13, “Perl Installation Notes”).

Invoke mysql_convert_table_format like this:

```
shell> mysql_convert_table_format [options] db_name
```

The db_name argument indicates the database containing the tables to be converted.

mysql_convert_table_format supports the options described in the following list.

- **--help**
  Display a help message and exit.

- **--force**
  Continue even if errors occur.

- **--host=host_name**
  Connect to the MySQL server on the given host.

- **--password=password**
  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- **--port=port_num**
  The TCP/IP port number to use for the connection.

- **--socket=path**
For connections to `localhost`, the Unix socket file to use.

- `--type=engine_name`
  Specify the storage engine that the tables should be converted to use. The default is `MyISAM` if this option is not given.

- `--user=user_name`
  The MySQL user name to use when connecting to the server.

- `--verbose`
  Verbose mode. Print more information about what the program does.

- `--version`
  Display version information and exit.

## 4.6.11 `mysql_find_rows` — Extract SQL Statements from Files

`mysql_find_rows` reads files containing SQL statements and extracts statements that match a given regular expression or that contain `USE db_name` or `SET` statements. The utility expects statements to be terminated with semicolon (`;`) characters.

Invoke `mysql_find_rows` like this:

```
shell> mysql_find_rows [options] [file_name ...]
```

Each `file_name` argument should be the name of file containing SQL statements. If no file names are given, `mysql_find_rows` reads the standard input.

Examples:

```
mysql_find_rows --regexp=problem_table --rows=20 < update.log
mysql_find_rows --regexp=problem_table  update-log.1  update-log.2
```

`mysql_find_rows` supports the following options:

- `--help`, `--Information`
  Display a help message and exit.

- `--regexp=pattern`
  Display queries that match the pattern.

- `--rows=N`
  Quit after displaying `N` queries.

- `--skip-use-db`
  Do not include `USE db_name` statements in the output.

- `--start_row=N`
  Start output from this row.
4.6.12 **mysql_fix_extensions** — Normalize Table File Name Extensions

`mysql_fix_extensions` converts the extensions for MyISAM (or ISAM) table files to their canonical forms. It looks for files with extensions matching any lettercase variant of `.frm`, `.myd`, `.myi`, `.isd`, and `.ism` and renames them to have extensions of `.frm`, `.MYD`, `.MYI`, `.ISD`, and `.ISM`, respectively. This can be useful after transferring the files from a system with case-insensitive file names (such as Windows) to a system with case-sensitive file names.

Invoke `mysql_fix_extensions` like this, where `data_dir` is the path name to the MySQL data directory.

```
shell> mysql_fix_extensions data_dir
```

4.6.13 **mysql_setpermission** — Interactively Set Permissions in Grant Tables

`mysql_setpermission` is a Perl script that was originally written and contributed by Luuk de Boer. It interactively sets permissions in the MySQL grant tables. `mysql_setpermission` is written in Perl and requires that the DBI and DBD::mysql Perl modules be installed (see Section 2.13, “Perl Installation Notes”).

Invoke `mysql_setpermission` like this:

```
shell> mysql_setpermission [options]
```

`options` should be either `--help` to display the help message, or options that indicate how to connect to the MySQL server. The account used when you connect determines which permissions you have when attempting to modify existing permissions in the grant tables.

`mysql_setpermissions` also reads options from the [client] and [perl] groups in the `.my.cnf` file in your home directory, if the file exists.

`mysql_setpermission` supports the following options:

- `--help`
  Display a help message and exit.

- `--host=host_name`
  Connect to the MySQL server on the given host.

- `--password=password`
  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. To avoid giving the password on the command line, use an option file. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- `--port=port_num`
  The TCP/IP port number to use for the connection.

- `--socket=path`
For connections to **localhost**, the Unix socket file to use.

- **--user=user_name**

  The MySQL user name to use when connecting to the server.

### 4.6.14 `mysql_waitpid` — Kill Process and Wait for Its Termination

`mysql_waitpid` signals a process to terminate and waits for the process to exit. It uses the `kill()` system call and Unix signals, so it runs on Unix and Unix-like systems.

Invoke `mysql_waitpid` like this:

```shell
shell> mysql_waitpid [options] pid wait_time
```

`mysql_waitpid` sends signal 0 to the process identified by `pid` and waits up to `wait_time` seconds for the process to terminate. `pid` and `wait_time` must be positive integers.

If process termination occurs within the wait time or the process does not exist, `mysql_waitpid` returns 0. Otherwise, it returns 1.

If the `kill()` system call cannot handle signal 0, `mysql_waitpid()` uses signal 1 instead.

`mysql_waitpid` supports the following options:

- **--help, -?, -I**
  
  Display a help message and exit.

- **--verbose, -v**
  
  Verbose mode. Display a warning if signal 0 could not be used and signal 1 is used instead.

- **--version, -V**
  
  Display version information and exit.

### 4.6.15 `mysql_zap` — Kill Processes That Match a Pattern

`mysql_zap` kills processes that match a pattern. It uses the `ps` command and Unix signals, so it runs on Unix and Unix-like systems.

Invoke `mysql_zap` like this:

```shell
shell> mysql_zap [-signal] [-?If] pattern
```

A process matches if its output line from the `ps` command contains the pattern. By default, `mysql_zap` asks for confirmation for each process. Respond **y** to kill the process, or **q** to exit `mysql_zap`. For any other response, `mysql_zap` does not attempt to kill the process.

If the `-signal` option is given, it specifies the name or number of the signal to send to each process. Otherwise, `mysql_zap` tries first with **TERM** (signal 15) and then with **KILL** (signal 9).

`mysql_zap` supports the following additional options:

- **--help, -?, -I**
  
  Display a help message and exit.
Program Development Utilities

• -f
  Force mode. `mysql_zap` attempts to kill each process without confirmation.

• -t
  Test mode. Display information about each process but do not kill it.

4.7 Program Development Utilities

This section describes some utilities that you may find useful when developing MySQL programs.

In shell scripts, you can use the `my_print_defaults` program to parse option files and see what options would be used by a given program. The following example shows the output that `my_print_defaults` might produce when asked to show the options found in the `[client]` and `[mysql]` groups:

```
shell> my_print_defaults client mysql
--port=3306
--socket=/tmp/mysql.sock
--no-auto-rehash
```

Note for developers: Option file handling is implemented in the C client library simply by processing all options in the appropriate group or groups before any command-line arguments. This works well for programs that use the last instance of an option that is specified multiple times. If you have a C or C++ program that handles multiply specified options this way but that doesn’t read option files, you need add only two lines to give it that capability. Check the source code of any of the standard MySQL clients to see how to do this.

Several other language interfaces to MySQL are based on the C client library, and some of them provide a way to access option file contents. These include Perl and Python. For details, see the documentation for your preferred interface.

4.7.1 msql2mysql — Convert mSQL Programs for Use with MySQL

Initially, the MySQL C API was developed to be very similar to that for the mSQL database system. Because of this, mSQL programs often can be converted relatively easily for use with MySQL by changing the names of the C API functions.

The `msql2mysql` utility performs the conversion of mSQL C API function calls to their MySQL equivalents. `msql2mysql` converts the input file in place, so make a copy of the original before converting it. For example, use `msql2mysql` like this:

```
shell> cp client-prog.c client-prog.c.orig
shell> msql2mysql client-prog.c
client-prog.c converted
```

Then examine `client-prog.c` and make any post-conversion revisions that may be necessary.

`msql2mysql` uses the `replace` utility to make the function name substitutions. See Section 4.8.2, "replace — A String-Replacement Utility".

4.7.2 mysql_config — Display Options for Compiling Clients

`mysql_config` provides you with useful information for compiling your MySQL client and connecting it to MySQL. It is a shell script, so it is available only on Unix and Unix-like systems.

`mysql_config` supports the following options.
- **--cflags**
  Compiler flags to find include files and critical compiler flags and defines used when compiling the `libmysqlclient` library. The options returned are tied to the specific compiler that was used when the library was created and might clash with the settings for your own compiler. Use `--include` for more portable options that contain only include paths.

- **--include**
  Compiler options to find MySQL include files.

- **--libmysqld-libs, --embedded-libs, --embedded**
  Libraries and options required to link with `libmysqld`, the MySQL embedded server.

- **--libs**
  Libraries and options required to link with the MySQL client library.

- **--libs_r**
  Libraries and options required to link with the thread-safe MySQL client library. In MySQL 5.5, all client libraries are thread-safe, so this option need not be used. The `--libs` option can be used in all cases.

- **--plugindir**
  The default plugin directory path name, defined when configuring MySQL.

- **--port**
  The default TCP/IP port number, defined when configuring MySQL.

- **--socket**
  The default Unix socket file, defined when configuring MySQL.

- **--variable=var_name**
  Display the value of the named configuration variable. Permitted `var_name` values are `pkgincludedir` (the header file directory), `pkglibdir` (the library directory), and `plugindir` (the plugin directory).

- **--version**
  Version number for the MySQL distribution.

If you invoke `mysql_config` with no options, it displays a list of all options that it supports, and their values:

```
shell> mysql_config
Usage: /usr/local/mysql/bin/mysql_config [options]
Options:
--cflags       [-I/usr/local/mysql/include/mysql -mcpu=pentiumpro]
--include      [-I/usr/local/mysql/include/mysql]
--libs         [-L/usr/local/mysql/lib/mysql -lmysqlclient
               -lpthread -lm -lrt -lssl -lcrypto -ldl]
--libs_r       [-L/usr/local/mysql/lib/mysql -lmysqlclient_r
               -lpthread -lm -lrt -lssl -lcrypto -ldl]
--plugindir    [/usr/local/mysql/lib/plugin]
--socket       [/tmp/mysql.sock]
--port         [3306]
--version      [5.5.31]
```
my_print_defaults — Display Options from Option Files

--libmysqld-libs [-L/usr/local/mysql/lib/mysql -lmymqld
   -lpthread -lm -lrt -lssl -lcrypto -ldl -lcrypt]
--variable=VAR   VAR is one of:
   pkgincludedir [/usr/local/mysql/include]
   pkglibdir     [/usr/local/mysql/lib]
   plugindir     [/usr/local/mysql/lib/plugin]

You can use mysql_config within a command line using backticks to include the output that it produces
for particular options. For example, to compile and link a MySQL client program, use mysql_config as
follows:

gcc -c `mysql_config --cflags` progname.c
gcc -o progname progname.o `mysql_config --libs`

4.7.3 my_print_defaults — Display Options from Option Files

my_print_defaults displays the options that are present in option groups of option files. The output
indicates what options will be used by programs that read the specified option groups. For example, the
mysqlcheck program reads the [mysqlcheck] and [client] option groups. To see what options are
present in those groups in the standard option files, invoke my_print_defaults like this:

shell> my_print_defaults mysqlcheck client
   --user=myusername
   --password=password
   --host=localhost

The output consists of options, one per line, in the form that they would be specified on the command line.

my_print_defaults supports the following options.

•  --help, -?
   Display a help message and exit.

•  --config-file=file_name, --defaults-file=file_name, -c file_name
   Read only the given option file.

•  --debug=debug_options, -# debug_options
   Write a debugging log. A typical debug_options string is d:t:o, file_name. The default is d:t:o,/tmp/my_print_defaults.trace.

•  --defaults-extra-file=file_name, --extra-file=file_name, -e file_name
   Read this option file after the global option file but (on Unix) before the user option file.

   For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line
   Options that Affect Option-File Handling”.

•  --defaults-group-suffix=suffix, -g suffix
   In addition to the groups named on the command line, read groups that have the given suffix.

   For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line
   Options that Affect Option-File Handling”.

•  --no-defaults, -n
   Return an empty string.
resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--verbose, -v**
  Verbose mode. Print more information about what the program does.

- **--version, -V**
  Display version information and exit.

4.7.4 **resolve_stack_dump** — Resolve Numeric Stack Trace Dump to Symbols

resolve_stack_dump resolves a numeric stack dump to symbols.

Invoke `resolve_stack_dump` like this:

```
shell> resolve_stack_dump [options] symbols_file [numeric_dump_file]
```

The symbols file should include the output from the `nm --numeric-sort mysqld` command. The numeric dump file should contain a numeric stack track from `mysqld`. If no numeric dump file is named on the command line, the stack trace is read from the standard input.

`resolve_stack_dump` supports the following options.

- **--help, -h**
  Display a help message and exit.

- **--numeric-dump-file=file_name, -n file_name**
  Read the stack trace from the given file.

- **--symbols-file=file_name, -s file_name**
  Use the given symbols file.

- **--version, -V**
  Display version information and exit.

For more information, see Section 24.5.1.5, “Using a Stack Trace”.

4.8 Miscellaneous Programs

4.8.1 **perror** — Display MySQL Error Message Information

For most system errors, MySQL displays, in addition to an internal text message, the system error code in one of the following styles:

```
message ... (errno: #)
message ... (Errcode: #)
```

You can find out what the error code means by examining the documentation for your system or by using the `perror` utility.
**perror** prints a description for a system error code or for a storage engine (table handler) error code.

Invoke **perror** like this:

```
shell> perror [options] errorcode ...
```

Examples:

```
shell> perror 1231
MySQL error code 1231 (ER_WRONG_VALUE_FOR_VAR): Variable '%-.64s' can't be set to the value of '%-.200s'
```

```
shell> perror 13 64
OS error code 13: Permission denied
OS error code 64: Machine is not on the network
```

To obtain the error message for an NDB Cluster error code, invoke **perror** with the **--ndb** option:

```
shell> perror --ndb errorcode
```

The meaning of system error messages may be dependent on your operating system. A given error code may mean different things on different operating systems.

**perror** supports the following options.

- **--help, --info, -I, -?**
  Display a help message and exit.

- **--ndb**
  Print the error message for an NDB Cluster error code.

- **--silent, -s**
  Silent mode. Print only the error message.

- **--verbose, -v**
  Verbose mode. Print error code and message. This is the default behavior.

- **--version, -V**
  Display version information and exit.

### 4.8.2 replace — A String-Replacement Utility

The **replace** utility program changes strings in place in files or on the standard input.

Invoke **replace** in one of the following ways:

```
shell> replace from to [from to] ... -- file_name [file_name] ...
shell> replace from to [from to] ... < file_name
```

**from** represents a string to look for and **to** represents its replacement. There can be one or more pairs of strings.

Use the **--** option to indicate where the string-replacement list ends and the file names begin. In this case, any file named on the command line is modified in place, so you may want to make a copy of the original before converting it. **replace** prints a message indicating which of the input files it actually modifies.
If the \texttt{--} option is not given, \texttt{replace} reads the standard input and writes to the standard output.  \texttt{replace} uses a finite state machine to match longer strings first. It can be used to swap strings. For example, the following command swaps \texttt{a} and \texttt{b} in the given files, \texttt{file1} and \texttt{file2}:

\begin{verbatim}
shell> replace a b b a -- file1 file2 ...
\end{verbatim}

The \texttt{replace} program is used by \texttt{msql2mysql}. See Section 4.7.1, “\texttt{msql2mysql} — Convert mSQL Programs for Use with MySQL”.

\texttt{replace} supports the following options.
\begin{enumerate}
\item \texttt{--help, --info, --?, --I}
Display a help message and exit.
\item \texttt{--debug_options}
Enable debugging.
\item \texttt{--silent, --s}
Silent mode. Print less information what the program does.
\item \texttt{--verbose, --v}
Verbose mode. Print more information about what the program does.
\item \texttt{--version, --v}
Display version information and exit.
\end{enumerate}

\textbf{4.8.3 resolveip — Resolve Host name to IP Address or Vice Versa}

The \texttt{resolveip} utility resolves host names to IP addresses and vice versa.  

Invoke \texttt{resolveip} like this:

\begin{verbatim}
shell> resolveip [options] {host_name|ip-addr} ...
\end{verbatim}

\texttt{resolveip} supports the following options.
\begin{enumerate}
\item \texttt{--help, --info, --?, --I}
Display a help message and exit.
\item \texttt{--silent, --s}
Silent mode. Produce less output.
\item \texttt{--version, --v}
Display version information and exit.
\end{enumerate}

\textbf{4.9 Environment Variables}

This section lists environment variables that are used directly or indirectly by MySQL. Most of these can also be found in other places in this manual.
Options on the command line take precedence over values specified in option files and environment variables, and values in option files take precedence over values in environment variables. In many cases, it is preferable to use an option file instead of environment variables to modify the behavior of MySQL. See Section 4.2.2.2, “Using Option Files”.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTHENTICATION_PAM_LOG</td>
<td>PAM authentication plugin debug logging settings.</td>
</tr>
<tr>
<td>CC</td>
<td>The name of your C compiler (for running CMake).</td>
</tr>
<tr>
<td>CXX</td>
<td>The name of your C++ compiler (for running CMake).</td>
</tr>
<tr>
<td>CC</td>
<td>The name of your C compiler (for running CMake).</td>
</tr>
<tr>
<td>DBI_USER</td>
<td>The default user name for Perl DBI.</td>
</tr>
<tr>
<td>DBI_TRACE</td>
<td>Trace options for Perl DBI.</td>
</tr>
<tr>
<td>HOME</td>
<td>The default path for the mysql history file is $HOME/.mysql_history.</td>
</tr>
<tr>
<td>LD_RUN_PATH</td>
<td>Used to specify the location of libmysqlclient.so.</td>
</tr>
<tr>
<td>LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN</td>
<td>Enable mysql_clear_password authentication plugin; see Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.</td>
</tr>
<tr>
<td>MYSQL_DEBUG</td>
<td>Debug trace options when debugging.</td>
</tr>
<tr>
<td>MYSQL_GROUP_SUFFIX</td>
<td>Option group suffix value (like specifying --defaults-group-suffix).</td>
</tr>
<tr>
<td>MYSQL_HISTFILE</td>
<td>The path to the mysql history file. If this variable is set, its value overrides the default for $HOME/.mysql_history.</td>
</tr>
<tr>
<td>MYSQL_HOME</td>
<td>The path to the directory in which the server-specific my.cnf file resides.</td>
</tr>
<tr>
<td>MYSQL_HOST</td>
<td>The default host name used by the mysql command-line client.</td>
</tr>
<tr>
<td>MYSQL_PS1</td>
<td>The command prompt to use in the mysql command-line client.</td>
</tr>
<tr>
<td>MYSQL_PWD</td>
<td>The default password when connecting to mysqld. Using this is insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.</td>
</tr>
<tr>
<td>MYSQL_TCP_PORT</td>
<td>The default TCP/IP port number.</td>
</tr>
<tr>
<td>MYSQL_UNIX_PORT</td>
<td>The default Unix socket file name; used for connections to localhost.</td>
</tr>
<tr>
<td>PATH</td>
<td>Used by the shell to find MySQL programs.</td>
</tr>
<tr>
<td>TMPDIR</td>
<td>The directory in which temporary files are created.</td>
</tr>
<tr>
<td>TZ</td>
<td>This should be set to your local time zone. See Section B.4.3.7, “Time Zone Problems”.</td>
</tr>
<tr>
<td>UMASK</td>
<td>The user-file creation mode when creating files. See note following table.</td>
</tr>
<tr>
<td>UMASK_DIR</td>
<td>The user-directory creation mode when creating directories. See note following table.</td>
</tr>
<tr>
<td>USER</td>
<td>The default user name on Windows when connecting to mysqld.</td>
</tr>
</tbody>
</table>
Unix Signal Handling in MySQL

For information about the `mysql` history file, see Section 4.5.1.3, “mysql Client Logging”.

The default UMASK and UMASK_DIR values are 0660 and 0700, respectively. MySQL assumes that the value for UMASK or UMASK_DIR is in octal if it starts with a zero. For example, setting UMASK=0600 is equivalent to UMASK=384 because 0600 octal is 384 decimal.

The UMASK and UMASK_DIR variables, despite their names, are used as modes, not masks:

- If UMASK is set, mysqld uses ($UMASK | 0600) as the mode for file creation, so that newly created files have a mode in the range from 0600 to 0666 (all values octal).

- If UMASK_DIR is set, mysqld uses ($UMASK_DIR | 0700) as the base mode for directory creation, which then is AND-ed with (~($UMASK & 0666)), so that newly created directories have a mode in the range from 0700 to 0777 (all values octal). The AND operation may remove read and write permissions from the directory mode, but not execute permissions.

See also Section B.4.3.1, “Problems with File Permissions”.

4.10 Unix Signal Handling in MySQL

On Unix and Unix-like systems, a process can be the recipient of signals sent to it by root or the account that owns the process. Signals can be sent using the `kill` command. Some command interpreters associate certain key sequences with signals, such as Control+C to send a SIGINT signal. This section describes how the MySQL server and client programs respond to signals.

- Server Response to Signals
- Client Response to Signals

Server Response to Signals

mysqld responds to signals as follows:

- SIGTERM causes the server to shut down.

- SIGHUP causes the server to reload the grant tables and to flush tables, logs, the thread cache, and the host cache. These actions are like various forms of the `FLUSH` statement. The server also writes a status report to the error log that has this format:

```
Status information:
Current dir: /var/mysql/data/
Running threads: 0  Stack size: 196608
Current locks:
Key caches:
default
Buffer_size: 8388600
Block_size: 1024
Division_limit: 100
Age_limit: 300
blocks used: 0
not flushed: 0
w_requests: 0
writes: 0
r_requests: 0
reads: 0
handler status:
read_key: 0
```

450
• **SIGINT** normally is ignored by the server. Starting the server with the **--gdb** option installs an interrupt handler for **SIGINT** for debugging purposes. See Section 24.5.1.4, “Debugging mysqld under gdb”.

**Client Response to Signals**

MySQL client programs respond to signals as follows:

• The **mysql** client interprets **SIGINT** (typically the result of typing **Control+C**) as instruction to interrupt the current statement if there is one, or to cancel any partial input line otherwise. This behavior can be disabled using the **--sigint-ignore** option to ignore **SIGINT** signals.

• Client programs that use the MySQL client library block **SIGPIPE** signals by default. These variations are possible:
  
  • Client can install their own **SIGPIPE** handler to override the default behavior. See Section 23.7.3.2, “Writing C API Threaded Client Programs”.

  • Clients can prevent installation of **SIGPIPE** handlers by specifying the **CLIENT_IGNORE_SIGPIPE** option to **mysql_real_connect()** at connect time. See Section 23.7.6.52, “mysql_real_connect()”.

<table>
<thead>
<tr>
<th>Table status:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Opened tables:</td>
<td>5</td>
</tr>
<tr>
<td>Open tables:</td>
<td>0</td>
</tr>
<tr>
<td>Open files:</td>
<td>7</td>
</tr>
<tr>
<td>Open streams:</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alarm status:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Active alarms:</td>
<td>1</td>
</tr>
<tr>
<td>Max used alarms:</td>
<td>2</td>
</tr>
<tr>
<td>Next alarm time:</td>
<td>67</td>
</tr>
</tbody>
</table>
Chapter 5 MySQL Server Administration

Table of Contents

5.1 The MySQL Server ................................................................. 454
  5.1.1 Configuring the Server .................................................. 454
  5.1.2 Server Configuration Defaults .......................................... 456
  5.1.3 Server Option, System Variable, and Status Variable Reference .......... 456
  5.1.4 Server System Variable Reference .................................... 481
  5.1.5 Server Status Variable Reference ..................................... 493
  5.1.6 Server Command Options ................................................ 504
  5.1.7 Server System Variables .................................................. 528
  5.1.8 Using System Variables .................................................... 622
  5.1.9 Server Status Variables ................................................... 634
  5.1.10 Server SQL Modes .......................................................... 650
  5.1.11 IPv6 Support ............................................................... 659
  5.1.12 MySQL Server Time Zone Support ..................................... 662
  5.1.13 Server-Side Help Support ................................................. 667
  5.1.14 The Server Shutdown Process ......................................... 668
5.2 The MySQL Data Directory .................................................... 669
5.3 The mysql System Database .................................................. 670
5.4 MySQL Server Logs ............................................................... 672
  5.4.1 Selecting General Query Log and Slow Query Log Output Destinations .. 673
  5.4.2 The Error Log ............................................................... 675
  5.4.3 The General Query Log .................................................... 677
  5.4.4 The Binary Log ............................................................. 679
  5.4.5 The Slow Query Log ....................................................... 690
  5.4.6 The DDL Log ............................................................... 692
  5.4.7 Server Log Maintenance .................................................... 692
5.5 MySQL Server Plugins ........................................................ 694
  5.5.1 Installing and Uninstalling Plugins ..................................... 694
  5.5.2 Obtaining Server Plugin Information .................................. 698
  5.5.3 MySQL Enterprise Thread Pool .......................................... 699
5.6 MySQL Server User-Defined Functions ...................................... 705
  5.6.1 Installing and Uninstalling User-Defined Functions ..................... 705
  5.6.2 Obtaining User-Defined Function Information ........................... 706
5.7 Running Multiple MySQL Instances on One Machine ....................... 706
  5.7.1 Setting Up Multiple Data Directories .................................. 708
  5.7.2 Running Multiple MySQL Instances on Windows ......................... 709
  5.7.3 Running Multiple MySQL Instances on Unix ............................. 712
  5.7.4 Using Client Programs in a Multiple-Server Environment ............... 713
5.8 Tracing mysqld Using DTrace .................................................. 714
  5.8.1 mysqld DTrace Probe Reference ......................................... 715

MySQL Server (mysqld) is the main program that does most of the work in a MySQL installation. This chapter provides an overview of MySQL Server and covers general server administration:

• Server configuration

• The data directory, particularly the mysql system database

• The server log files
• Management of multiple servers on a single machine

For additional information on administrative topics, see also:
• Chapter 6, Security
• Chapter 7, Backup and Recovery
• Chapter 17, Replication

5.1 The MySQL Server

`mysqld` is the MySQL server. The following discussion covers these MySQL server configuration topics:

• Startup options that the server supports. You can specify these options on the command line, through configuration files, or both.

• Server system variables. These variables reflect the current state and values of the startup options, some of which can be modified while the server is running.

• Server status variables. These variables contain counters and statistics about runtime operation.

• How to set the server SQL mode. This setting modifies certain aspects of SQL syntax and semantics, for example for compatibility with code from other database systems, or to control the error handling for particular situations.

• Configuring and using IPv6 support.

• Configuring and using time zone support.

• Server-side help capabilities.

• The server shutdown process. There are performance and reliability considerations depending on the type of table (transactional or nontransactional) and whether you use replication.

**Note**

Not all storage engines are supported by all MySQL server binaries and configurations. To find out how to determine which storage engines your MySQL server installation supports, see Section 13.7.5.17, "SHOW ENGINES Statement".

5.1.1 Configuring the Server

The MySQL server, `mysqld`, has many command options and system variables that can be set at startup to configure its operation. To determine the default command option and system variable values used by the server, execute this command:

```shell
shell> mysqld --verbose --help
```

The command produces a list of all `mysqld` options and configurable system variables. Its output includes the default option and variable values and looks something like this:

<table>
<thead>
<tr>
<th>Option</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow-suspicious-udfs</td>
<td>FALSE</td>
</tr>
<tr>
<td>archive</td>
<td>ON</td>
</tr>
<tr>
<td>auto-increment-increment</td>
<td>1</td>
</tr>
<tr>
<td>auto-increment-offset</td>
<td>1</td>
</tr>
<tr>
<td>autocommit</td>
<td>TRUE</td>
</tr>
<tr>
<td>automatic-sp-privileges</td>
<td>TRUE</td>
</tr>
<tr>
<td>back-log</td>
<td>50</td>
</tr>
</tbody>
</table>
Configuring the Server

To see the current system variable values actually used by the server as it runs, connect to it and execute this statement:

```
mysql> SHOW VARIABLES;
```

To see some statistical and status indicators for a running server, execute this statement:

```
mysql> SHOW STATUS;
```

System variable and status information also is available using the `mysqladmin` command:

```
shell> mysqladmin variables
shell> mysqladmin extended-status
```

For a full description of all command options, system variables, and status variables, see these sections:

- Section 5.1.6, “Server Command Options”
- Section 5.1.7, “Server System Variables”
- Section 5.1.9, “Server Status Variables”

More detailed monitoring information is available from the Performance Schema; see Chapter 22, MySQL Performance Schema.

MySQL uses algorithms that are very scalable, so you can usually run with very little memory. However, normally better performance results from giving MySQL more memory.

When tuning a MySQL server, the two most important variables to configure are `key_buffer_size` and `table_open_cache`. You should first feel confident that you have these set appropriately before trying to change any other variables.

The following examples indicate some typical variable values for different runtime configurations.

- If you have at least 1-2GB of memory and many tables and want maximum performance with a moderate number of clients, use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=384M --table_open_cache=4000
  --sort_buffer_size=4M --read_buffer_size=1M
  &
  ```

- If you have only 256MB of memory and only a few tables, but you still do a lot of sorting, you can use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=64M --sort_buffer_size=1M
  ```

  If there are very many simultaneous connections, swapping problems may occur unless `mysqld` has been configured to use very little memory for each connection. `mysqld` performs better if you have enough memory for all connections.

- With little memory and lots of connections, use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=512K --sort_buffer_size=100K
  ```
Server Configuration Defaults

--read_buffer_size=100K &

Or even this:

```
shell> mysql_safe --key_buffer_size=512K --sort_buffer_size=16K \
    --table_open_cache=32 --read_buffer_size=8K \
    --net_buffer_length=1K &
```

If you are performing GROUP BY or ORDER BY operations on tables that are much larger than your available memory, increase the value of read_rnd_buffer_size to speed up the reading of rows following sorting operations.

You can make use of the example option files included with your MySQL distribution; see Section 5.1.2, “Server Configuration Defaults”.

If you specify an option on the command line for mysql or mysql_safe, it remains in effect only for that invocation of the server. To use the option every time the server runs, put it in an option file. See Section 4.2.2.2, “Using Option Files”.

### 5.1.2 Server Configuration Defaults

The MySQL server has many operating parameters, which you can change at server startup using command-line options or configuration files (option files). It is also possible to change many parameters at runtime. For general instructions on setting parameters at startup or runtime, see Section 5.1.6, “Server Command Options”, and Section 5.1.7, “Server System Variables”.

MySQL provides a number of preconfigured option files that can be used as a basis for tuning the MySQL server. Look for files named my-small.cnf, my-medium.cnf, my-large.cnf, and my-huge.cnf, which are sample option files for small, medium, large, and very large systems. On Windows, the extension is .ini rather than .cnf.

**Note**

On Windows, the .ini or .cnf option file extension might not be displayed.

For a binary distribution, look for the sample files in or under your installation directory. If you have a source distribution, look in the support-files directory. To use a sample file as a base configuration file, rename a copy of it and place the copy in the appropriate location. Regarding names and appropriate location, see the general information provided in Section 4.2.2.2, “Using Option Files”. That section also describes option file format and syntax.

### 5.1.3 Server Option, System Variable, and Status Variable Reference

The following table lists all command-line options, system variables, and status variables applicable within mysql.

The table lists command-line options (Cmd-line), options valid in configuration files (Option file), server system variables (System Var), and status variables (Status var) in one unified list, with an indication of where each option or variable is valid. If a server option set on the command line or in an option file differs from the name of the corresponding system variable, the variable name is noted immediately below the corresponding option. For system and status variables, the scope of the variable (Var Scope) is Global, Session, or both. Please see the corresponding item descriptions for details on setting and using the options and variables. Where appropriate, direct links to further information about the items are provided.

For a version of this table that is specific to NDB Cluster, see Section 18.3.2.5, “NDB Cluster mysql Option and Variable Reference”.

456
## Table 5.1 Command-Line Option, System Variable, and Status Variable Summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dyn</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>abort-slave-event-count</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aborted_clients</strong></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>Aborted_connects</strong></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><code>allow-suspicious-udfs</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>ansi</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>audit-log</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>audit_log_buffer_size</code></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><code>audit_log_file</code></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><code>audit_log_flush</code></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><code>audit_log_format</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>audit_log_policy</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>audit_log_rotate_on_size</code></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><code>audit_log_strategy</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>authentication_windows_log_level</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>authentication_windows_use_principal_name</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>auto_increment_increment</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>auto_increment_offset</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>autocommit</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Varies</td>
<td>Yes</td>
</tr>
<tr>
<td><code>automatic_sp_privileges</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>back_log</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td><code>basedir</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td><code>big_tables</code></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Varies</td>
<td>Yes</td>
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**Notes:**

1. This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

### 5.1.4 Server System Variable Reference

The following table lists all system variables applicable within `mysqld`.

The table lists command-line options (Cmd-line), options valid in configuration files (Option file), server system variables (System Var), and status variables (Status var) in one unified list, with an indication of where each option or variable is valid. If a server option set on the command line or in an option file differs from the name of the corresponding system variable, the variable name is noted immediately below the
corresponding option. The scope of the variable (Var Scope) is Global, Session, or both. Please see the corresponding item descriptions for details on setting and using the variables. Where appropriate, direct links to further information about the items are provided.

Table 5.2 System Variable Summary

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Server Status Variable Reference

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Notes:

1. This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

5.1.5 Server Status Variable Reference

The following table lists all status variables applicable within `mysqld`.

The table lists each variable’s data type and scope. The last column indicates whether the scope for each variable is Global, Session, or both. Please see the corresponding item descriptions for details on setting and using the variables. Where appropriate, direct links to further information about the items are provided.

Table 5.3 Status Variable Summary

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<tr>
<td>Table_locks_waited</td>
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</tr>
</tbody>
</table>
5.1.6 Server Command Options

When you start the `mysqld` server, you can specify program options using any of the methods described in Section 4.2.2, “Specifying Program Options”. The most common methods are to provide options in an option file or on the command line. However, in most cases it is desirable to make sure that the server uses the same options each time it runs. The best way to ensure this is to list them in an option file. See Section 4.2.2.2, “Using Option Files”. That section also describes option file format and syntax.

`mysqld` reads options from the `[mysqld]` and `[server]` groups. `mysqld_safe` reads options from the `[mysqld], [server], [mysqld_safe], and [safe_mysqld] groups. `mysql.server` reads options from the `[mysqld]` and `[mysql.server]` groups.

An embedded MySQL server usually reads options from the `[server], [embedded], and [xxxxx_SERVER]` groups, where `xxxxx` is the name of the application into which the server is embedded.

`mysqld` accepts many command options. For a brief summary, execute this command:

```
mysqld --help
```

To see the full list, use this command:

```
mysqld --verbose --help
```

Some of the items in the list are actually system variables that can be set at server startup. These can be displayed at runtime using the `SHOW VARIABLES` statement. Some items displayed by the preceding `mysqld` command do not appear in `SHOW VARIABLES` output; this is because they are options only and not system variables.

The following list shows some of the most common server options. Additional options are described in other sections:

- Options that affect security: See Section 6.1.4, “Security-Related mysqld Options and Variables”.
- SSL-related options: See Command Options for Encrypted Connections.
- Binary log control options: See Section 5.4.4, “The Binary Log”.
- Replication-related options: See Section 17.1.3, “Replication and Binary Logging Options and Variables”.
- Options for loading plugins such as pluggable storage engines: See Section 5.5.1, “Installing and Uninstalling Plugins”.
- Options specific to particular storage engines: See Section 14.17, “InnoDB Startup Options and System Variables”, Section 15.3.1, “MyISAM Startup Options”, and MySQL Server Options for NDB Cluster.
Some options control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to an option that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to an option for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some options take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is `/var/mysql/data`. If a file-valued option is given as a relative path name, it will be located under `/var/mysql/data`. If the value is an absolute path name, its location is as given by the path name.

You can also set the values of server system variables at server startup by using variable names as options. To assign a value to a server system variable, use an option of the form `--var_name=value`. For example, `--key_buffer_size=32M` sets the `key_buffer_size` variable to a value of 32MB.

When you assign a value to a variable, MySQL might automatically correct the value to stay within a given range, or adjust the value to the closest permissible value if only certain values are permitted.

To restrict the maximum value to which a system variable can be set at runtime with the `SET` statement, specify this maximum by using an option of the form `--maximum-var_name=value` at server startup.

You can change the values of most system variables at runtime with the `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.

Section 5.1.7, “Server System Variables”, provides a full description for all variables, and additional information for setting them at server startup and runtime. For information on changing system variables, see Section 5.1.1, “Configuring the Server”.

- `--help, -?`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--help</code></td>
</tr>
</tbody>
</table>

Display a short help message and exit. Use both the `--verbose` and `--help` options to see the full message.

- `--allow-suspicious-udfs`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--allow-suspicious-udfs[={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This option controls whether user-defined functions that have only an `xxx` symbol for the main function can be loaded. By default, the option is off and only UDFs that have at least one auxiliary symbol can be loaded; this prevents attempts at loading functions from shared object files other than those containing legitimate UDFs. See UDF Security Precautions.

- `--ansi`
Server Command Options

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ansi</td>
</tr>
</tbody>
</table>

Use standard (ANSI) SQL syntax instead of MySQL syntax. For more precise control over the server SQL mode, use the `--sql-mode` option instead. See Section 1.7, "MySQL Standards Compliance", and Section 5.1.10, "Server SQL Modes".

- `--basedir=dir_name, -b dir_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--basedir=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>basedir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
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<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
<tr>
<td>Default Value</td>
<td>configuration-dependent default</td>
</tr>
</tbody>
</table>

The path to the MySQL installation directory. This option sets the `basedir` system variable.

- `--bind-address=addr`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--bind-address=addr</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
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</tr>
</tbody>
</table>

The MySQL server listens on a single network socket for TCP/IP connections. This socket is bound to a single address, but it is possible for an address to map onto multiple network interfaces. The default address is `0.0.0.0`. To specify an address explicitly, use the `--bind-address=addr` option at server startup, where `addr` is an IPv4 or IPv6 address or a host name. If `addr` is a host name, the server resolves the name to an IP address and binds to that address. If a host name resolves to multiple IP addresses, the server uses the first IPv4 address if there are any, or the first IPv6 address otherwise.

The server treats different types of addresses as follows:

- If the address is `0.0.0.0`, the server accepts TCP/IP connections on all server host IPv4 interfaces.

- If the address is `::`, the server accepts TCP/IP connections on all server host IPv4 and IPv6 interfaces. Use this address to permit both IPv4 and IPv6 connections on all server interfaces.

- If the address is an IPv4-mapped address, the server accepts TCP/IP connections for that address, in either IPv4 or IPv6 format. For example, if the server is bound to `::ffff:127.0.0.1`, clients can connect using `--host=127.0.0.1` or `--host=:ffff:127.0.0.1`. 
• If the address is a “regular” IPv4 or IPv6 address (such as 127.0.0.1 or ::1), the server accepts TCP/IP connections only for that IPv4 or IPv6 address.

If binding to the address fails, the server produces an error and does not start.

If you intend to bind the server to a specific address, be sure that the mysql.user system table contains an account with administrative privileges that you can use to connect to that address. Otherwise, you will not be able to shut down the server. For example, if you bind the server to ::, you can connect to it using all existing accounts. But if you bind the server to ::1, it accepts connections only on that address. In that case, first make sure that the 'root'@'::1' account is present in the mysql.user table so you can still connect to the server to shut it down.

• --bootstrap

<table>
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<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--bootstrap</td>
</tr>
</tbody>
</table>

This option is used by the mysql_install_db program to create the MySQL privilege tables without having to start a full MySQL server.

When the server operates in bootstrap mode, some functionality is unavailable that limits the statements permitted in any file named by the init_file system variable. For more information, see the description of that variable.

• --character-set-client-handshake

<table>
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<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
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<td>Type</td>
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</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Do not ignore character set information sent by the client. To ignore client information and use the default server character set, use --skip-character-set-client-handshake; this makes MySQL behave like MySQL 4.0.

• --chroot=dir_name, -r dir_name

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--chroot=dir_name</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

Put the mysqld server in a closed environment during startup by using the chroot() system call. This is a recommended security measure. Use of this option somewhat limits LOAD DATA and SELECT ... INTO OUTFILE.

• --console

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--console</td>
</tr>
</tbody>
</table>
Server Command Options

<table>
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<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
</tbody>
</table>

(Windows only.) Write error log messages to stderr and stdout (the console). mysqld does not close the console window if this option is used.

--log-error takes precedence over --console if both are given.

- **--core-file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--core-file=[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Write a core file if mysqld dies. The name and location of the core file is system dependent. On Linux, a core file named core.pid is written to the current working directory of the process, which for mysqld is the data directory. pid represents the process ID of the server process. On macOS, a core file named core.pid is written to the /cores directory. On Solaris, use the coreadm command to specify where to write the core file and how to name it.

For some systems, to get a core file you must also specify the --core-file-size option to mysqld_safe. See Section 4.3.2, "mysqld_safe — MySQL Server Startup Script". On some systems, such as Solaris, you do not get a core file if you are also using the --user option. There might be additional restrictions or limitations. For example, it might be necessary to execute ulimit -c unlimited before starting the server. Consult your system documentation.

- **--datadir=dir_name, -h dir_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--datadir=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>datadir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The path to the MySQL server data directory. This option sets the datadir system variable. See the description of that variable.

- **--debug[=debug_options], -# [debug_options]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--debug[=debug_options]</td>
</tr>
<tr>
<td>System Variable</td>
<td>debug</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value (Windows)</td>
<td>d:t:i:0,\mysqld.trace</td>
</tr>
</tbody>
</table>
If MySQL is configured with the `-DWITH_DEBUG=1` CMake option, you can use this option to get a trace file of what mysqld is doing. A typical `debug_options` string is `d:t:o, file_name`. The default is `d:t:i:o, /tmp/mysqld.trace` on Unix and `d:t:i:O, \mysqld.trace` on Windows.

Using `-DWITH_DEBUG=1` to configure MySQL with debugging support enables you to use the `--debug="d, parser debug"` option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

This option may be given multiple times. Values that begin with `+` or `-` are added to or subtracted from the previous value. For example, `--debug=T --debug=P` sets the value to `P:T`.

For more information, see Section 24.5.3, “The DBUG Package”.

• `--debug-sync-timeout[=N]`

Controls whether the Debug Sync facility for testing and debugging is enabled. Use of Debug Sync requires that MySQL be configured with the `-DENABLE_DEBUG_SYNC=1` CMake option (see Section 2.9.7, “MySQL Source-Configuration Options”). If Debug Sync is not compiled in, this option is not available. The option value is a timeout in seconds. The default value is 0, which disables Debug Sync. To enable it, specify a value greater than 0; this value also becomes the default timeout for individual synchronization points. If the option is given without a value, the timeout is set to 300 seconds.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

For additional information about this option, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• `--default-time-zone=timezone`

Set the default server time zone. This option sets the global `time_zone` system variable. If this option is not given, the default time zone is the same as the system time zone (given by the value of the `system_time_zone` system variable).

• `--defaults-extra-file=file_name`

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current
directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--defaults-file=file_name**

Read only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. file_name is interpreted relative to the current directory if given as a relative path name rather than a full path name.

```
Note
This must be the first option on the command line if it is used, except that if the server is started with the --defaults-file and --install (or --install-manual) options, --install (or --install-manual) must be first.
```

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--defaults-group-suffix=str**

Read not only the usual option groups, but also groups with the usual names and a suffix of str. For example, mysqld normally reads the [mysqld] group. If the --defaults-group-suffix=_other option is given, mysqld also reads the [mysqld_other] group.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--des-key-file=file_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--des-key-file=file_name</td>
</tr>
</tbody>
</table>

Read the default DES keys from this file. These keys are used by the DES_ENCRYPT() and DES_DECRYPT() functions.

For additional information about this option, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--exit-info[=flags], -T [flags]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--exit-info[=flags]</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

This is a bitmask of different flags that you can use for debugging the mysqld server. Do not use this option unless you know exactly what it does!

- **--external-locking**

```bash
Property       | Value                                      |
----------------|--------------------------------------------|
Command-Line Format | --external-locking[=(OFF|ON)]              |
```
Enable external locking (system locking), which is disabled by default. If you use this option on a system on which `lockd` does not fully work (such as Linux), it is easy for `mysqld` to deadlock.

To disable external locking explicitly, use `--skip-external-locking`.

External locking affects only MyISAM table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.5, “External Locking”.

### --flush

Flush (synchronize) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

#### Note

If `--flush` is specified, the value of `flush_time` does not matter and changes to `flush_time` have no effect on flush behavior.

### --gdb

Install an interrupt handler for `SIGINT` (needed to stop `mysqld` with `^C` to set breakpoints) and disable stack tracing and core file handling. See Section 24.5.1.4, “Debugging mysqld under gdb”.

### --innodb-xxx

Set an option for the InnoDB storage engine. The InnoDB options are listed in Section 14.17, “InnoDB Startup Options and System Variables”.

### --install [service_name]
(Windows only) Install the server as a Windows service that starts automatically during Windows startup. The default service name is MySQL if no `service_name` value is given. For more information, see Section 2.3.6.7, “Starting MySQL as a Windows Service”.

**Note**

If the server is started with the `--defaults-file` and `--install` options, `--install` must be first.

- `--install-manual [service_name]`

(Windows only) Install the server as a Windows service that must be started manually. It does not start automatically during Windows startup. The default service name is MySQL if no `service_name` value is given. For more information, see Section 2.3.6.7, “Starting MySQL as a Windows Service”.

**Note**

If the server is started with the `--defaults-file` and `--install-manual` options, `--install-manual` must be first.

- `--language=lang_name, -L lang_name`

The language to use for error messages. `lang_name` can be given as the language name or as the full path name to the directory where the language files are installed. See Section 10.12, “Setting the Error Message Language”.

As of MySQL 5.5, `--lc-messages-dir` and `--lc-messages` should be used rather than `--language`, which is deprecated and handled as an alias for `--lc-messages-dir`.

- `--large-pages`

```
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--large-pages[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>large_pages</code></td>
</tr>
</tbody>
</table>
```
Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

MySQL supports the Linux implementation of large page support (which is called HugeTLB in Linux). See Section 8.12.4.2, “Enabling Large Page Support”. For Solaris support of large pages, see the description of the `--super-large-pages` option.

`--large-pages` is disabled by default.

- `--lc-messages=locale_name`

The locale to use for error messages. The default is `en_US`. The server converts the argument to a language name and combines it with the value of `--lc-messages-dir` to produce the location for the error message file. See Section 10.12, “Setting the Error Message Language”.

- `--lc-messages-dir=dir_name`

The directory where error messages are located. The server uses the value together with the value of `--lc-messages` to produce the location for the error message file. See Section 10.12, “Setting the Error Message Language”.

```
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Linux</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lc-messages=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lc_messages</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>en_US</code></td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lc-messages-dir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lc_messages_dir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>
```
### Server Command Options

- **--local-service**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--local-service</td>
</tr>
</tbody>
</table>

(Windows only) A **--local-service** option following the service name causes the server to run using the `LocalService` Windows account that has limited system privileges. If both **--defaults-file** and **--local-service** are given following the service name, they can be in any order. See Section 2.3.6.7, “Starting MySQL as a Windows Service”.

- **--log[=file_name], -l [file_name]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log[=file_name]</td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes; use <code>general_log</code> instead</td>
</tr>
<tr>
<td>System Variable</td>
<td>log</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

This option enables logging to the general query log, which contains entries that record client connections and SQL statements received from clients. The log output destination can be selected with the `log_output` system variable. If you omit the file name, MySQL uses `host_name.log` as the file name. See Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”, and Section 5.4.3, “The General Query Log”.

The **--log** option is deprecated and is removed (along with the `log` system variable) in MySQL 5.6. Instead, use the `general_log` system variable to enable the general query log and the `general_log_file` system variable to set the general query log file name.

- **--log-error[=file_name]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-error[=file_name]</td>
</tr>
<tr>
<td>System Variable</td>
<td>log_error</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

Write the error log and startup messages to this file. See Section 5.4.2, “The Error Log”.

If the option names no file, the error log file name on Unix and Unix-like systems is `host_name.err` in the data directory. The file name on Windows is the same, unless the **--pid-file** option is specified. In that case, the file name is the PID file base name with a suffix of `.err` in the data directory.

If the option names a file, the error log file has that name (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.

On Windows, **--log-error** takes precedence over **--console** if both are given.
Server Command Options

- **--log-isam=file_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-isam=file_name</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

Log all *MyISAM* changes to this file (used only when debugging *MyISAM*).

- **--log-long-format**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-long-format</td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Log extra information to the binary log and slow query log, if they have been activated. For example, the user name and timestamp are logged for all queries. This option is deprecated, as it now represents the default logging behavior. (See the description for **--log-short-format**.) The *log_queries_not_using_indexes* system variable can be enabled for the purpose of logging queries that do not use indexes to the slow query log. **--log-long-format** was removed in MySQL 5.5.3.

- **--log-short-format**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-short-format={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Log less information to the slow query log, if it has been activated.

- **--log-slow-admin-statements**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-slow-admin-statements={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Include slow administrative statements in the statements written to the slow query log. Administrative statements include `ALTER TABLE, ANALYZE TABLE, CHECK TABLE, CREATE INDEX, DROP INDEX, OPTIMIZE TABLE, and REPAIR TABLE`.

- **--log-tc=file_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-tc=file_name</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>
### Server Command Options

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>tc.log</td>
</tr>
</tbody>
</table>

The name of the memory-mapped transaction coordinator log file (for XA transactions that affect multiple storage engines when the binary log is disabled). The default name is `tc.log`. The file is created under the data directory if not given as a full path name. This option is unused.

- **--log-tc-size=size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-tc-size=#</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>24576</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The size in bytes of the memory-mapped transaction coordinator log. The default size is 24KB.

- **--log-warnings=[level],-W [level]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--log-warnings=[#]</td>
</tr>
<tr>
<td>System Variable</td>
<td>log_warnings</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Print out warnings such as Aborted connection... to the error log. This option is enabled (1) by default. To disable it, use `--log-warnings=0`. Specifying the option without a `level` value increments the current value by 1. Enabling this option by setting it greater than 0 is recommended, for example, if you use replication (you get more information about what is happening, such as messages about network failures and reconnections). If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.4.2.11, “Communication Errors and Aborted Connections”.

If a slave server was started with `--log-warnings` enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth.
The server logs messages about statements that are unsafe for statement-based logging if `--log-warnings` is greater than 0.

The `--warnings` option was removed in MySQL 5.5.3. It had the same meaning as `--log-warnings`, which should be used instead.

- `--memlock`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--memlock[={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Lock the `mysqld` process in memory. This option might help if you have a problem where the operating system is causing `mysqld` to swap to disk.

`--memlock` works on systems that support the `mlockall()` system call; this includes Solaris, most Linux distributions that use a 2.4 or higher kernel, and perhaps other Unix systems. On Linux systems, you can tell whether or not `mlockall()` (and thus this option) is supported by checking to see whether or not it is defined in the system `mman.h` file, like this:

```
shell> grep mlockall /usr/include/sys/mman.h
```

If `mlockall()` is supported, you should see in the output of the previous command something like the following:

```
extern int mlockall (int __flags) __THROW;
```

⚠️ **Important**

Use of this option may require you to run the server as `root`, which, for reasons of security, is normally not a good idea. See Section 6.1.5, “How to Run MySQL as a Normal User”.

On Linux and perhaps other systems, you can avoid the need to run the server as `root` by changing the `limits.conf` file. See the notes regarding the memlock limit in Section 8.12.4.2, “Enabling Large Page Support”.

You must not try to use this option on a system that does not support the `mlockall()` system call; if you do so, `mysqld` will very likely crash as soon as you try to start it.

- `--myisam-block-size=N`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--myisam-block-size=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>16384</td>
</tr>
</tbody>
</table>

The block size to be used for MyISAM index pages.
• --no-defaults

Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read. This must be the first option on the command line if it is used.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

• --old-style-user-limits

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--old-style-user-limits={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Enable old-style user limits. (Before MySQL 5.0.3, account resource limits were counted separately for each host from which a user connected rather than per account row in the user table.) See Section 6.2.12, “Setting Account Resource Limits”.

• --one-thread

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--one-thread</td>
</tr>
</tbody>
</table>

Only use one thread (for debugging under Linux). This option is available only if the server is built with debugging enabled. See Section 24.5, “Debugging and Porting MySQL”.

This option is deprecated and is removed in MySQL 5.6. Use --thread_handling=no-threads instead.

• --partition=[value]

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--partition={OFF</td>
</tr>
<tr>
<td>Disabled by</td>
<td>skip-partition</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Enables or disables user-defined partitioning support in the MySQL Server.

• --plugin-load=plugin_list

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--plugin-load=plugin_list</td>
</tr>
<tr>
<td>System Variable</td>
<td>plugin_load</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>
This option tells the server to load the named plugins at startup. All plugins to load must be named in the same --plugin-load option. If multiple --plugin-load options are given, only the last one is used.

The option value is a semicolon-separated list of name=plugin_library and plugin_library values. Each name is the name of a plugin to load, and plugin_library is the name of the library file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the plugin_dir system variable.

For example, if plugins named myplug1 and myplug2 have library files myplug1.so and myplug2.so, use this option to perform an early plugin load:

```
shell> mysqld --plugin-load="myplug1=myplug1.so;myplug2=myplug2.so"
```

Quotes are used around the argument value here because otherwise semicolon (;) is interpreted as a special character by some command interpreters. (Unix shells treat it as a command terminator, for example.)

Each named plugin is loaded for a single invocation of mysqld only. After a restart, the plugin is not loaded unless --plugin-load is used again. This is in contrast to INSTALL PLUGIN, which adds an entry to the mysql.plugins table to cause the plugin to be loaded for every normal server startup.

Under normal startup, the server determines which plugins to load by reading the mysql.plugins system table. If the server is started with the --skip-grant-tables option, it does not consult the mysql.plugins table and does not load plugins listed there. --plugin-load enables plugins to be loaded even when --skip-grant-tables is given. --plugin-load also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

- --plugin-xxx

Specifies an option that pertains to a server plugin. For example, many storage engines can be built as plugins, and for such engines, options for them can be specified with a --plugin prefix. Thus, the --innodb-file-per-table option for InnoDB can be specified as --plugin-innodb-file-per-table.

For boolean options that can be enabled or disabled, the --skip prefix and other alternative formats are supported as well (see Section 4.2.2.4, “Program Option Modifiers”). For example, --skip-plugin-innodb-file-per-table disables innodb-file-per-table.

The rationale for the --plugin prefix is that it enables plugin options to be specified unambiguously if there is a name conflict with a built-in server option. For example, were a plugin writer to name a plugin "sql" and implement a "mode" option, the option name might be --sql-mode, which would conflict with the built-in option of the same name. In such cases, references to the conflicting name are resolved in favor of the built-in option. To avoid the ambiguity, users can specify the plugin option as --plugin-sql-mode. Use of the --plugin prefix for plugin options is recommended to avoid any question of ambiguity.
• \texttt{--port=port\_num, -P port\_num}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--port=port_num}</td>
</tr>
<tr>
<td>System Variable</td>
<td>port</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>3306</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

The port number to use when listening for TCP/IP connections. On Unix and Unix-like systems, the port number must be 1024 or higher unless the server is started by the root operating system user. Setting this option to 0 causes the default value to be used.

• \texttt{--port-open-timeout=num}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--port-open-timeout=#}</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

On some systems, when the server is stopped, the TCP/IP port might not become available immediately. If the server is restarted quickly afterward, its attempt to reopen the port can fail. This option indicates how many seconds the server should wait for the TCP/IP port to become free if it cannot be opened. The default is not to wait.

• \texttt{--print-defaults}

Print the program name and all options that it gets from option files. This must be the first option on the command line if it is used, except that it may be used immediately after \texttt{--defaults-file} or \texttt{--defaults-extra-file}.

For additional information about this and other option-file options, see Section 4.2.2.3, "Command-Line Options that Affect Option-File Handling".

• \texttt{--remove [service\_name]}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--remove [service_name]}</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
</tbody>
</table>

(Windows only) Remove a MySQL Windows service. The default service name is MySQL if no service\_name value is given. For more information, see Section 2.3.6.7, "Starting MySQL as a Windows Service".
Server Command Options

• **--safe-mode**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--safe-mode</td>
</tr>
<tr>
<td>Deprecated</td>
<td>5.5.26</td>
</tr>
</tbody>
</table>

Skip some optimization stages. This option is deprecated and is removed in MySQL 5.6.

• **--safe-user-create**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--safe-user-create[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If this option is enabled, a user cannot create new MySQL users by using the `GRANT` statement unless the user has the `INSERT` privilege for the `mysql.user` system table or any column in the table. If you want a user to have the ability to create new users that have those privileges that the user has the right to grant, you should grant the user the following privilege:

```
GRANT INSERT(user) ON mysql.user TO 'user_name'@'host_name';
```

This ensures that the user cannot change any privilege columns directly, but has to use the `GRANT` statement to give privileges to other users.

• **--skip-grant-tables**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-grant-tables[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This option affects the server startup sequence:

• **--skip-grant-tables** causes the server not to read the grant tables in the `mysql` system database, and thus to start without using the privilege system at all. This gives anyone with access to the server *unrestricted access to all databases*.

To cause a server started with **--skip-grant-tables** to load the grant tables at runtime, perform a privilege-flushing operation, which can be done in these ways:

• Issue a MySQL `FLUSH PRIVILEGES` statement after connecting to the server.

• Execute a `mysqladmin flush-privileges` or `mysqladmin reload` command from the command line.

Privilege flushing might also occur implicitly as a result of other actions performed after startup, thus causing the server to start using the grant tables. For example, `mysql_upgrade` flushes the privileges during the upgrade procedure.

• In addition to causing the startup sequence not to load the grant tables, **--skip-grant-tables** causes the server not to load certain other objects stored in the `mysql` system database: plugins that
were installed with the `INSTALL PLUGIN` statement, scheduled events, and user-defined functions (UDFs). To cause plugins to be loaded anyway, use the `--plugin-load` option.

- **--skip-host-cache**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--skip-host-cache</code></td>
</tr>
</tbody>
</table>

Disable use of the internal host cache for faster name-to-IP resolution. With the cache disabled, the server performs a DNS lookup every time a client connects.

For more information about how the host cache works, see Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- **--skip-innodb**

Disable the InnoDB storage engine. In this case, if the default storage engine is InnoDB, the server will not start unless you also change the `default_storage_engine` system variable to set the default to some other available engine.

- **--skip-new**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--skip-new</code></td>
</tr>
</tbody>
</table>

This option disables (what used to be considered) new, possibly unsafe behaviors. It results in these settings: `delay_key_write=OFF, concurrent_insert=NEVER, automatic_sp_privileges=OFF`. It also causes `OPTIMIZE TABLE` to be mapped to `ALTER TABLE` for storage engines for which `OPTIMIZE TABLE` is not supported.

- **--skip-partition**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--skip-partition</code></td>
</tr>
<tr>
<td></td>
<td><code>--disable-partition</code></td>
</tr>
</tbody>
</table>

Disables user-defined partitioning. Partitioned tables can be seen using `SHOW TABLES` or by querying the `INFORMATION_SCHEMA.TABLES` table, but cannot be created or modified, nor can data in such tables be accessed. All partition-specific columns in the `INFORMATION_SCHEMA.PARTITIONS` table display `NULL`.

Since `DROP TABLE` removes table definition (.frm) files, this statement works on partitioned tables even when partitioning is disabled using the option. The statement, however, does not remove .par files associated with partitioned tables in such cases. For this reason, you should avoid dropping partitioned tables with partitioning disabled, or take action to remove the orphaned .par files manually.

- **--skip-show-database**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--skip-show-database</code></td>
</tr>
</tbody>
</table>

System Variable: `skip_show_database`
Scope: Global
This option sets the `skip_show_database` system variable that controls who is permitted to use the `SHOW DATABASES` statement. See Section 5.1.7, “Server System Variables”.

- **--skip-stack-trace**

Do not write stack traces. This option is useful when you are running `mysqld` under a debugger. On some systems, you also must use this option to get a core file. See Section 24.5, “Debugging and Porting MySQL”.

- **--skip-thread-priority**

Disable using thread priorities for faster response time. This option is deprecated and is removed in MySQL 5.6.

- **--slow-start-timeout=timeout**

This option controls the Windows service control manager’s service start timeout. The value is the maximum number of milliseconds that the service control manager waits before trying to kill the windows service during startup. The default value is 15000 (15 seconds). If the MySQL service takes too long to start, you may need to increase this value. A value of 0 means there is no timeout.

- **--socket=path**
### Server Command Options

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Default Value (Windows)</strong></td>
<td>MySQL</td>
</tr>
</tbody>
</table>

On Unix, this option specifies the Unix socket file to use when listening for local connections. The default value is `/tmp/mysql.sock`. If this option is given, the server creates the file in the data directory unless an absolute path name is given to specify a different directory. On Windows, the option specifies the pipe name to use when listening for local connections that use a named pipe. The default value is MySQL (not case-sensitive).

- `--sql-mode=value[,value[,value...]]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--sql-mode=name</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>sql_mode</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global, Session</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Set</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>''</td>
</tr>
<tr>
<td><strong>Valid Values</strong></td>
<td>ALLOW_INVALID_DATES</td>
</tr>
<tr>
<td></td>
<td>ANSI_QUOTES</td>
</tr>
<tr>
<td></td>
<td>ERROR_FOR_DIVISION_BY_ZERO</td>
</tr>
<tr>
<td></td>
<td>HIGH_NOT_PRECEDENCE</td>
</tr>
<tr>
<td></td>
<td>IGNORE_SPACE</td>
</tr>
<tr>
<td></td>
<td>NO_AUTO_CREATE_USER</td>
</tr>
<tr>
<td></td>
<td>NO_AUTO_VALUE_ON_ZERO</td>
</tr>
<tr>
<td></td>
<td>NO_BACKSLASH_ESCAPES</td>
</tr>
<tr>
<td></td>
<td>NO_DIR_IN_CREATE</td>
</tr>
<tr>
<td></td>
<td>NO_ENGINE_SUBSTITUTION</td>
</tr>
<tr>
<td></td>
<td>NO_FIELD_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_KEY_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_TABLE_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_UNSIGNED_SUBTRACTION</td>
</tr>
<tr>
<td></td>
<td>NO_ZERO_DATE</td>
</tr>
<tr>
<td></td>
<td>NO_ZERO_IN_DATE</td>
</tr>
<tr>
<td></td>
<td>ONLY_FULL_GROUP_BY</td>
</tr>
<tr>
<td></td>
<td>PAD_CHAR_TO_FULL_LENGTH</td>
</tr>
</tbody>
</table>
Set the SQL mode. See Section 5.1.10, “Server SQL Modes”.

Note
MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

• --ssl*

Options that begin with --ssl specify whether to permit clients to connect using SSL and indicate where to find SSL keys and certificates. See Command Options for Encrypted Connections.

• --standalone

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--standalone</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
</tbody>
</table>

Available on Windows only; instructs the MySQL server not to run as a service.

• --super-large-pages

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--super-large-pages={OFF</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Solaris</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature is available for recent SPARC platforms. It can be enabled or disabled by using the --super-large-pages or --skip-super-large-pages option.

• --symbolic-links, --skip-symbolic-links

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--symbolic-links={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Enable or disable symbolic link support. This option has different effects on Windows and Unix:
• On Windows, enabling symbolic links enables you to establish a symbolic link to a database directory by creating a `db_name.sym` file that contains the path to the real directory. See Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”.

• On Unix, enabling symbolic links means that you can link a `MyISAM` index file or data file to another directory with the `INDEX DIRECTORY` or `DATA DIRECTORY` option of the `CREATE TABLE` statement. If you delete or rename the table, the files that its symbolic links point to also are deleted or renamed. See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”.

The `--skip-symlink` and `--use-symbolic-links` server options were removed in MySQL 5.5.3. They had the same meanings as `--skip-symbolic-links` and `--symbolic-links`, which should be used instead.

• `--sysdate-is-now`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--sysdate-is-now={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

`SYSDATE()` by default returns the time at which it executes, not the time at which the statement in which it occurs begins executing. This differs from the behavior of `NOW()`.
This option causes `SYSDATE()` to be an alias for `NOW()`. For information about the implications for binary logging and replication, see the description for `SYSDATE()` in Section 12.6, “Date and Time Functions” and for `SET TIMESTAMP` in Section 5.1.7, “Server System Variables”.

• `--tc-heuristic-recover={COMMIT|ROLLBACK}`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--tc-heuristic-recover=name</code></td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>COMMIT</td>
</tr>
<tr>
<td>Valid Values</td>
<td>COMMIT, ROLLBACK</td>
</tr>
</tbody>
</table>

The type of decision to use in the heuristic recovery process. To use this option, two or more storage engines that support XA transactions must be installed.

• `--temp-pool`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--temp-pool={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value (Other)</td>
<td>OFF</td>
</tr>
<tr>
<td>Default Value (Linux)</td>
<td>ON</td>
</tr>
</tbody>
</table>

This option is ignored except on Linux. On Linux, it causes most temporary files created by the server to use a small set of names, rather than a unique name for each new file. This works around a problem in the Linux kernel dealing with creating many new files with different names. With the old behavior, Linux
seems to “leak” memory, because it is being allocated to the directory entry cache rather than to the disk cache.

- \(--transaction-isolation=\text{level}\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--transaction-isolation=name</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>REPEATABLE-READ</td>
</tr>
<tr>
<td>Valid Values</td>
<td>READ-UNCOMMITTED, READ-COMMITTED,</td>
</tr>
<tr>
<td></td>
<td>REPEATABLE-READ, SERIALIZABLE</td>
</tr>
</tbody>
</table>

Sets the default transaction isolation level. The \text{level} value can be \text{READ-UNCOMMITTED}, \text{READ-COMMITTED}, \text{REPEATABLE-READ}, or \text{SERIALIZABLE}. See Section 13.3.6, “SET TRANSACTION Statement”.

The default transaction isolation level can also be set at runtime using the \text{SET TRANSACTION} statement or by setting the \text{tx_isolation} system variable.

- \(--\text{tmpdir}=\text{dir_name}, -t \text{ dir_name}\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--tmpdir=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>tmpdir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The path of the directory to use for creating temporary files. It might be useful if your default /\text{tmp} directory resides on a partition that is too small to hold temporary tables. This option accepts several paths that are used in round-robin fashion. Paths should be separated by colon characters (:) on Unix and semicolon characters (;) on Windows. If the MySQL server is acting as a replication slave, you should not set --\text{tmpdir} to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. For more information about the storage location of temporary files, see Section B.4.3.5, “Where MySQL Stores Temporary Files”. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or \text{LOAD DATA} operations. If files in the temporary file directory are lost when the server restarts, replication fails.

- \(--\text{user}=(\text{user_name}|\text{user_id}), -u (\text{user_name}|\text{user_id})\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--user=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

Run the \text{mysql}d server as the user having the name \text{user_name} or the numeric user ID \text{user_id}. (“User” in this context refers to a system login account, not a MySQL user listed in the grant tables.)
This option is *mandatory* when starting *mysqld* as *root*. The server changes its user ID during its startup sequence, causing it to run as that particular user rather than as *root*. See Section 6.1.1, “Security Guidelines”.

To avoid a possible security hole where a user adds a `--user=root` option to a *my.cnf* file (thus causing the server to run as *root*), *mysqld* uses only the first `--user` option specified and produces a warning if there are multiple `--user` options. Options in `/etc/my.cnf` and `$MYSQL_HOME/my.cnf` are processed before command-line options, so it is recommended that you put a `--user` option in `/etc/my.cnf` and specify a value other than *root*. The option in `/etc/my.cnf` is found before any other `--user` options, which ensures that the server runs as a user other than *root*, and that a warning results if any other `--user` option is found.

- `--verbose, -v`

  Use this option with the `--help` option for detailed help.

- `--version, -V`

  Display version information and exit.

### 5.1.7 Server System Variables

The MySQL server maintains many system variables that configure its operation. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically at runtime using the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. You can also use system variable values in expressions.

At runtime, setting a global system variable value requires the `SUPER` privilege. Setting a session system variable value normally requires no special privileges and can be done by any user, although there are exceptions. For more information, see Section 5.1.8.1, “System Variable Privileges”

There are several ways to see the names and values of system variables:

- To see the values that a server will use based on its compiled-in defaults and any option files that it reads, use this command:

  ```
  mysqld --verbose --help
  ```

- To see the values that a server will use based only on its compiled-in defaults, ignoring the settings in any option files, use this command:

  ```
  mysqld --no-defaults --verbose --help
  ```

- To see the current values used by a running server, use the `SHOW VARIABLES` statement.

This section provides a description of each system variable. For a system variable summary table, see Section 5.1.4, “Server System Variable Reference”. For more information about manipulation of system variables, see Section 5.1.8, “Using System Variables”.

For additional system variable information, see these sections:

- Section 5.1.8, “Using System Variables”, discusses the syntax for setting and displaying system variable values.

- Section 5.1.8.2, “Dynamic System Variables”, lists the variables that can be set at runtime.

- Information on tuning system variables can be found in Section 5.1.1, “Configuring the Server”. 
Server System Variables

- Section 14.17, “InnoDB Startup Options and System Variables”, lists InnoDB system variables.
- NDB Cluster System Variables, lists system variables which are specific to NDB Cluster.
- For information on server system variables specific to replication, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

Note

Some of the following variable descriptions refer to “enabling” or “disabling” a variable. These variables can be enabled with the SET statement by setting them to ON or 1, or disabled by setting them to OFF or 0. However, before MySQL 5.5.10, to set such a variable on the command line or in an option file, you must set it to 1 or 0; setting it to ON or OFF will not work. For example, on the command line, --delay_key_write=1 works but --delay_key_write=ON does not. As of MySQL 5.5.10, boolean variables can be set at startup to the values ON, TRUE, OFF, and FALSE (not case-sensitive). See Section 4.2.2.4, “Program Option Modifiers”.

Some system variables control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to a system variable that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to a variable for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some system variables take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is /var/mysql/data. If a file-valued variable is given as a relative path name, it will be located under /var/mysql/data. If the value is an absolute path name, its location is as given by the path name.

- **authentication_windows_log_level**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--authentication-windows-log-level=#</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td>authentication_windows_log_level</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>2</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4</td>
</tr>
</tbody>
</table>

This variable is available only if the authentication_windows Windows authentication plugin is enabled and debugging code is enabled. See Section 6.4.1.5, “Windows Pluggable Authentication”.

This variable sets the logging level for the Windows authentication plugin. The following table shows the permitted values.
### Server System Variables

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No logging</td>
</tr>
<tr>
<td>1</td>
<td>Log only error messages</td>
</tr>
<tr>
<td>2</td>
<td>Log level 1 messages and warning messages</td>
</tr>
<tr>
<td>3</td>
<td>Log level 2 messages and information notes</td>
</tr>
<tr>
<td>4</td>
<td>Log level 3 messages and debug messages</td>
</tr>
</tbody>
</table>

This variable was added in MySQL 5.5.16.

- **authentication_windows_use_principal_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--authentication-windows-use-principal-name[={OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td>authentication_windows_use_principal_name</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

This variable is available only if the **authentication_windows** Windows authentication plugin is enabled. See Section 6.4.1.5, “Windows Pluggable Authentication”.

A client that authenticates using the `InitSecurityContext()` function should provide a string identifying the service to which it connects (targetName). MySQL uses the principal name (UPN) of the account under which the server is running. The UPN has the form `user_id@computer_name` and need not be registered anywhere to be used. This UPN is sent by the server at the beginning of authentication handshake.

This variable controls whether the server sends the UPN in the initial challenge. By default, the variable is enabled. For security reasons, it can be disabled to avoid sending the server's account name to a client as cleartext. If the variable is disabled, the server always sends a 0x00 byte in the first challenge, the client does not specify `targetName`, and as a result, NTLM authentication is used.

If the server fails to obtain its UPN (which will happen primarily in environments that do not support Kerberos authentication), the UPN is not sent by the server and NTLM authentication is used.

This variable was added in MySQL 5.5.16.

- **autocommit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--autocommit[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>autocommit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The autocommit mode. If set to 1, all changes to a table take effect immediately. If set to 0, you must use COMMIT to accept a transaction or ROLLBACK to cancel it. If autocommit is 0 and you change it to 1, MySQL performs an automatic COMMIT of any open transaction. Another way to begin a transaction is to use a START TRANSACTION or BEGIN statement. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”.

By default, client connections begin with autocommit set to 1. To cause clients to begin with a default of 0, set the global autocommit value by starting the server with the --autocommit=0 option. To set the variable using an option file, include these lines:

```
[mysqld]
autocommit=0
```

The init_connect variable can also be set on the command line or in an option file. To set the variable as just shown using an option file, include these lines:

```
[mysqld]
init_connect='SET autocommit=0'
```

For users that have the SUPER privilege, the content of init_connect is not executed (unlike the effect of setting the global autocommit value at startup).

- automatic_sp_privileges

When this variable has a value of 1 (the default), the server automatically grants the EXECUTE and ALTER ROUTINE privileges to the creator of a stored routine, if the user cannot already execute and alter or drop the routine. (The ALTER ROUTINE privilege is required to drop the routine.) The server also automatically drops those privileges from the creator when the routine is dropped. If automatic_sp_privileges is 0, the server does not automatically add or drop these privileges.

The creator of a routine is the account used to execute the CREATE statement for it. This might not be the same as the account named as the DEFINER in the routine definition.

If you start mysql with --skip-new, automatic_sp_privileges is set to OFF.

See also Section 20.2.2, “Stored Routines and MySQL Privileges”.

---
### back_log

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--back-log=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>back_log</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>50</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

The number of outstanding connection requests MySQL can have. This comes into play when the main MySQL thread gets very many connection requests in a very short time. It then takes some time (although very little) for the main thread to check the connection and start a new thread. The `back_log` value indicates how many requests can be stacked during this short time before MySQL momentarily stops answering new requests. You need to increase this only if you expect a large number of connections in a short period of time.

In other words, this value is the size of the listen queue for incoming TCP/IP connections. Your operating system has its own limit on the size of this queue. The manual page for the Unix `listen()` system call should have more details. Check your OS documentation for the maximum value for this variable. `back_log` cannot be set higher than your operating system limit.

### basedir

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--basedir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>basedir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>configuration-dependent default</code></td>
</tr>
</tbody>
</table>

The path to the MySQL installation base directory.

### big_tables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--big-tables[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>big_tables</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
If enabled, the server stores all temporary tables on disk rather than in memory. This prevents most `The table tbl_name is full` errors for `SELECT` operations that require a large temporary table, but also slows down queries for which in-memory tables would suffice.

The default value for new connection is `OFF` (use in-memory temporary tables). Normally, it should never be necessary to enable this variable because the server is able to handle large result sets automatically by using memory for small temporary tables and switching to disk-based tables as required.

Note

This variable was formerly named `sql_big_tables`.

**bulk_insert_buffer_size**

- **Property**: Command-Line Format
  - **Value**: `--bulk-insert-buffer-size=#`

- **Property**: System Variable
  - **Value**: `bulk_insert_buffer_size`

- **Property**: Scope
  - **Value**: Global, Session

- **Property**: Dynamic
  - **Value**: Yes

- **Property**: Type
  - **Value**: Integer

- **Property**: Default Value
  - **Value**: `8388608`

- **Property**: Minimum Value
  - **Value**: `0`

- **Property**: Maximum Value (64-bit platforms)
  - **Value**: `18446744073709551615`

- **Property**: Maximum Value (32-bit platforms)
  - **Value**: `4294967295`

*MyISAM* uses a special tree-like cache to make bulk inserts faster for `INSERT ... SELECT`, `INSERT ... VALUES (...), (...), ...`, and `LOAD DATA` when adding data to nonempty tables. This variable limits the size of the cache tree in bytes per thread. Setting it to 0 disables this optimization. The default value is 8MB.

- **character_set_client**

- **Property**: System Variable
  - **Value**: `character_set_client`

- **Property**: Scope
  - **Value**: Global, Session

- **Property**: Dynamic
  - **Value**: Yes

- **Property**: Type
  - **Value**: String

- **Property**: Default Value
  - **Value**: `utf8`

The character set for statements that arrive from the client. The session value of this variable is set using the character set requested by the client when the client connects to the server. (Many clients support a `--default-character-set` option to enable this character set to be specified explicitly. See also..."
Section 10.4, “Connection Character Sets and Collations”.) The global value of the variable is used to set the session value in cases when the client-requested value is unknown or not available, or the server is configured to ignore client requests:

- The client requests a character set not known to the server. For example, a Japanese-enabled client requests sjis when connecting to a server not configured with sjis support.
- The client is from a version of MySQL older than MySQL 4.1, and thus does not request a character set.
- mysqld was started with the --skip-character-set-client-handshake option, which causes it to ignore client character set configuration. This reproduces MySQL 4.0 behavior and is useful should you wish to upgrade the server without upgrading all the clients.

Some character sets cannot be used as the client character set. Attempting to use them as the character_set_client value produces an error. See Impermissible Client Character Sets.

- \textbf{character_set_connection}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>character_set_connection</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>utf8</td>
</tr>
</tbody>
</table>

The character set used for literals specified without a character set introducer and for number-to-string conversion. For information about introducers, see Section 10.3.8, “Character Set Introducers”.

- \textbf{character_set_database}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>character_set_database</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>latin1</td>
</tr>
</tbody>
</table>

Footnote: This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

The character set used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as character_set_server.

- \textbf{character_set_filesystem}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--character-set-filesystem=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>character_set_filesystem</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
</tbody>
</table>
### character_set_filesystem

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>binary</td>
</tr>
</tbody>
</table>

The file system character set. This variable is used to interpret string literals that refer to file names, such as in the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. Such file names are converted from `character_set_client` to `character_set_filesystem` before the file opening attempt occurs. The default value is `binary`, which means that no conversion occurs. For systems on which multibyte file names are permitted, a different value may be more appropriate. For example, if the system represents file names using UTF-8, set `character_set_filesystem` to `'utf8mb4'`.

- **character_set_results**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>character_set_results</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>utf8</code></td>
</tr>
</tbody>
</table>

The character set used for returning query results to the client. This includes result data such as column values, result metadata such as column names, and error messages.

- **character_set_server**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--character-set-server=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>character_set_server</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>latin1</code></td>
</tr>
</tbody>
</table>

The server's default character set. See Section 10.15, “Character Set Configuration”. If you set this variable, you should also set `collation_server` to specify the collation for the character set.

- **character_set_system**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>character_set_system</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

535
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>utf8</td>
</tr>
</tbody>
</table>

The character set used by the server for storing identifiers. The value is always **utf8**.

- **character_sets_dir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--character-sets-dir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>character_sets_dir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The directory where character sets are installed. See Section 10.15, “Character Set Configuration”.

- **collation_connection**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>collation_connection</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The collation of the connection character set. **collation_connection** is important for comparisons of literal strings. For comparisons of strings with column values, **collation_connection** does not matter because columns have their own collation, which has a higher collation precedence (see Section 10.8.4, “Collation Coercibility in Expressions”).

- **collation_database**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>collation_database</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>latin1_swedish_ci</code></td>
</tr>
<tr>
<td>Footnote</td>
<td>This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.</td>
</tr>
</tbody>
</table>

The collation used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as **collation_server**.

- **collation_server**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--collation-server=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>collation_server</code></td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>latin1_swedish_ci</td>
</tr>
</tbody>
</table>

The server's default collation. See [Section 10.15, “Character Set Configuration”](#).

- **completion_type**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--completion-type=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>completion_type</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>NO_CHAIN</td>
</tr>
</tbody>
</table>
| Valid Values         | NO_CHAIN
|                      | CHAIN                                        |
|                      | RELEASE                                      |
|                      | 0                                            |
|                      | 1                                            |
|                      | 2                                            |

The transaction completion type. This variable can take the values shown in the following table.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO_CHAIN (or 0)</td>
<td>COMMIT and ROLLBACK are unaffected. This is the default value.</td>
</tr>
<tr>
<td>CHAIN (or 1)</td>
<td>COMMIT and ROLLBACK are equivalent to COMMIT AND CHAIN and ROLLBACK AND CHAIN, respectively. (A new transaction starts immediately with the same isolation level as the just-terminated transaction.)</td>
</tr>
<tr>
<td>RELEASE (or 2)</td>
<td>COMMIT and ROLLBACK are equivalent to COMMIT RELEASE and ROLLBACK RELEASE, respectively. (The server disconnects after terminating the transaction.)</td>
</tr>
</tbody>
</table>

**completion_type** affects transactions that begin with START TRANSACTION or BEGIN and end with COMMIT or ROLLBACK. It does not apply to implicit commits resulting from execution of the statements listed in [Section 13.3.3, “Statements That Cause an Implicit Commit”](#). It also does not apply for XA COMMIT, XA ROLLBACK, or when autocommit=1.
Server System Variables

- **concurrent_insert**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--concurrent-insert[=value]</td>
</tr>
<tr>
<td>System Variable</td>
<td>concurrent_insert</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>AUTO</td>
</tr>
</tbody>
</table>

Valid Values

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEVER (or 0)</td>
<td>Disables concurrent inserts</td>
</tr>
<tr>
<td>AUTO (or 1)</td>
<td>(Default) Enables concurrent insert for MyISAM tables that do not have holes</td>
</tr>
<tr>
<td>ALWAYS (or 2)</td>
<td>Enables concurrent inserts for all MyISAM tables, even those that have holes. For a table with a hole, new rows are inserted at the end of the table if it is in use by another thread. Otherwise, MySQL acquires a normal write lock and inserts the row into the hole.</td>
</tr>
</tbody>
</table>

If **AUTO** (the default), MySQL permits INSERT and SELECT statements to run concurrently for MyISAM tables that have no free blocks in the middle of the data file.

This variable can take the values shown in the following table.

If you start mysqld with **--skip-new**, concurrent_insert is set to **NEVER**.

See also Section 8.11.3, "Concurrent Inserts".

- **connect_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--connect-timeout=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>connect_timeout</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
</tbody>
</table>
## Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Value</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>31536000</td>
</tr>
</tbody>
</table>

The number of seconds that the `mysqld` server waits for a connect packet before responding with **Bad handshake**. The default value is 10 seconds.

Increasing the `connect_timeout` value might help if clients frequently encounter errors of the form **Lost connection to MySQL server at 'XXX', system error: errno.**

- **datadir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--datadir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>datadir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The path to the MySQL server data directory. Relative paths are resolved with respect to the current directory. If the server will be started automatically (that is, in contexts for which you cannot assume what the current directory will be), it is best to specify the `datadir` value as an absolute path.

- **date_format**

  This variable is unused.

- **datetime_format**

  This variable is unused.

- **debug**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--debug[=debug_options]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>debug</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value (Windows)</td>
<td><code>d:t:i:O,\mysqld.trace</code></td>
</tr>
</tbody>
</table>
This variable indicates the current debugging settings. It is available only for servers built with debugging support. The initial value comes from the value of instances of the `--debug` option given at server startup. The global and session values may be set at runtime.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

Assigning a value that begins with `+` or `−` cause the value to added to or subtracted from the current value:

```
mysql> SET debug = 'T';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+
mysql> SET debug = '+P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| P:T     |
+---------+
mysql> SET debug = '-P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+
```

For more information, see Section 24.5.3, “The DBUG Package”.

- `debug_sync`

This variable is the user interface to the Debug Sync facility. Use of Debug Sync requires that MySQL be configured with the `--DENABLE_DEBUG_SYNC=1` CMake option (see Section 2.9.7, “MySQL Source-Configuration Options”). If Debug Sync is not compiled in, this system variable is not available.

The global variable value is read only and indicates whether the facility is enabled. By default, Debug Sync is disabled and the value of `debug_sync` is `OFF`. If the server is started with `--debug-sync-timeout=N`, where `N` is a timeout value greater than 0, Debug Sync is enabled and the value of
**debug_sync** is **ON – current signal** followed by the signal name. Also, \( N \) becomes the default timeout for individual synchronization points.

The session value can be read by any user and will have the same value as the global variable. The session value can be set to control synchronization points.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- **default_storage_engine**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--default-storage-engine=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>default_storage_engine</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>InnoDB</td>
</tr>
</tbody>
</table>

The default storage engine for tables. See Chapter 15, Alternative Storage Engines.

To see which storage engines are available and enabled, use the **SHOW ENGINES** statement or query the **INFORMATION_SCHEMA.ENGINES** table.

If you disable the default storage engine at server startup, you must set the default engine to a different engine or the server will not start.

This variable is to be used in preference to **storage_engine**, which is now deprecated.

- **default_week_format**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--default-week-format=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>default_week_format</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>7</td>
</tr>
</tbody>
</table>

The default mode value to use for the **WEEK()** function. See Section 12.6, “Date and Time Functions”.

- **delay_key_write**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--delay-key-write=[OFF</td>
</tr>
</tbody>
</table>
This variable specifies how to use delayed key writes. It applies only to MyISAM tables. Delayed key writing causes key buffers not to be flushed between writes. See also Section 15.3.1, “MyISAM Startup Options”.

This variable can have one of the following values to affect handling of the DELAY_KEY_WRITE table option that can be used in CREATE TABLE statements.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>DELAY_KEY_WRITE is ignored.</td>
</tr>
<tr>
<td>ON</td>
<td>MySQL honors any DELAY_KEY_WRITE option specified in CREATE TABLE statements. This is the default value.</td>
</tr>
<tr>
<td>ALL</td>
<td>All new opened tables are treated as if they were created with the DELAY_KEY_WRITE option enabled.</td>
</tr>
</tbody>
</table>

Note

If you set this variable to ALL, you should not use MyISAM tables from within another program (such as another MySQL server or myisamchk) when the tables are in use. Doing so leads to index corruption.

If DELAY_KEY_WRITE is enabled for a table, the key buffer is not flushed for the table on every index update, but only when the table is closed. This speeds up writes on keys a lot, but if you use this feature, you should add automatic checking of all MyISAM tables by starting the server with the myisam_recover_options system variable set (for example, myisam_recover_options='BACKUP,FORCE'). See Section 5.1.7, “Server System Variables”, and Section 15.3.1, “MyISAM Startup Options”.

If you start mysqld with --skip-new, delay_key_write is set to OFF.

Warning

If you enable external locking with --external-locking, there is no protection against index corruption for tables that use delayed key writes.

• delayed_insert_limit
After inserting `delayed_insert_limit` delayed rows, the `INSERT DELAYED` handler thread checks whether there are any `SELECT` statements pending. If so, it permits them to execute before continuing to insert delayed rows.

* `delayed_insert_timeout`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--delayed-insert-timeout=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>delayed_insert_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>300</td>
</tr>
</tbody>
</table>

How many seconds an `INSERT DELAYED` handler thread should wait for `INSERT` statements before terminating.

* `delayed_queue_size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--delayed-queue-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>delayed_queue_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This is a per-table limit on the number of rows to queue when handling `INSERT DELAYED` statements. If the queue becomes full, any client that issues an `INSERT DELAYED` statement waits until there is room in the queue again.
• **div_precision_increment**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--div-precision-increment=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>div_precision_increment</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>30</td>
</tr>
</tbody>
</table>

This variable indicates the number of digits by which to increase the scale of the result of division operations performed with the `/` operator. The default value is 4. The minimum and maximum values are 0 and 30, respectively. The following example illustrates the effect of increasing the default value.

```sql
mysql> SELECT 1/7;
+--------+
| 1/7    |
+--------+
| 0.1429 |
+--------+
mysql> SET div_precision_increment = 12;
mysql> SELECT 1/7;
+----------------+
| 1/7            |
+----------------+
| 0.142857142857 |
+----------------+
```

• **engine_condition_pushdown**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--engine-condition-pushdown[={OFF</td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes; use optimizer_switch instead</td>
</tr>
<tr>
<td>System Variable</td>
<td>engine_condition_pushdown</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

The engine condition pushdown optimization enables processing for certain comparisons to be “pushed down” to the storage engine level for more efficient execution. For more information, see Section 8.2.1.4, “Engine Condition Pushdown Optimization”.

Engine condition pushdown is used only by the `NDBCLUSTER` storage engine. Enabling this optimization on a MySQL Server acting as an NDB Cluster SQL node causes `WHERE` conditions on unindexed columns to be evaluated on the cluster’s data nodes and only the rows that match to be sent back to the server.
SQL node that issued the query. This greatly reduces the amount of cluster data that must be sent over the network, increasing the efficiency with which results are returned.

The `engine_condition_pushdown` variable controls whether engine condition pushdown is enabled. By default, this variable is `ON` (1). Setting it to `OFF` (0) disables pushdown.

This variable is deprecated in MySQL 5.5 and is removed in MySQL 5.6. Use the `engine_condition_pushdown` flag of the `optimizer_switch` variable instead. See Section 8.9.2, “Switchable Optimizations”.

• **error_count**

The number of errors that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.18, “SHOW ERRORS Statement”.

• **event_scheduler**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--event-scheduler[=value]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>event_scheduler</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>OFF</code></td>
</tr>
<tr>
<td>Valid Values</td>
<td><code>ON</code>, <code>OFF</code>, <code>DISABLED</code></td>
</tr>
</tbody>
</table>

This variable enables or disables, and starts or stops, the Event Scheduler. The possible status values are `ON`, `OFF`, and `DISABLED`, with the default being `OFF`. Turning the Event Scheduler `OFF` is not the same as disabling the Event Scheduler, which requires setting the status to `DISABLED`. This variable and its effects on the Event Scheduler's operation are discussed in greater detail in Section 20.4.2, “Event Scheduler Configuration”.

• **expire_logs_days**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--expire-logs-days=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>expire_logs_days</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>
**Property** | **Value**
---|---
Maximum Value | 99

The number of days for automatic binary log file removal. The default is 0, which means “no automatic removal.” Possible removals happen at startup and when the binary log is flushed. Log flushing occurs as indicated in Section 5.4, “MySQL Server Logs”.

To remove binary log files manually, use the `PURGE BINARY LOGS` statement. See Section 13.4.1.1, “PURGE BINARY LOGS Statement”.

- **external_user**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>external_user</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The external user name used during the authentication process, as set by the plugin used to authenticate the client. With native (built-in) MySQL authentication, or if the plugin does not set the value, this variable is `NULL`. See Section 6.2.11, “Proxy Users”.

- **flush**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--flush={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>flush</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>OFF</code></td>
</tr>
</tbody>
</table>

If `ON`, the server flushes (synchronizes) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”. This variable is set to `ON` if you start `mysqld` with the `--flush` option.

**Note**

If `flush` is enabled, the value of `flush_time` does not matter and changes to `flush_time` have no effect on flush behavior.

- **flush_time**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--flush-time=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>flush_time</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value (Other)</td>
<td>0</td>
</tr>
<tr>
<td>Default Value (Windows)</td>
<td>1800</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>

If this is set to a nonzero value, all tables are closed every `flush_time` seconds to free up resources and synchronize unflushed data to disk. This option is best used only on systems with minimal resources.

**Note**

If `flush` is enabled, the value of `flush_time` does not matter and changes to `flush_time` have no effect on flush behavior.

- `foreign_key_checks`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>foreign_key_checks</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If set to 1 (the default), foreign key constraints for InnoDB tables are checked. If set to 0, foreign key constraints are ignored, with a couple of exceptions. When re-creating a table that was dropped, an error is returned if the table definition does not conform to the foreign key constraints referencing the table. Likewise, an `ALTER TABLE` operation returns an error if a foreign key definition is incorrectly formed. For more information, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

Disabling foreign key checking can be useful for reloading InnoDB tables in an order different from that required by their parent/child relationships. See Section 13.1.17.6, “FOREIGN KEY Constraints”.

Setting `foreign_key_checks` to 0 also affects data definition statements: `DROP_SCHEMA` drops a schema even if it contains tables that have foreign keys that are referred to by tables outside the schema, and `DROP TABLE` drops tables that have foreign keys that are referred to by other tables.

**Note**

Setting `foreign_key_checks` to 1 does not trigger a scan of the existing table data. Therefore, rows added to the table while `foreign_key_checks=0` will not be verified for consistency.

**Warning**

With `foreign_key_checks=0`, dropping an index required by a foreign key constraint places the table in an inconsistent state and causes the foreign key check that occurs at table load to fail. To avoid this problem, remove the foreign key constraint before dropping the index (Bug #70260).
The list of operators supported by boolean full-text searches performed using `IN BOOLEAN MODE`. See Section 12.9.2, "Boolean Full-Text Searches".

The default variable value is `'+ -><()~*:"&|'`. The rules for changing the value are as follows:

- Operator function is determined by position within the string.
- The replacement value must be 14 characters.
- Each character must be an ASCII nonalphanumeric character.
- Either the first or second character must be a space.
- No duplicates are permitted except the phrase quoting operators in positions 11 and 12. These two characters are not required to be the same, but they are the only two that may be.
- Positions 10, 13, and 14 (which by default are set to :, &, and |) are reserved for future extensions.

### ft_max_word_len

The maximum length of the word to be included in a `FULLTEXT` index.

**Note**

`FULLTEXT` indexes must be rebuilt after changing this variable. Use `REPAIR TABLE tbl_name QUICK`.

### ft_min_word_len

The maximum length of the word to be included in a `FULLTEXT` index.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ft-min-word-len=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ft_min_word_len</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>10</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

The minimum length of the word to be included in a FULLTEXT index.

**Note**

FULLTEXT indexes must be rebuilt after changing this variable. Use `REPAIR TABLE tbl_name QUICK`.

- `ft_query_expansion_limit`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ft-query-expansion-limit=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ft_query_expansion_limit</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>20</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The number of top matches to use for full-text searches performed using `WITH QUERY EXPANSION`.

- `ft_stopword_file`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ft-stopword-file=file_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ft_stopword_file</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The file from which to read the list of stopwords for full-text searches. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. All the words from the file are used; comments are not honored. By default, a built-in list of stopwords is used (as defined in the `storage/myisam/ft_static.c` file). Setting this variable to the empty string (`''`) disables stopword filtering. See also Section 12.9.4, “Full-Text Stopwords”.

**Note**

FULLTEXT indexes must be rebuilt after changing this variable or the contents of the stopword file. Use `REPAIR TABLE tbl_name QUICK`.
Server System Variables

- **general_log**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--general-log=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>general_log</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether the general query log is enabled. The value can be 0 (or OFF) to disable the log or 1 (or ON) to enable the log. The destination for log output is controlled by the log_output system variable; if that value is NONE, no log entries are written even if the log is enabled.

- **general_log_file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--general-log-file=file_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>general_log_file</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td>host_name.log</td>
</tr>
</tbody>
</table>

The name of the general query log file. The default value is host_name.log, but the initial value can be changed with the --general_log_file option.

- **group_concat_max_len**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--group-concat-max-len=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>group_concat_max_len</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The maximum permitted result length in bytes for the GROUP_CONCAT() function. The default is 1024.
• **have_compress**

  **YES** if the *zlib* compression library is available to the server, **NO** if not. If not, the *COMPRESS()* and *UNCOMPRESS()* functions cannot be used.

• **have_crypt**

  **YES** if the *crypt()* system call is available to the server, **NO** if not. If not, the *ENCRYPT()* function cannot be used.

• **have_csv**

  **YES** if *mysqld* supports *CSV* tables, **NO** if not.

  This variable is deprecated and is removed in MySQL 5.6. Use *SHOW ENGINES* instead.

• **have_dynamic_loading**

  **YES** if *mysqld* supports dynamic loading of plugins, **NO** if not. If the value is **NO**, you cannot use options such as *--plugin-load* to load plugins at server startup, or the *INSTALL PLUGIN* statement to load plugins at runtime.

• **have_geometry**

  **YES** if the server supports spatial data types, **NO** if not.

• **have_innodb**

  **YES** if *mysqld* supports InnoDB tables. **DISABLED** if *--skip-innodb* is used.

  This variable is deprecated and is removed in MySQL 5.6. Use *SHOW ENGINES* instead.

• **have_openssl**

  This variable is an alias for **have_ssl**.

• **have_partitioning**

  **YES** if *mysqld* supports partitioning.

  This variable is deprecated and is removed in MySQL 5.6. Use *SHOW PLUGINS* instead. For more information, see Chapter 19, *Partitioning*.

• **have_profiling**

  **YES** if statement profiling capability is present, **NO** if not. If present, the *profiling* system variable controls whether this capability is enabled or disabled. See Section 13.7.5.32, “SHOW PROFILES Statement”.

• **have_query_cache**

  **YES** if *mysqld* supports the query cache, **NO** if not.

• **have_rtree_keys**

  **YES** if RTREE indexes are available, **NO** if not. (These are used for spatial indexes in *MyISAM* tables.)
Server System Variables

- **have_ssl**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>have_ssl</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
| Valid Values (>= 5.5.56) | YES (SSL support available)  
DISABLED (SSL support was compiled into the server, but the server was not started with the necessary options to enable it) |
| Valid Values (<= 5.5.55) | YES (SSL support available)  
NO (No SSL support was compiled into the server)  
DISABLED (SSL support was compiled into the server, but the server was not started with the necessary options to enable it) |

*YES* if *mysqld* supports SSL connections, *NO* if not. *DISABLED* indicates that the server was compiled with SSL support, but was not started with the appropriate *--ssl-xxx* options. For more information, see Section 2.9.6, “Configuring SSL Library Support”. As of MySQL 5.5.56, MySQL must be compiled with SSL support, so *NO* is not a permitted value.

- **have_symlink**

  *YES* if symbolic link support is enabled, *NO* if not. This is required on Unix for support of the DATA DIRECTORY and INDEX DIRECTORY table options, and on Windows for support of data directory symlinks. If the server is started with the *--skip-symbolic-links* option, the value is *DISABLED*.

- **hostname**

  The server sets this variable to the server host name at startup.

- **identity**

  This variable is a synonym for the *last_insert_id* variable. It exists for compatibility with other database systems. You can read its value with `SELECT @identity`, and set it using `SET identity`.

- **init_connect**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--init-connect=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>init_connect</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
A string to be executed by the server for each client that connects. The string consists of one or more SQL statements, separated by semicolon characters.

For users that have the SUPER privilege, the content of `init_connect` is not executed. This is done so that an erroneous value for `init_connect` does not prevent all clients from connecting. For example, the value might contain a statement that has a syntax error, thus causing client connections to fail. Not executing `init_connect` for users that have the SUPER privilege enables them to open a connection and fix the `init_connect` value.

The server discards any result sets produced by statements in the value of `init_connect`.

- `init_file`

If specified, this variable names a file containing SQL statements to be read and executed during the startup process. Each statement must be on a single line and should not include comments.

If the server is started with the `--bootstrap` option, it operates in bootstrap mode and some functionality is unavailable that limits the statements permitted in the file. These include statements that relate to account management (such as `CREATE USER` or `GRANT`).

- `innodb_xxx`

  InnoDB system variables are listed in Section 14.17, “InnoDB Startup Options and System Variables”. These variables control many aspects of storage, memory use, and I/O patterns for InnoDB tables, and are especially important now that InnoDB is the default storage engine.

- `insert_id`

  The value to be used by the following `INSERT` or `ALTER TABLE` statement when inserting an `AUTO_INCREMENT` value. This is mainly used with the binary log.

- `interactive_timeout`

  The value to be used by the following `INSERT` or `ALTER TABLE` statement when inserting an `AUTO_INCREMENT` value. This is mainly used with the binary log.
Server System Variables

### Default Value

- **Value**: 28800

- **Minimum Value**: 1

The number of seconds the server waits for activity on an interactive connection before closing it. An interactive client is defined as a client that uses the `CLIENT_INTERACTIVE` option to `mysql_real_connect()`. See also `wait_timeout`.

- **join_buffer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--join-buffer-size=\#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>join_buffer_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>131072</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>128</td>
</tr>
<tr>
<td>Maximum Value (Other, 64-bit platforms)</td>
<td>18446744073709547520</td>
</tr>
<tr>
<td>Maximum Value (Other, 32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Maximum Value (Windows)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The minimum size of the buffer that is used for plain index scans, range index scans, and joins that do not use indexes and thus perform full table scans. Normally, the best way to get fast joins is to add indexes. Increase the value of `join_buffer_size` to get a faster full join when adding indexes is not possible. One join buffer is allocated for each full join between two tables. For a complex join between several tables for which indexes are not used, multiple join buffers might be necessary.

There is no gain from setting the buffer larger than required to hold each matching row, and all joins allocate at least the minimum size, so use caution in setting this variable to a large value globally. It is better to keep the global setting small and change to a larger setting only in sessions that are doing large joins. Memory allocation time can cause substantial performance drops if the global size is larger than needed by most queries that use it.

The maximum permissible setting for `join_buffer_size` is 4GB–1. Larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB–1 with a warning).

For additional information about join buffering, see Section 8.2.1.5, "Nested-Loop Join Algorithms".

- **keep_files_on_create**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--keep-files-on-create=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>keep_files_on_create</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>

For additional information about `keep_files_on_create`, see Section 8.2.1.5, "Nested-Loop Join Algorithms".
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If a `MyISAM` table is created with no `DATA DIRECTORY` option, the `.MYD` file is created in the database directory. By default, if `MyISAM` finds an existing `.MYD` file in this case, it overwrites it. The same applies to `.MYI` files for tables created with no `INDEX DIRECTORY` option. To suppress this behavior, set the `keep_files_on_create` variable to `ON` (1), in which case `MyISAM` will not overwrite existing files and returns an error instead. The default value is `OFF` (0).

If a `MyISAM` table is created with a `DATA DIRECTORY` or `INDEX DIRECTORY` option and an existing `.MYD` or `.MYI` file is found, `MyISAM` always returns an error. It will not overwrite a file in the specified directory.

- **key_buffer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--key-buffer-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>key_buffer_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8388608</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>8</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td><code>OS_PER_PROCESS_LIMIT</code></td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Index blocks for `MyISAM` tables are buffered and are shared by all threads. `key_buffer_size` is the size of the buffer used for index blocks. The key buffer is also known as the key cache.

The maximum permissible setting for `key_buffer_size` is 4GB−1 on 32-bit platforms. Larger values are permitted for 64-bit platforms. The effective maximum size might be less, depending on your available physical RAM and per-process RAM limits imposed by your operating system or hardware platform. The value of this variable indicates the amount of memory requested. Internally, the server allocates as much memory as possible up to this amount, but the actual allocation might be less.

You can increase the value to get better index handling for all reads and multiple writes: on a system whose primary function is to run MySQL using the `MyISAM` storage engine, 25% of the machine’s total memory is an acceptable value for this variable. However, you should be aware that, if you make the value too large (for example, more than 50% of the machine’s total memory), your system might start to page and become extremely slow. This is because MySQL relies on the operating system to perform file system caching for data reads, so you must leave some room for the file system cache. You should
also consider the memory requirements of any other storage engines that you may be using in addition to MyISAM.

For even more speed when writing many rows at the same time, use LOCK TABLES. See Section 8.2.4.1, “Optimizing INSERT Statements”.

You can check the performance of the key buffer by issuing a SHOW STATUS statement and examining the Key_read_requests, Key_reads, Key_write_requests, and Key_writes status variables. (See Section 13.7.5, “SHOW Statements”.) The Key_reads/Key_read_requests ratio should normally be less than 0.01. The Key_writes/Key_write_requests ratio is usually near 1 if you are using mostly updates and deletes, but might be much smaller if you tend to do updates that affect many rows at the same time or if you are using the DELAY_KEY_WRITE table option.

The fraction of the key buffer in use can be determined using key_buffer_size in conjunction with the Key_blocks_unused status variable and the buffer block size, which is available from the key_cache_block_size system variable:

\[ 1 - (\text{Key_blocks_unused} \times \text{key_cache_block_size}) / \text{key_buffer_size} \]

This value is an approximation because some space in the key buffer is allocated internally for administrative structures. Factors that influence the amount of overhead for these structures include block size and pointer size. As block size increases, the percentage of the key buffer lost to overhead tends to decrease. Larger blocks results in a smaller number of read operations (because more keys are obtained per read), but conversely an increase in reads of keys that are not examined (if not all keys in a block are relevant to a query).

It is possible to create multiple MyISAM key caches. The size limit of 4GB applies to each cache individually, not as a group. See Section 8.10.2, “The MyISAM Key Cache”.

• key_cache_age_threshold

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--key-cache-age-threshold=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>key_cache_age_threshold</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>300</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>100</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This value controls the demotion of buffers from the hot sublist of a key cache to the warm sublist. Lower values cause demotion to happen more quickly. The minimum value is 100. The default value is 300. See Section 8.10.2, “The MyISAM Key Cache”.

556
• **key_cache_block_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--key-cache-block-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>key_cache_block_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>512</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>16384</td>
</tr>
</tbody>
</table>

The size in bytes of blocks in the key cache. The default value is 1024. See Section 8.10.2, “The MyISAM Key Cache”.

• **key_cache_division_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--key-cache-division-limit=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>key_cache_division_limit</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>100</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100</td>
</tr>
</tbody>
</table>

The division point between the hot and warm sublists of the key cache buffer list. The value is the percentage of the buffer list to use for the warm sublist. Permissible values range from 1 to 100. The default value is 100. See Section 8.10.2, “The MyISAM Key Cache”.

• **language**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--language=name</code></td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes; use <code>lc-messages-dir</code> instead</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>language</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>/usr/local/mysql/share/mysql/english/</td>
</tr>
</tbody>
</table>

The directory where error messages are located. See [Section 10.12, “Setting the Error Message Language”](#).

The `language` system variable is removed as of MySQL 5.5.0 (although the `--language` command-line option can still be used). Similar information is available from the `lc_messages_dir` and `lc_messages` variables.

- **large_files_support**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>large_files_support</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>

Whether `mysqld` was compiled with options for large file support.

- **large_pages**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--large-pages[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>large_pages</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Linux</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether large page support is enabled (via the `--large-pages` option). See [Section 8.12.4.2, “Enabling Large Page Support”](#).

- **large_page_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>large_page_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

If large page support is enabled, this shows the size of memory pages. Large memory pages are supported only on Linux; on other platforms, the value of this variable is always 0. See [Section 8.12.4.2, “Enabling Large Page Support”](#).
Server System Variables

- **last_insert_id**
  The value to be returned from `LAST_INSERT_ID()`. This is stored in the binary log when you use `LAST_INSERT_ID()` in a statement that updates a table. Setting this variable does not update the value returned by the `mysql_insert_id()` C API function.

- **lc_messages**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lc-messages=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lc_messages</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>en_US</code></td>
</tr>
</tbody>
</table>

  The locale to use for error messages. The default is `en_US`. The server converts the argument to a language name and combines it with the value of `lc_messages_dir` to produce the location for the error message file. See Section 10.12, “Setting the Error Message Language”.

- **lc_messages_dir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lc-messages-dir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lc_messages_dir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

  The directory where error messages are located. The server uses the value together with the value of `lc_messages` to produce the location for the error message file. See Section 10.12, “Setting the Error Message Language”.

- **lc_time_names**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lc-time-names=value</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lc_time_names</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

  This variable specifies the locale that controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()` and `MONTHNAME()` functions. Locale names are POSIX-style values such as `'ja_JP'` or `'pt_BR'`. The default value is `'en_US'` regardless of your system's locale setting. For further information, see Section 10.16, “MySQL Server Locale Support”.

- **license**
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>license</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>GPL</td>
</tr>
</tbody>
</table>

The type of license the server has.

- **local_infile**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--local-infile=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>local_infile</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

This variable controls server-side `LOCAL` capability for `LOAD DATA` statements. Depending on the `local_infile` setting, the server refuses or permits local data loading by clients that have `LOCAL` enabled on the client side.

To explicitly cause the server to refuse or permit `LOAD DATA LOCAL` statements (regardless of how client programs and libraries are configured at build time or runtime), start `mysqld` with `local_infile` disabled or enabled, respectively. `local_infile` can also be set at runtime. For more information, see Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

- **lock_wait_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lock-wait-timeout=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lock_wait_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>31536000</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>31536000</td>
</tr>
</tbody>
</table>

This variable specifies the timeout in seconds for attempts to acquire metadata locks. The permissible values range from 1 to 31536000 (1 year). The default is 31536000.

This timeout applies to all statements that use metadata locks. These include DML and DDL operations on tables, views, stored procedures, and stored functions, as well as `LOCK TABLES`, `FLUSH TABLES WITH READ LOCK`, and `HANDLER` statements.

This timeout does not apply to implicit accesses to system tables in the `mysql` database, such as grant tables modified by `GRANT` or `REVOKE` statements or table logging statements. The timeout does apply to system tables accessed directly, such as with `SELECT` or `UPDATE`.

The timeout value applies separately for each metadata lock attempt. A given statement can require more than one lock, so it is possible for the statement to block for longer than the `lock_wait_timeout` value before reporting a timeout error. When lock timeout occurs, `ER_LOCK_WAIT_TIMEOUT` is reported.

`lock_wait_timeout` does not apply to delayed inserts, which always execute with a timeout of 1 year. This is done to avoid unnecessary timeouts because a session that issues a delayed insert receives no notification of delayed insert timeouts.

- **locked_in_memory**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>locked_in_memory</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>

Whether `mysqld` was locked in memory with `--memlock`.

- **log**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log[=file_name]</code></td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes; use <code>general_log</code> instead</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

Whether logging of all statements to the general query log is enabled. See Section 5.4.3, “The General Query Log”.

This variable is deprecated and is removed in MySQL 5.6. Use `general_log` instead.

- **log_error**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log-error[=file_name]</code></td>
</tr>
</tbody>
</table>
The name of the error log file, or empty if the server is writing error messages to the console rather than to a named file. See Section 5.4.2, “The Error Log”.

- **log_output**

The destination or destinations for general query log and slow query log output. The value is a list one or more comma-separated words chosen from TABLE, FILE, and NONE. TABLE selects logging to the general_log and slow_log tables in the mysql system database. FILE selects logging to log files. NONE disables logging. If NONE is present in the value, it takes precedence over any other words that are present. TABLE and FILE can both be given to select both log output destinations.

This variable selects log output destinations, but does not enable log output. To do that, enable the general_log and slow_query_log system variables. For FILE logging, the general_log_file and slow_query_log_file system variables determine the log file locations. For more information, see Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”.

- **log_queries_not_using_indexes**

If you enable this variable with the slow query log enabled, queries that are expected to retrieve all rows are logged. See Section 5.4.5, “The Slow Query Log”. This option does not necessarily mean that
no index is used. For example, a query that uses a full index scan uses an index but would be logged because the index would not limit the number of rows.

- **log_slow_queries**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--log_slow_queries=[OFF</td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes; use <code>slow_query_log</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log_slow_queries</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

Whether slow queries should be written to the slow query log, which contains entries for all queries that have taken more than `long_query_time` seconds to execute. See the descriptions of the `--log-long-format` and `--log-short-format` options for details. The log output destination can be selected with the `log_output` system variable. If the log file name is not defined, MySQL uses `host_name-slow.log` as the file name. See Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”, and Section 5.4.5, “The Slow Query Log”.

This variable is deprecated and is removed in MySQL 5.6. Instead, use the `slow_query_log` system variable to enable the slow query log and the `slow_query_log_file` system variable to set the slow query log file name.

- **log_warnings**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log-warnings=[#]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log_warnings</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td><code>18446744073709551615</code></td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td><code>4294967295</code></td>
</tr>
</tbody>
</table>

Whether to produce additional warning messages to the error log. This variable is enabled by default with a value of 1. To disable it, set it to 0. If the value is greater than 0, the server logs messages about statements that are unsafe for statement-based logging. If the value is greater than 1, the server logs aborted connections and access-denied errors for new connection attempts. See Section B.4.2.11, “Communication Errors and Aborted Connections”. 
• long_query_time

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--long-query-time=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>long_query_time</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>

If a query takes longer than this many seconds, the server increments the `Slow_queries` status variable. If the slow query log is enabled, the query is logged to the slow query log file. This value is measured in real time, not CPU time, so a query that is under the threshold on a lightly loaded system might be above the threshold on a heavily loaded one. The minimum and default values of `long_query_time` are 0 and 10, respectively. The value can be specified to a resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored. See Section 5.4.5, “The Slow Query Log”.

• low_priority_updates

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--low-priority-updates[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>low_priority_updates</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If set to 1, all `INSERT`, `UPDATE`, `DELETE`, and `LOCK TABLE WRITE` statements wait until there is no pending `SELECT` or `LOCK TABLE READ` on the affected table. The same effect can be obtained using `(INSERT | REPLACE | DELETE | UPDATE) LOW_PRIORITY ...` to lower the priority of only one query. This variable affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`). See Section 8.11.2, “Table Locking Issues”. This variable previously was named `sql_low_priority_updates`.

• lower_case_file_system

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>lower_case_file_system</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

This variable describes the case sensitivity of file names on the file system where the data directory is located. `OFF` means file names are case-sensitive, `ON` means they are not case-sensitive. This variable
is read only because it reflects a file system attribute and setting it would have no effect on the file system.

- `lower_case_table_names`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lower-case-table-names [=#]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>lower_case_table_names</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>2</td>
</tr>
</tbody>
</table>

If set to 0, table names are stored as specified and comparisons are case-sensitive. If set to 1, table names are stored in lowercase on disk and comparisons are not case-sensitive. If set to 2, table names are stored as given but compared in lowercase. This option also applies to database names and table aliases. For additional information, see Section 9.2.3, “Identifier Case Sensitivity”.

On Windows the default value is 1. On macOS, the default value is 2. On Linux, a value of 2 is not supported; the server forces the value to 0 instead.

You should **not** set `lower_case_table_names` to 0 if you are running MySQL on a system where the data directory resides on a case-insensitive file system (such as on Windows or macOS). It is an unsupported combination that could result in a hang condition when running an `INSERT INTO ... SELECT ... FROM tbl_name` operation with the wrong `tbl_name` lettercase. With MyISAM, accessing table names using different lettercases could cause index corruption.

As of MySQL 5.5.46, an error message is printed and the server exits if you attempt to start the server with `--lower_case_table_names=0` on a case-insensitive file system.

If you are using InnoDB tables, you should set this variable to 1 on all platforms to force names to be converted to lowercase.

The setting of this variable has no effect on replication filtering options. This is a known issue which is fixed in MySQL 5.6. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”, for more information.

You should not use different settings for `lower_case_table_names` on replication masters and slaves. In particular, you should not do this when the slave uses a case-sensitive file system, as this can cause replication to fail. This is a known issue which is fixed in MySQL 5.6. For more information, see Section 17.4.1.37, “Replication and Variables”.

- `max_allowed_packet`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-allowed-packet=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_allowed_packet</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
</tbody>
</table>
The maximum size of one packet or any generated/intermediate string.

The packet message buffer is initialized to net_buffer_length bytes, but can grow up to max_allowed_packet bytes when needed. This value by default is small, to catch large (possibly incorrect) packets.

You must increase this value if you are using large BLOB columns or long strings. It should be as big as the largest BLOB you want to use. The protocol limit for max_allowed_packet is 1GB. The value should be a multiple of 1024; nonmultiples are rounded down to the nearest multiple.

When you change the message buffer size by changing the value of the max_allowed_packet variable, you should also change the buffer size on the client side if your client program permits it. The default max_allowed_packet value built in to the client library is 1GB, but individual client programs might override this. For example, mysql and mysqldump have defaults of 16MB and 24MB, respectively. They also enable you to change the client-side value by setting max_allowed_packet on the command line or in an option file.

The session value of this variable is read only. The client can receive up to as many bytes as the session value. However, the server will not send to the client more bytes than the current global max_allowed_packet value. (The global value could be less than the session value if the global value is changed after the client connects.)

- max_connect_errors

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--max-connect-errors=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>max_connect_errors</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

After max_connect_errors successive connection requests from a host are interrupted without a successful connection, the server blocks that host from further connections. If a connection from a host is established successfully within fewer than max_connect_errors attempts after a previous connection was interrupted, the error count for the host is cleared to zero. However, once a host is
blocked, flushing the host cache is the only way to unblock it. To flush the host cache, execute a `FLUSH HOSTS` statement or `mysqladmin flush-hosts` command.

For more information about how the host cache works, see Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- **max_connections**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-connections=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_connections</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>151</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100000</td>
</tr>
</tbody>
</table>

The maximum permitted number of simultaneous client connections. For more information, see Section 8.12.5.1, “How MySQL Handles Client Connections”.

- **max_delayed_threads**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-delayed-threads=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_delayed_threads</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>20</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>16384</td>
</tr>
</tbody>
</table>

Do not start more than this number of threads to handle `INSERT DELAYED` statements. If you try to insert data into a new table after all `INSERT DELAYED` threads are in use, the row is inserted as if the `DELAYED` attribute was not specified. If you set this to 0, MySQL never creates a thread to handle `DELAYED` rows; in effect, this disables `DELAYED` entirely.

For the `SESSION` value of this variable, the only valid values are 0 or the `GLOBAL` value.

- **max_error_count**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-error-count=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_error_count</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>

For the `SESSION` value of this variable, the only valid values are 0 or the `GLOBAL` value.
The maximum number of error, warning, and information messages to be stored for display by the `SHOW ERRORS` and `SHOW WARNINGS` statements.

- **max_heap_table_size**

  This variable sets the maximum size to which user-created `MEMORY` tables are permitted to grow. The value of the variable is used to calculate `MEMORY` table `MAX_ROWS` values. Setting this variable has no effect on any existing `MEMORY` table, unless the table is re-created with a statement such as `CREATE TABLE` or altered with `ALTER TABLE` or `TRUNCATE TABLE`. A server restart also sets the maximum size of existing `MEMORY` tables to the global `max_heap_table_size` value.

  This variable is also used in conjunction with `tmp_table_size` to limit the size of internal in-memory tables. See Section 8.4.4, “Internal Temporary Table Use in MySQL”.

  `max_heap_table_size` is not replicated. See Section 17.4.1.20, “Replication and MEMORY Tables”, and Section 17.4.1.37, “Replication and Variables”, for more information.

- **max_insert_delayed_threads**

  This variable is a synonym for `max_delayed_threads`. 
• **max_join_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-join-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_join_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>

Do not permit statements that probably need to examine more than `max_join_size` rows (for single-table statements) or row combinations (for multiple-table statements) or that are likely to do more than `max_join_size` disk seeks. By setting this value, you can catch statements where keys are not used properly and that would probably take a long time. Set it if your users tend to perform joins that lack a `WHERE` clause, that take a long time, or that return millions of rows. For more information, see Using Safe-Updates Mode (`--safe-updates`).

Setting this variable to a value other than DEFAULT resets the value of `sql_big_selects` to 0. If you set the `sql_big_selects` value again, the `max_join_size` variable is ignored.

If a query result is in the query cache, no result size check is performed, because the result has previously been computed and it does not burden the server to send it to the client.

This variable previously was named `sql_max_join_size`.

• **max_length_for_sort_data**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-length-for-sort-data=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_length_for_sort_data</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>8388608</td>
</tr>
</tbody>
</table>

The cutoff on the size of index values that determines which `filesort` algorithm to use. See Section 8.2.1.10, “ORDER BY Optimization”.

• **max_long_data_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-long-data-size=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.11</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deprecated</td>
<td>5.5.11</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_long_data_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1048576</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The maximum size of parameter values that can be sent with the `mysql_stmt_send_long_data()` C API function. If not set at server startup, the default is the value of the `max_allowed_packet` system variable. This variable is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

- **`max_prepared_stmt_count`**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-prepared-stmt-count=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_prepared_stmt_count</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>16382</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1048576</td>
</tr>
</tbody>
</table>

This variable limits the total number of prepared statements in the server. (The sum of the number of prepared statements across all sessions.) It can be used in environments where there is the potential for denial-of-service attacks based on running the server out of memory by preparing huge numbers of statements. If the value is set lower than the current number of prepared statements, existing statements are not affected and can be used, but no new statements can be prepared until the current number drops below the limit. Setting the value to 0 disables prepared statements.

- **`max_relay_log_size`**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-relay-log-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_relay_log_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1073741824</td>
</tr>
</tbody>
</table>
If a write by a replication slave to its relay log causes the current log file size to exceed the value of this variable, the slave rotates the relay logs (closes the current file and opens the next one). If \texttt{max_relay_log_size} is 0, the server uses \texttt{max_binlog_size} for both the binary log and the relay log. If \texttt{max_relay_log_size} is greater than 0, it constrains the size of the relay log, which enables you to have different sizes for the two logs. You must set \texttt{max_relay_log_size} to between 4096 bytes and 1GB (inclusive), or to 0. The default value is 0. See Section 17.2.1, “Replication Implementation Details”.

\begin{itemize}
\item \textbf{max\_seeks\_for\_key}
\end{itemize}

\begin{tabular}{|l|l|}
\hline
Property & Value \\
\hline
Command-Line Format & \texttt{--max-seeks-for-key=#} \\
System Variable & \texttt{max_seeks_for_key} \\
Scope & Global, Session \\
Dynamic & Yes \\
Type & Integer \\
Default Value (64-bit platforms) & \texttt{18446744073709551615} \\
Default Value (32-bit platforms) & \texttt{4294967295} \\
Minimum Value & 1 \\
Maximum Value (64-bit platforms) & \texttt{18446744073709551615} \\
Maximum Value (32-bit platforms) & \texttt{4294967295} \\
\hline
\end{tabular}

Limit the assumed maximum number of seeks when looking up rows based on a key. The MySQL optimizer assumes that no more than this number of key seeks are required when searching for matching rows in a table by scanning an index, regardless of the actual cardinality of the index (see Section 13.7.5.23, “SHOW INDEX Statement”). By setting this to a low value (say, 100), you can force MySQL to prefer indexes instead of table scans.

\begin{itemize}
\item \textbf{max\_sort\_length}
\end{itemize}

\begin{tabular}{|l|l|}
\hline
Property & Value \\
\hline
Command-Line Format & \texttt{--max-sort-length=#} \\
System Variable & \texttt{max_sort_length} \\
Scope & Global, Session \\
Dynamic & Yes \\
Type & Integer \\
Default Value & \texttt{1024} \\
Minimum Value & \texttt{4} \\
Maximum Value & \texttt{8388608} \\
\hline
\end{tabular}

The number of bytes to use when sorting data values. The server uses only the first \texttt{max_sort_length} bytes of each value and ignores the rest. Consequently, values that differ only after the first \texttt{max_sort_length} bytes compare as equal for \texttt{GROUP BY}, \texttt{ORDER BY}, and \texttt{DISTINCT} operations.
Increasing the value of `max_sort_length` may require increasing the value of `sort_buffer_size` as well. For details, see Section 8.2.1.10, "ORDER BY Optimization"

- **max_sp_recursion_depth**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-sp-recursion-depth[#]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_sp_recursion_depth</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>255</td>
</tr>
</tbody>
</table>

  The number of times that any given stored procedure may be called recursively. The default value for this option is 0, which completely disables recursion in stored procedures. The maximum value is 255.

  Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup.

- **max_tmp_tables**

  This variable is unused.

- **max_user_connections**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-user-connections=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_user_connections</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

  The maximum number of simultaneous connections permitted to any given MySQL user account. A value of 0 (the default) means “no limit.”

  This variable has a global value that can be set at server startup or runtime. It also has a read-only session value that indicates the effective simultaneous-connection limit that applies to the account associated with the current session. The session value is initialized as follows:

  - If the user account has a nonzero `MAX_USER_CONNECTIONS` resource limit, the session `max_user_connections` value is set to that limit.
• Otherwise, the session `max_user_connections` value is set to the global value.

Account resource limits are specified using the `GRANT` statement. See Section 6.2.12, “Setting Account Resource Limits”, and Section 13.7.1.3, “GRANT Statement”.

• `max_write_lock_count`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-write-lock-count=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_write_lock_count</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Default Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

After this many write locks, permit some pending read lock requests to be processed in between. Write lock requests have higher priority than read lock requests. However, if `max_write_lock_count` is set to some low value (say, 10), read lock requests may be preferred over pending write lock requests if the read lock requests have already been passed over in favor of 10 write lock requests. Normally this behavior does not occur because `max_write_lock_count` by default has a very large value.

• `metadata_locks_cache_size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--metadata-locks-cache-size=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.19</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>metadata_locks_cache_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1048576</td>
</tr>
</tbody>
</table>

The size of the metadata locks cache. The server uses this cache to avoid creation and destruction of synchronization objects. This is particularly helpful on systems where such operations are expensive, such as Windows XP. This variable was added in MySQL 5.5.19.

• `min_examined_row_limit`
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--min-examined-row-limit=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>min_examined_row_limit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Queries that examine fewer than this number of rows are not logged to the slow query log.

- **multi_range_count**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--multi-range-count=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>multi_range_count</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>256</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The maximum number of ranges to send to a table handler at once during range selects. The default value is 256. Sending multiple ranges to a handler at once can improve the performance of certain selects dramatically. This is especially true for the **NDBCLUSTER** table handler, which needs to send the range requests to all nodes. Sending a batch of those requests at once reduces communication costs significantly.

This variable is deprecated in MySQL 5.1, and is no longer supported in MySQL 5.5, in which arbitrarily long lists of ranges can be processed.

- **myisam_data_pointer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--myisam-data-pointer-size=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>myisam_data_pointer_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>6</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>7</td>
</tr>
</tbody>
</table>

The default pointer size in bytes, to be used by `CREATE TABLE` for MyISAM tables when no `MAX_ROWS` option is specified. This variable cannot be less than 2 or larger than 7. The default value is 6. See Section B.4.2.12, "The table is full".

- **myisam_max_sort_file_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--myisam-max-sort-file-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>myisam_max_sort_file_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value (64-bit platforms)</td>
<td>9223372036854775807</td>
</tr>
<tr>
<td>Default Value (32-bit platforms)</td>
<td>2147483648</td>
</tr>
</tbody>
</table>

The maximum size of the temporary file that MySQL is permitted to use while re-creating a MyISAM index (during `REPAIR TABLE`, `ALTER TABLE`, or `LOAD DATA`). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

If MyISAM index files exceed this size and disk space is available, increasing the value may help performance. The space must be available in the file system containing the directory where the original index file is located.

- **myisam_mmap_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--myisam-mmap-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>myisam_mmap_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Default Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>7</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The maximum amount of memory to use for memory mapping compressed MyISAM files. If many compressed MyISAM tables are used, the value can be decreased to reduce the likelihood of memory-swapping problems.

- `myisam_recover_options`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--myisam-recover-options[=list]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>myisam_recover_options</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
<tr>
<td>Valid Values</td>
<td>OFF, DEFAULT, BACKUP, FORCE, QUICK</td>
</tr>
</tbody>
</table>

Set the MyISAM storage engine recovery mode. The variable value is any combination of the values OFF, DEFAULT, BACKUP, FORCE, or QUICK. If you specify multiple values, separate them by commas. Specifying the variable with no value at server startup is the same as specifying DEFAULT, and specifying with an explicit value of "" disables recovery (same as a value of OFF). If recovery is enabled, each time mysqld opens a MyISAM table, it checks whether the table is marked as crashed or was not closed properly. (The last option works only if you are running with external locking disabled.) If this is the case, mysqld runs a check on the table. If the table was corrupted, mysqld attempts to repair it.

The following options affect how the repair works.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>No recovery.</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>Recovery without backup, forcing, or quick checking.</td>
</tr>
<tr>
<td>BACKUP</td>
<td>If the data file was changed during recovery, save a backup of the tbl_name.MYD file as tbl_name-datetime.BAK.</td>
</tr>
<tr>
<td>FORCE</td>
<td>Run recovery even if we would lose more than one row from the .MYD file.</td>
</tr>
<tr>
<td>QUICK</td>
<td>Do not check the rows in the table if there are not any delete blocks.</td>
</tr>
</tbody>
</table>

Before the server automatically repairs a table, it writes a note about the repair to the error log. If you want to be able to recover from most problems without user intervention, you should use the options BACKUP, FORCE. This forces a repair of a table even if some rows would be deleted, but it keeps the old data file as a backup so that you can later examine what happened.
Server System Variables

See Section 15.3.1, “MyISAM Startup Options”.

- **myisam_repair_threads**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--myisam-repair-threads=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>myisam_repair_threads</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value (64-bit</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>platforms)</td>
<td>Maximum Value (32-bit platforms)</td>
</tr>
<tr>
<td>Maximum Value (Other, 64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (Other, 32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If this value is greater than 1, MyISAM table indexes are created in parallel (each index in its own thread) during the Repair by sorting process. The default value is 1.

**Note**

Multithreaded repair is still beta-quality code.

- **myisam_sort_buffer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--myisam-sort-buffer-size=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>myisam_sort_buffer_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8388608</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value (Other, 64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (Other, 32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Maximum Value (Windows, 64-bit platforms, &gt;= 5.5.22)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (Windows, 64-bit platforms, &lt;= 5.5.21)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value (Windows, 32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The size of the buffer that is allocated when sorting MyISAM indexes during a REPAIR TABLE or when creating indexes with CREATE INDEX or ALTER TABLE.

The maximum permissible setting for myisam_sort_buffer_size is 4GB−1. Larger values are permitted for 64-bit platforms (except 64-bit Windows prior to MySQL 5.5.22, for which large values are truncated to 4GB−1 with a warning).

- **myisam_stats_method**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--myisam-stats-method=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>myisam_stats_method</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>nulls_unequal</td>
</tr>
<tr>
<td>Valid Values</td>
<td>nulls_equal</td>
</tr>
<tr>
<td></td>
<td>nulls_unequal</td>
</tr>
<tr>
<td></td>
<td>nulls_ignored</td>
</tr>
</tbody>
</table>

How the server treats NULL values when collecting statistics about the distribution of index values for MyISAM tables. This variable has three possible values, nulls_equal, nulls_unequal, and nulls_ignored. For nulls_equal, all NULL index values are considered equal and form a single value group that has a size equal to the number of NULL values. For nulls_unequal, NULL values are considered unequal, and each NULL forms a distinct value group of size 1. For nulls_ignored, NULL values are ignored.

The method that is used for generating table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

- **myisam_use_mmap**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--myisam-use-mmap=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>myisam_use_mmap</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Use memory mapping for reading and writing MyISAM tables.
Server System Variables

- **named_pipe**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--named-pipe=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>named_pipe</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

(Windows only.) Indicates whether the server supports connections over named pipes.

- **net_buffer_length**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--net-buffer-length=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>net_buffer_length</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>16384</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1048576</td>
</tr>
</tbody>
</table>

Each client thread is associated with a connection buffer and result buffer. Both begin with a size given by `net_buffer_length` but are dynamically enlarged up to `max_allowed_packet` bytes as needed. The result buffer shrinks to `net_buffer_length` after each SQL statement.

This variable should not normally be changed, but if you have very little memory, you can set it to the expected length of statements sent by clients. If statements exceed this length, the connection buffer is automatically enlarged. The maximum value to which `net_buffer_length` can be set is 1MB.

The session value of this variable is read only.

- **net_read_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--net-read-timeout=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>net_read_timeout</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of seconds to wait for more data from a connection before aborting the read. When the server is reading from the client, `net_read_timeout` is the timeout value controlling when to abort. When the server is writing to the client, `net_write_timeout` is the timeout value controlling when to abort. See also `slave_net_timeout`.

- **net_retry_count**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--net-retry-count=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>net_retry_count</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If a read or write on a communication port is interrupted, retry this many times before giving up. This value should be set quite high on FreeBSD because internal interrupts are sent to all threads.

- **net_write_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--net-write-timeout=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>net_write_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>60</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of seconds to wait for a block to be written to a connection before aborting the write. See also `net_read_timeout`.

- **new**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--new=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>new</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Disabled by</td>
<td>skip-new</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable was used in MySQL 4.0 to turn on some 4.1 behaviors, and is retained for backward compatibility. Its value is always OFF.

In NDB Cluster, setting this variable to ON makes it possible to employ partitioning types other than KEY or LINEAR KEY with NDB tables. *This feature is experimental only, and not supported in production.* For additional information, see User-defined partitioning and the NDB storage engine (NDB Cluster).

- **old**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--old=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>old</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

`old` is a compatibility variable. It is disabled by default, but can be enabled at startup to revert the server to behaviors present in older versions.

When `old` is enabled, it changes the default scope of index hints to that used prior to MySQL 5.1.17. That is, index hints with no FOR clause apply only to how indexes are used for row retrieval and not to resolution of ORDER BY or GROUP BY clauses. (See Section 8.9.3, “Index Hints".) Take care about enabling this in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

- **old_alter_table**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--old-alter-table=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>old_alter_table</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When this variable is enabled, the server does not use the optimized method of processing an ALTER TABLE operation. It reverts to using a temporary table, copying over the data, and then renaming the temporary table to the original, as used by MySQL 5.0 and earlier. For more information on the operation of ALTER TABLE, see Section 13.1.7, “ALTER TABLE Statement".
• **old_passwords**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--old-passwords=value</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>old_passwords</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

This variable controls the password hashing method used by the `PASSWORD()` function. It also influences password hashing performed by `CREATE USER` and `GRANT` statements that specify a password using an `IDENTIFIED BY` clause.

The following table shows, for each password hashing method, the permitted value of `old_passwords` and which authentication plugins use the hashing method.

<table>
<thead>
<tr>
<th>Password Hashing Method</th>
<th>old_passwords Value</th>
<th>Associated Authentication Plugin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MySQL 4.1 native hashing</td>
<td>0 or OFF</td>
<td><code>mysql_native_password</code></td>
</tr>
<tr>
<td>Pre-4.1 (&quot;old&quot;) hashing</td>
<td>1 or ON</td>
<td><code>mysql_old_password</code></td>
</tr>
</tbody>
</table>

If `old_passwords=1`, `PASSWORD(str)` returns the same value as `OLD_PASSWORD(str)`. The latter function is not affected by the value of `old_passwords`.

For additional information about authentication plugins and hashing formats, see Section 6.2.10, "Pluggable Authentication", and Section 6.1.2.4, "Password Hashing in MySQL".

**Note**

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

• **one_shot**

This is not a variable, but it can be used when setting some variables. It is described in Section 13.7.4.1, "SET Syntax for Variable Assignment".

• **open_files_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--open-files-limit=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>open_files_limit</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>platform dependent</td>
</tr>
</tbody>
</table>
The number of file descriptors available to `mysqld` from the operating system. `mysqld` reserves descriptors with `setrlimit()`, using the value requested at startup by setting this variable directly or by using the `--open-files-limit` option to `mysqld_safe`. If `mysqld` produces the error `Too many open files`, try increasing the `open_files_limit` value. Internally, the maximum value for this variable is the maximum unsigned integer value, but the actual maximum is platform dependent.

The value of `open_files_limit` at runtime indicates the number of file descriptors actually permitted to `mysqld` by the operating system, which might differ from the value requested at startup. If the number of file descriptors requested during startup cannot be allocated, `mysqld` writes a warning to the error log.

`mysqld` may attempt to allocate more than the requested number of descriptors (if they are available), using the values of `max_connections` and `table_open_cache` to estimate whether more descriptors will be needed.

The effective value is 0 on systems where MySQL cannot change the number of open files.

On Unix, the value cannot be set greater than `ulimit -n`.

- **optimizer_prune_level**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--optimizer-prune-level=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>optimizer_prune_level</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

Controls the heuristics applied during query optimization to prune less-promising partial plans from the optimizer search space. A value of 0 disables heuristics so that the optimizer performs an exhaustive search. A value of 1 causes the optimizer to prune plans based on the number of rows retrieved by intermediate plans.

- **optimizer_search_depth**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--optimizer-search-depth=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>optimizer_search_depth</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>62</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>
The maximum depth of search performed by the query optimizer. Values larger than the number of relations in a query result in better query plans, but take longer to generate an execution plan for a query. Values smaller than the number of relations in a query return an execution plan quicker, but the resulting plan may be far from being optimal. If set to 0, the system automatically picks a reasonable value. If set to 63, the optimizer switches to the algorithm used in MySQL 5.0.0 (and previous versions) for performing searches. The value of 63 is deprecated and will be treated as invalid in a future MySQL release.

- **optimizer_switch**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>63</td>
</tr>
</tbody>
</table>

The optimizer_switch system variable enables control over optimizer behavior. The value of this variable is a set of flags, each of which has a value of on or off to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                   index_merge_sort_union=on,
                   index_merge_intersection=on,
                   engine_condition_pushdown=on
```

For more information about the syntax of this variable and the optimizer behaviors that it controls, see Section 8.9.2, “Switchable Optimizations”.

- **performance_schema_xxx**

Performance Schema System variables are listed in Section 22.12, “Performance Schema System Variables”. These variables may be used to configure Performance Schema operation.
• **pid_file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--pid-file=file_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>pid_file</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The path name of the file in which the server writes its process ID. The server creates the file in the data directory unless an absolute path name is given to specify a different directory. This file is used by other programs such as `mysqld_safe` to determine the server's process ID. On Windows, this variable also affects the default error log file name. See Section 5.4.2, “The Error Log”

• **plugin_dir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--plugin-dir=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>plugin_dir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
<tr>
<td>Default Value</td>
<td>BASEDIR/lib/plugin</td>
</tr>
</tbody>
</table>

The path name of the plugin directory.

If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `secure_file_priv` to a directory where `SELECT` writes can be made safely.

• **port**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--port=port_num</td>
</tr>
<tr>
<td>System Variable</td>
<td>port</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>3306</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

The number of the port on which the server listens for TCP/IP connections. This variable can be set with the `--port` option.
• **preload_buffer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--preload-buffer-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>preload_buffer_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32768</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1073741824</td>
</tr>
</tbody>
</table>

The size of the buffer that is allocated when preloading indexes.

• **profiling**

If set to 0 or `OFF` (the default), statement profiling is disabled. If set to 1 or `ON`, statement profiling is enabled and the `SHOW PROFILE` and `SHOW PROFILES` statements provide access to profiling information. See Section 13.7.5.32, “SHOW PROFILES Statement”.

• **profiling_history_size**

The number of statements for which to maintain profiling information if `profiling` is enabled. The default value is 15. The maximum value is 100. Setting the value to 0 effectively disables profiling. See Section 13.7.5.32, “SHOW PROFILES Statement”.

• **protocol_version**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>protocol_version</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

The version of the client/server protocol used by the MySQL server.

• **proxy_user**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>proxy_user</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

If the current client is a proxy for another user, this variable is the proxy user account name. Otherwise, this variable is `NULL`. See Section 6.2.11, “Proxy Users”.
### Server System Variables

- **pseudo_slave_mode**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduced</td>
<td>5.5.30</td>
</tr>
<tr>
<td>System Variable</td>
<td>pseudo_slave_mode</td>
</tr>
<tr>
<td>Scope</td>
<td>Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

This variable is for internal server use. It was added in MySQL 5.5.30.

- **pseudo_thread_id**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>pseudo_thread_id</td>
</tr>
<tr>
<td>Scope</td>
<td>Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

This variable is for internal server use.

- **query_alloc_block_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query-alloc-block-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td>query_alloc_block_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8192</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Block Size</td>
<td>1024</td>
</tr>
</tbody>
</table>

The allocation size of memory blocks that are allocated for objects created during statement parsing and execution. If you have problems with memory fragmentation, it might help to increase this parameter.

- **query_cache_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query-cache-limit=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td>query_cache_limit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1048576</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maximum Value (64-bit platforms)</strong></td>
<td>18446744073709551615</td>
</tr>
<tr>
<td><strong>Maximum Value (32-bit platforms)</strong></td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Do not cache results that are larger than this number of bytes. The default value is 1MB.

- **query_cache_min_res_unit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query-cache-min-res-unit=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>query_cache_min_res_unit</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4096</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>512</td>
</tr>
<tr>
<td><strong>Maximum Value (64-bit platforms)</strong></td>
<td>18446744073709551615</td>
</tr>
<tr>
<td><strong>Maximum Value (32-bit platforms)</strong></td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The minimum size (in bytes) for blocks allocated by the query cache. The default value is 4096 (4KB). Tuning information for this variable is given in Section 8.10.3.3, “Query Cache Configuration”.

- **query_cache_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query-cache-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>query_cache_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maximum Value (64-bit platforms)</strong></td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>
The amount of memory allocated for caching query results. The default value is 0, which disables the query cache. To reduce overhead significantly, you should also start the server with `query_cache_type=0` if you will not be using the query cache.

The permissible values are multiples of 1024; other values are rounded down to the nearest multiple. For nonzero values of `query_cache_size`, that many bytes of memory are allocated even if `query_cache_type=0`. See Section 8.10.3.3, “Query Cache Configuration”, for more information.

The query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value of `query_cache_size` too small, a warning will occur, as described in Section 8.10.3.3, “Query Cache Configuration”.

- `query_cache_type`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query-cache-type=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>query_cache_type</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Valid Values</td>
<td>0, 1, 2</td>
</tr>
</tbody>
</table>

Set the query cache type. Setting the `GLOBAL` value sets the type for all clients that connect thereafter. Individual clients can set the `SESSION` value to affect their own use of the query cache. Possible values are shown in the following table.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or OFF</td>
<td>Do not cache results in or retrieve results from the query cache. Note that this does not deallocate the query cache buffer. To do that, you should set <code>query_cache_size</code> to 0.</td>
</tr>
<tr>
<td>1 or ON</td>
<td>Cache all cacheable query results except for those that begin with <code>SELECT SQL_NO_CACHE</code>.</td>
</tr>
<tr>
<td>2 or DEMAND</td>
<td>Cache results only for cacheable queries that begin with <code>SELECT SQL_CACHE</code>.</td>
</tr>
</tbody>
</table>

This variable defaults to `ON`.

If the server is started with `query_cache_type` set to 0, it does not acquire the query cache mutex at all, which means that the query cache cannot be enabled at runtime and there is reduced overhead in query execution.

- `query_cache_wlock_invalidate`
 Normally, when one client acquires a WRITE lock on a MyISAM table, other clients are not blocked from issuing statements that read from the table if the query results are present in the query cache. Setting this variable to 1 causes acquisition of a WRITE lock for a table to invalidate any queries in the query cache that refer to the table. This forces other clients that attempt to access the table to wait while the lock is in effect.

- `query_prealloc_size`

 The size of the persistent buffer used for statement parsing and execution. This buffer is not freed between statements. If you are running complex queries, a larger `query_prealloc_size` value might be helpful in improving performance, because it can reduce the need for the server to perform memory allocation during query execution operations.

- `rand_seed1`
The `rand_seed1` and `rand_seed2` variables exist as session variables only, and can be set but not read. The variables—but not their values—are shown in the output of `SHOW VARIABLES`.

The purpose of these variables is to support replication of the `RAND()` function. For statements that invoke `RAND()`, the master passes two values to the slave, where they are used to seed the random number generator. The slave uses these values to set the session variables `rand_seed1` and `rand_seed2` so that `RAND()` on the slave generates the same value as on the master.

- `rand_seed2`

  See the description for `rand_seed1`.

- `range_alloc_block_size`

  The size of blocks that are allocated when doing range optimization.

- `read_buffer_size`

  Each thread that does a sequential scan for a `MyISAM` table allocates a buffer of this size (in bytes) for each table it scans. If you do many sequential scans, you might want to increase this value, which...
Server System Variables

defaults to 131072. The value of this variable should be a multiple of 4KB. If it is set to a value that is not a multiple of 4KB, its value will be rounded down to the nearest multiple of 4KB.

This option is also used in the following context for all storage engines:

- For caching the indexes in a temporary file (not a temporary table), when sorting rows for ORDER BY.
- For bulk insert into partitions.
- For caching results of nested queries.

read_buffer_size is also used in one other storage engine-specific way: to determine the memory block size for MEMORY tables.

For more information about memory use during different operations, see Section 8.12.4.1, “How MySQL Uses Memory”.

- read_only

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--read-only[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>read_only</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When the read_only system variable is enabled, the server permits no client updates except from users who have the SUPER privilege. This variable is disabled by default.

Even with read_only enabled, the server permits these operations:

- Updates performed by slave threads, if the server is a replication slave. In replication setups, it can be useful to enable read_only on slave servers to ensure that slaves accept updates only from the master server and not from clients.
- Use of ANALYZE TABLE or OPTIMIZE TABLE statements. The purpose of read-only mode is to prevent changes to table structure or contents. Analysis and optimization do not qualify as such changes. This means, for example, that consistency checks on read-only replication slaves can be performed with mysqlcheck --all-databases --analyze.
- Operations on TEMPORARY tables.
- Inserts into the log tables (mysql.general_log and mysql.slow_log; see Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”).

read_only exists only as a GLOBAL variable, so changes to its value require the SUPER privilege. Changes to read_only on a master server are not replicated to slave servers. The value can be set on a slave server independent of the setting on the master.

The following conditions apply to attempts to enable read_only:

- The attempt fails and an error occurs if you have any explicit locks (acquired with LOCK TABLES) or have a pending transaction.
Server System Variables

- The attempt blocks while other clients have any ongoing statement, active LOCK TABLES WRITE, or ongoing commit, until the locks are released and the statements and transactions end. While the attempt to enable read_only is pending, requests by other clients for table locks or to begin transactions also block until read_only has been set.

- The attempt blocks if there are active transactions that hold metadata locks, until those transactions end.

- read_only can be enabled while you hold a global read lock (acquired with FLUSH TABLES WITH READ LOCK) because that does not involve table locks.

- read_rnd_buffer_size

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--read-rnd-buffer-size=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>read_rnd_buffer_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>262144</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>2147483647</td>
</tr>
</tbody>
</table>

When reading rows from a MyISAM table in sorted order following a key-sorting operation, the rows are read through this buffer to avoid disk seeks. See Section 8.2.1.10, “ORDER BY Optimization”. Setting the variable to a large value can improve ORDER BY performance by a lot. However, this is a buffer allocated for each client, so you should not set the global variable to a large value. Instead, change the session variable only from within those clients that need to run large queries.

For more information about memory use during different operations, see Section 8.12.4.1, “How MySQL Uses Memory”.

- relay_log_purge

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--relay-log-purge[=OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>relay_log_purge</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Disables or enables automatic purging of relay log files as soon as they are not needed any more. The default value is 1 (ON).
• **relay_log_space_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--relay-log-space-limit=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>relay_log_space_limit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>platforms)</td>
<td></td>
</tr>
<tr>
<td>Maximum Value (32-bit</td>
<td>4294967295</td>
</tr>
<tr>
<td>platforms)</td>
<td></td>
</tr>
</tbody>
</table>

The maximum amount of space to use for all relay logs.

• **rpl_semi_sync_master_enabled**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--rpl-semi-sync-master-enabled[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>rpl_semi_sync_master_enabled</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Controls whether semisynchronous replication is enabled on the master. To enable or disable the plugin, set this variable to ON or OFF (or 1 or 0), respectively. The default is OFF.

This variable is available only if the master-side semisynchronous replication plugin is installed.

• **rpl_semi_sync_master_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--rpl-semi-sync-master-timeout=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>rpl_semi_sync_master_timeout</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10000</td>
</tr>
</tbody>
</table>

A value in milliseconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10000 (10 seconds).

This variable is available only if the master-side semisynchronous replication plugin is installed.
Server System Variables

- **rpl_semi_sync_master_trace_level**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--rpl-semi-sync-master-trace-level=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>rpl_semi_sync_master_trace_level</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32</td>
</tr>
</tbody>
</table>

The semisynchronous replication debug trace level on the master. Four levels are defined:

- 1 = general level (for example, time function failures)
- 16 = detail level (more verbose information)
- 32 = net wait level (more information about network waits)
- 64 = function level (information about function entry and exit)

This variable is available only if the master-side semisynchronous replication plugin is installed.

- **rpl_semi_sync_master_wait_no_slave**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--rpl-semi-sync-master-wait-no-slave=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>rpl_semi_sync_master_wait_no_slave</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

With semisynchronous replication, for each transaction, the master waits until timeout for acknowledgment of receipt from some semisynchronous slave. If no response occurs during this period, the master reverts to normal replication. This variable controls whether the master waits for the timeout to expire before reverting to normal replication even if the slave count drops to zero during the timeout period.

If the value is **ON** (the default), it is permissible for the slave count to drop to zero during the timeout period (for example, if slaves disconnect). The master still waits for the timeout, so as long as some slave reconnects and acknowledges the transaction within the timeout interval, semisynchronous replication continues.

If the value is **OFF**, the master reverts to normal replication if the slave count drops to zero during the timeout period.

This variable is available only if the master-side semisynchronous replication plugin is installed.
• **rpl_semi_sync_slave_enabled**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--rpl-semi-sync-slave-enabled[=(OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>rpl_semi_sync_slave_enabled</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Controls whether semisynchronous replication is enabled on the slave. To enable or disable the plugin, set this variable to **ON** or **OFF** (or 1 or 0), respectively. The default is **OFF**.

This variable is available only if the slave-side semisynchronous replication plugin is installed.

• **rpl_semi_sync_slave_trace_level**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--rpl-semi-sync-slave-trace-level=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>rpl_semi_sync_slave_trace_level</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32</td>
</tr>
</tbody>
</table>

The semisynchronous replication debug trace level on the slave. See `rpl_semi_sync_master_trace_level` for the permissible values.

This variable is available only if the slave-side semisynchronous replication plugin is installed.

• **secure_auth**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--secure-auth[=(OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>secure_auth</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
If this variable is enabled, the server blocks connections by clients that attempt to use accounts that have passwords stored in the old (pre-4.1) format. Enable this variable to prevent all use of passwords employing the old format (and hence insecure communication over the network).

Server startup fails with an error if this variable is enabled and the privilege tables are in pre-4.1 format. See Section B.4.2.4, “Client does not support authentication protocol”.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

• secure_file_priv

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--secure-file-priv=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>secure_file_priv</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value (&gt;= 5.5.53)</td>
<td>platform specific</td>
</tr>
<tr>
<td>Default Value (&lt;= 5.5.52)</td>
<td>empty string</td>
</tr>
<tr>
<td>Valid Values (&gt;= 5.5.53)</td>
<td>empty string, dirname, NULL</td>
</tr>
<tr>
<td>Valid Values (&lt;= 5.5.52)</td>
<td>empty string, dirname</td>
</tr>
</tbody>
</table>

This variable is used to limit the effect of data import and export operations, such as those performed by the LOAD DATA and SELECT ... INTO OUTFILE statements and the LOAD_FILE() function. These operations are permitted only to users who have the FILE privilege.

secure_file_priv may be set as follows:

- If empty, the variable has no effect. This is not a secure setting.
- If set to the name of a directory, the server limits import and export operations to work only with files in that directory. The directory must exist; the server will not create it.
- If set to NULL, the server disables import and export operations. This value is permitted as of MySQL 5.5.53.

Before MySQL 5.5.53, this variable is empty by default. As of 5.5.53, the default value is platform specific and depends on the value of the INSTALL_LAYOUT CMake option, as shown in the following table. To specify the default secure_file_priv value explicitly if you are building from source, use the INSTALL_SECURE_FILE_PRIVDIR CMake option.
Server System Variables

<table>
<thead>
<tr>
<th>INSTALL_LAYOUT Value</th>
<th>Default secure_file_priv Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDALONE, WIN</td>
<td>NULL</td>
</tr>
<tr>
<td>DEB, RPM, SLES, SVR4</td>
<td>/var/lib/mysql-files</td>
</tr>
<tr>
<td>Otherwise</td>
<td>mysql-files under the CMAKE_INSTALL_PREFIX value</td>
</tr>
</tbody>
</table>

To set the default `secure_file_priv` value for the `libmysql` embedded server, use the `INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR` CMake option. The default value for this option is `NULL`.

As of MySQL 5.5.53, the server checks the value of `secure_file_priv` at startup and writes a warning to the error log if the value is insecure. A non-NULL value is considered insecure if it is empty, or the value is the data directory or a subdirectory of it, or a directory that is accessible by all users. If `secure_file_priv` is set to a nonexistent path, the server writes an error message to the error log and exits.

- `shared_memory`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--shared-memory[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>shared_memory</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

(Windows only.) Whether the server permits shared-memory connections.

- `shared_memory_base_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--shared-memory-base-name=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>shared_memory_base_name</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>MYSQL</td>
</tr>
</tbody>
</table>

(Windows only.) The name of shared memory to use for shared-memory connections. This is useful when running multiple MySQL instances on a single physical machine. The default name is `MYSQL`. The name is case-sensitive.

This variable applies only if the server is started with the `shared_memory` system variable enabled to support shared-memory connections.
### Server System Variables

- **skip_external_locking**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-external-locking={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>skip_external_locking</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

This is **OFF** if `mysqld` uses external locking (system locking), **ON** if external locking is disabled. This affects only **MyISAM** table access.

This variable is set by the `--external-locking` or `--skip-external-locking` option. External locking is disabled by default.

External locking affects only **MyISAM** table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.5, “External Locking”.

- **skip_name_resolve**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-name-resolve={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>skip_name_resolve</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether to resolve host names when checking client connections. If this variable is **OFF**, `mysqld` resolves host names when checking client connections. If it is **ON**, `mysqld` uses only IP numbers; in this case, all `Host` column values in the grant tables must be IP addresses or `localhost`. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

Depending on the network configuration of your system and the `Host` values for your accounts, clients may need to connect using an explicit `--host` option, such as `--host=localhost`, `--host=127.0.0.1`, or `--host=:1`.

An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with `skip_name_resolve` enabled. If you plan to do that, make sure an account exists that can accept a connection. For example, to be able to connect as `root` using `--host=127.0.0.1` or `--host=:1`, create these accounts:

```
CREATE USER 'root'@'127.0.0.1' IDENTIFIED BY 'root-password';
CREATE USER 'root'@'::1' IDENTIFIED BY 'root-password';
```

- **skip_networking**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-networking={OFF</td>
</tr>
</tbody>
</table>

599
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Variable</strong></td>
<td><code>skip_networking</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Boolean</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable controls whether the server permits TCP/IP connections. By default, it is disabled (permit TCP connections). If enabled, the server permits only local (non-TCP/IP) connections and all interaction with `mysqld` must be made using named pipes or shared memory (on Windows) or Unix socket files (on Unix). This option is highly recommended for systems where only local clients are permitted. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- **skip_show_database**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--skip-show-database</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>skip_show_database</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
</tbody>
</table>

This prevents people from using the `SHOW DATABASES` statement if they do not have the `SHOW DATABASES` privilege. This can improve security if you have concerns about users being able to see databases belonging to other users. Its effect depends on the `SHOW DATABASES` privilege: If the variable value is `ON`, the `SHOW DATABASES` statement is permitted only to users who have the `SHOW DATABASES` privilege, and the statement displays all database names. If the value is `OFF`, `SHOW DATABASES` is permitted to all users, but displays the names of only those databases for which the user has the `SHOW DATABASES` or other privilege.

**Caution**

Because a global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with `SHOW DATABASES` or by examining the `INFORMATION_SCHEMA SCHEMATA` table.

- **slow_launch_time**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--slow-launch-time=#</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>slow_launch_time</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>2</td>
</tr>
</tbody>
</table>

If creating a thread takes longer than this many seconds, the server increments the `Slow_launch_threads` status variable.

- **slow_query_log**
**Server System Variables**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td>`--slow-query-log={OFF</td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>slow_query_log</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Boolean</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether the slow query log is enabled. The value can be 0 (or **OFF**) to disable the log or 1 (or **ON**) to enable the log. The destination for log output is controlled by the `log_output` system variable; if that value is **NONE**, no log entries are written even if the log is enabled.

“Slow” is determined by the value of the `long_query_time` variable. See Section 5.4.5, “The Slow Query Log”.

**• slow_query_log_file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--slow-query-log-file=file_name</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>slow_query_log_file</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>File name</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td><code>host_name-slow.log</code></td>
</tr>
</tbody>
</table>

The name of the slow query log file. The default value is `host_name-slow.log`, but the initial value can be changed with the `--slow_query_log_file` option.

**• socket**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td>`--socket={file_name</td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>socket</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>String</td>
</tr>
<tr>
<td><strong>Default Value (Other)</strong></td>
<td><code>/tmp/mysql.sock</code></td>
</tr>
<tr>
<td><strong>Default Value (Windows)</strong></td>
<td>MySQL</td>
</tr>
</tbody>
</table>

On Unix platforms, this variable is the name of the socket file that is used for local client connections. The default is `/tmp/mysql.sock`. (For some distribution formats, the directory might be different, such as `/var/lib/mysql` for RPMs.)

On Windows, this variable is the name of the named pipe that is used for local client connections. The default value is **MySQL** (not case-sensitive).

**• sort_buffer_size**


Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--sort-buffer-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>sort_buffer_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>2097144</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>32768</td>
</tr>
<tr>
<td>Maximum Value (Other, 64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (Other, 32-bit platforms)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Maximum Value (Windows)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Each session that must perform a sort allocates a buffer of this size. `sort_buffer_size` is not specific to any storage engine and applies in a general manner for optimization. At minimum the `sort_buffer_size` value must be large enough to accommodate fifteen tuples in the sort buffer. Also, increasing the value of `max_sort_length` may require increasing the value of `sort_buffer_size`. For more information, see Section 8.2.1.10, “ORDER BY Optimization”.

If you see many `Sort_merge_passes` per second in `SHOW GLOBAL STATUS` output, you can consider increasing the `sort_buffer_size` value to speed up `ORDER BY` or `GROUP BY` operations that cannot be improved with query optimization or improved indexing. The entire buffer is allocated even if it is not all needed, so setting it larger than required globally will slow down most queries that sort. It is best to increase it as a session setting, and only for the sessions that need a larger size. On Linux, there are thresholds of 256KB and 2MB where larger values may significantly slow down memory allocation, so you should consider staying below one of those values. Experiment to find the best value for your workload. See Section B.4.3.5, “Where MySQL Stores Temporary Files”.

The maximum permissible setting for `sort_buffer_size` is 4GB–1. Larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB–1 with a warning).

- `sql_auto_is_null`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>sql_auto_is_null</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If this variable is enabled, then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```sql
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.15.
"Information Functions". If no AUTO_INCREMENT value was successfully inserted, the SELECT statement returns no row.

The behavior of retrieving an AUTO_INCREMENT value by using an IS NULL comparison is used by some ODBC programs, such as Access. See Obtaining Auto-Increment Values. This behavior can be disabled by setting sql_auto_is_null to OFF.

The default value of sql_auto_is_null is OFF.

- sql_big_selects

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_big_selects</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If set to OFF, MySQL aborts SELECT statements that are likely to take a very long time to execute (that is, statements for which the optimizer estimates that the number of examined rows exceeds the value of max_join_size). This is useful when an inadvisable WHERE statement has been issued. The default value for a new connection is ON, which permits all SELECT statements.

If you set the max_join_size system variable to a value other than DEFAULT, sql_big_selects is set to OFF.

- sql_buffer_result

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_buffer_result</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If enabled, sql_buffer_result forces results from SELECT statements to be put into temporary tables. This helps MySQL free the table locks early and can be beneficial in cases where it takes a long time to send results to the client. The default value is OFF.

- sql_log_bin

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_log_bin</td>
</tr>
<tr>
<td>Scope (&gt;= 5.5.41)</td>
<td>Session</td>
</tr>
<tr>
<td>Scope (&lt;= 5.5.40)</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

This variable controls whether logging to the binary log is enabled for the current session (assuming that the binary log itself is enabled). The default value is ON. To disable or enable binary logging for the current session, set the session `sql_log_bin` variable to OFF or ON.

Set this variable to OFF for a session to temporarily disable binary logging while making changes to the master you do not want replicated to the slave.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

It is not possible to set the session value of `sql_log_bin` within a transaction or subquery.

As of MySQL 5.5.41, the global `sql_log_bin` variable is read only and cannot be modified. The global scope is deprecated and will be removed in a future MySQL release. Prior to 5.5.41, `sql_log_bin` can be set as a global or session variable. Setting `sql_log_bin` globally is only detected when a new session is started. Any sessions previously running are not impacted when setting `sql_log_bin` globally.

**Warning**

Incorrect use of `sql_log_bin` with a global scope means any changes made in an already running session are still being recorded to the binary log and therefore replicated. Exercise extreme caution using `sql_log_bin` with a global scope as the above situation could cause unexpected results including replication failure.

• `sql_log_off`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>sql_log_off</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
<tr>
<td>Valid Values</td>
<td>OFF (enable logging)</td>
</tr>
<tr>
<td></td>
<td>ON (disable logging)</td>
</tr>
</tbody>
</table>

This variable controls whether logging to the general query log is disabled for the current session (assuming that the general query log itself is enabled). The default value is OFF (that is, enable logging). To disable or enable general query logging for the current session, set the session `sql_log_off` variable to ON or OFF.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

• `sql_mode`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--sql-mode=name</code></td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_mode</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Set</td>
</tr>
<tr>
<td>Default Value</td>
<td>''</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ALLOW_INVALID_DATES</td>
</tr>
<tr>
<td></td>
<td>ANSI_QUOTES</td>
</tr>
<tr>
<td></td>
<td>ERROR_FOR_DIVISION_BY_ZERO</td>
</tr>
<tr>
<td></td>
<td>HIGH_NOT_PRECEDENCE</td>
</tr>
<tr>
<td></td>
<td>IGNORE_SPACE</td>
</tr>
<tr>
<td></td>
<td>NO_AUTO_CREATE_USER</td>
</tr>
<tr>
<td></td>
<td>NO_AUTO_VALUE_ON_ZERO</td>
</tr>
<tr>
<td></td>
<td>NO_BACKSLASH_ESCAPES</td>
</tr>
<tr>
<td></td>
<td>NO_DIR_IN_CREATE</td>
</tr>
<tr>
<td></td>
<td>NO_ENGINE_SUBSTITUTION</td>
</tr>
<tr>
<td></td>
<td>NO_FIELD_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_KEY_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_TABLE_OPTIONS</td>
</tr>
<tr>
<td></td>
<td>NO_UNSIGNED_SUBTRACTION</td>
</tr>
<tr>
<td></td>
<td>NO_ZERO_DATE</td>
</tr>
<tr>
<td></td>
<td>NO_ZERO_IN_DATE</td>
</tr>
<tr>
<td></td>
<td>ONLY_FULL_GROUP_BY</td>
</tr>
<tr>
<td></td>
<td>PAD_CHAR_TO_FULL_LENGTH</td>
</tr>
<tr>
<td></td>
<td>PIPES_AS_CONCAT</td>
</tr>
<tr>
<td></td>
<td>REAL_AS_FLOAT</td>
</tr>
<tr>
<td></td>
<td>STRICT_ALL_TABLES</td>
</tr>
</tbody>
</table>
The current server SQL mode, which can be set dynamically. For details, see Section 5.1.10, “Server SQL Modes”.

### Note
MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

**sql_notes**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_notes</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If enabled (the default), diagnostics of *Note* level increment *warning_count* and the server records them. If disabled, *Note* diagnostics do not increment *warning_count* and the server does not record them. *mysqldump* includes output to disable this variable so that reloading the dump file does not produce warnings for events that do not affect the integrity of the reload operation.

**sql_quote_show_create**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_quote_show_create</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If enabled (the default), the server quotes identifiers for *SHOW CREATE TABLE* and *SHOW CREATE DATABASE* statements. If disabled, quoting is disabled. This option is enabled by default so that replication works for identifiers that require quoting. See Section 13.7.5.12, “SHOW CREATE TABLE Statement”, and Section 13.7.5.8, “SHOW CREATE DATABASE Statement”.

**sql_safe_updates**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_safe_updates</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Server System Variables

If this variable is enabled, UPDATE and DELETE statements that do not use a key in the WHERE clause or a LIMIT clause produce an error. This makes it possible to catch UPDATE and DELETE statements where keys are not used properly and that would probably change or delete a large number of rows. The default value is OFF.

For the mysql client, sql_safe_updates can be enabled by using the --safe-updates option. For more information, see Using Safe-Updates Mode (--safe-updates).

• sql_select_limit

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_select_limit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

The maximum number of rows to return from SELECT statements. For more information, see Using Safe-Updates Mode (--safe-updates).

The default value for a new connection is the maximum number of rows that the server permits per table. Typical default values are \((2^{32})-1\) or \((2^{64})-1\). If you have changed the limit, the default value can be restored by assigning a value of DEFAULT.

If a SELECT has a LIMIT clause, the LIMIT takes precedence over the value of sql_select_limit.

• sql_warnings

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_warnings</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable controls whether single-row INSERT statements produce an information string if warnings occur. The default is OFF. Set the value to ON to produce an information string.

• ssl_ca

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ssl-ca=file_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>ssl_ca</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The path to a file with a list of trusted SSL Certificate Authorities.

• ssl_capath
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ssl-capath=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ssl_capath</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The path to a directory that contains trusted SSL CA certificates in PEM format. Support for this capability depends on the SSL library used to compile MySQL. See [Section 6.3.4, “SSL Library-Dependent Capabilities”](#).

- **ssl_cert**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ssl-cert=file_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ssl_cert</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The name of the SSL certificate file to use for establishing a secure connection.

- **ssl_cipher**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ssl-cipher=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ssl_cipher</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The list of permissible ciphers for SSL encryption.

- **ssl_key**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ssl-key=file_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ssl_key</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The name of the SSL key file to use for establishing a secure connection.
### Server System Variables

- **storage_engine**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>storage_engine</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>InnoDB</td>
</tr>
</tbody>
</table>


This variable is deprecated as of MySQL 5.5.3. Use `default_storage_engine` instead.

- **stored_program_cache**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--stored-program-cache=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.21</td>
</tr>
<tr>
<td>System Variable</td>
<td>stored_program_cache</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>256</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>256</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>524288</td>
</tr>
</tbody>
</table>

Sets a soft upper limit for the number of cached stored routines per connection. The value of this variable is specified in terms of the number of stored routines held in each of the two caches maintained by the MySQL Server for, respectively, stored procedures and stored functions.

Whenever a stored routine is executed this cache size is checked before the first or top-level statement in the routine is parsed; if the number of routines of the same type (stored procedures or stored functions according to which is being executed) exceeds the limit specified by this variable, the corresponding cache is flushed and memory previously allocated for cached objects is freed. This allows the cache to be flushed safely, even when there are dependencies between stored routines.

- **sync_frm**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--sync-frm=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>sync_frm</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If this variable is set to 1, when any nontemporary table is created its `.frm` file is synchronized to disk (using `fdatasync()`). This is slower but safer in case of a crash. The default is 1.

- **system_time_zone**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>system_time_zone</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The server system time zone. When the server begins executing, it inherits a time zone setting from the machine defaults, possibly modified by the environment of the account used for running the server or the startup script. The value is used to set `system_time_zone`. Typically the time zone is specified by the `TZ` environment variable. It also can be specified using the `--timezone` option of the `mysqld_safe` script.

The `system_time_zone` variable differs from `time_zone`. Although they might have the same value, the latter variable is used to initialize the time zone for each client that connects. See Section 5.1.12, "MySQL Server Time Zone Support".

- **table_definition_cache**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--table-definition-cache=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>table_definition_cache</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>400</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>400</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>524288</td>
</tr>
</tbody>
</table>

The number of table definitions (from `.frm` files) that can be stored in the definition cache. If you use a large number of tables, you can create a large table definition cache to speed up opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the normal table cache. The minimum and default values are both 400.

- **table_open_cache**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--table-open-cache=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>table_open_cache</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The number of open tables for all threads. Increasing this value increases the number of file descriptors that `mysqld` requires. You can check whether you need to increase the table cache by checking the `Opened_tables` status variable. See Section 5.1.9, “Server Status Variables”. If the value of `Opened_tables` is large and you do not use `FLUSH TABLES` often (which just forces all tables to be closed and reopened), then you should increase the value of the `table_open_cache` variable. For more information about the table cache, see Section 8.4.3.1, “How MySQL Opens and Closes Tables”.

- `thread_cache_size`

How many threads the server should cache for reuse. When a client disconnects, the client’s threads are put in the cache if there are fewer than `thread_cache_size` threads there. Requests for threads are satisfied by reusing threads taken from the cache if possible, and only when the cache is empty is a new thread created. This variable can be increased to improve performance if you have a lot of new connections. Normally, this does not provide a notable performance improvement if you have a good thread implementation. However, if your server sees hundreds of connections per second you should normally set `thread_cache_size` high enough so that most new connections use cached threads. By examining the difference between the `Connections` and `Threads_created` status variables, you can see how efficient the thread cache is. For details, see Section 5.1.9, “Server Status Variables”.

- `thread_concurrency`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--thread-concurrency=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>thread_concurrency</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>
This variable is specific to Solaris 8 and earlier systems, for which `mysql` invokes the `thr_setconcurrency()` function with the variable value. This function enables applications to give the threads system a hint about the desired number of threads that should be run at the same time. Current Solaris versions document this as having no effect.

- **thread_handling**

The thread-handling model used by the server for connection threads. The permissible user-settable values are `no-threads` (the server uses a single thread to handle one connection) and `one-thread-per-connection` (the server uses one thread to handle each client connection; this is the default). `no-threads` is useful for debugging under Linux; see Section 24.5, “Debugging and Porting MySQL”.

If the thread pool plugin is enabled, the server sets the `thread_handling` value to `loaded-dynamically`. See Section 5.5.3.2, “Thread Pool Installation”.

- **thread_pool_algorithm**

This variable controls which algorithm the thread pool plugin uses:
• A value of 0 (the default) uses a conservative low-concurrency algorithm which is most well tested and is known to produce very good results.

• A value of 1 increases the concurrency and uses a more aggressive algorithm which at times has been known to perform 5–10% better on optimal thread counts, but has degrading performance as the number of connections increases. Its use should be considered as experimental and not supported.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

• `thread_pool_high_priority_connection`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--thread-pool-high-priority-connection=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>thread_pool_high_priority_connection</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

This variable affects queuing of new statements prior to execution. If the value is 0 (false, the default), statement queuing uses both the low-priority and high-priority queues. If the value is 1 (true), queued statements always go to the high-priority queue.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

• `thread_pool_max_unused_threads`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--thread-pool-max-unused-threads=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>thread_pool_max_unused_threads</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>4096</td>
</tr>
</tbody>
</table>

The maximum permitted number of unused threads in the thread pool. This variable makes it possible to limit the amount of memory used by sleeping threads.

A value of 0 (the default) means no limit on the number of sleeping threads. A value of \( N \) where \( N \) is greater than 0 means 1 consumer thread and \( N-1 \) reserve threads. In this case, if a thread is ready to sleep but the number of sleeping threads is already at the maximum, the thread exits rather than going to sleep.

A sleeping thread is either sleeping as a consumer thread or a reserve thread. The thread pool permits one thread to be the consumer thread when sleeping. If a thread goes to sleep and there is no existing consumer thread, it will sleep as a consumer thread. When a thread must be woken up, a consumer thread is selected if there is one. A reserve thread is selected only when there is no consumer thread to wake up.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- **thread_pool_prio_kickup_timer**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--thread-pool-prio-kickup-timer=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>thread_pool_prio_kickup_timer</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967294</td>
</tr>
</tbody>
</table>

This variable affects statements waiting for execution in the low-priority queue. The value is the number of milliseconds before a waiting statement is moved to the high-priority queue. The default is 1000 (1 second). The range of values is 0 to \( 2^{32} - 2 \).

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- **thread_pool_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--thread-pool-size=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>thread_pool_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>
### Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>16</td>
</tr>
<tr>
<td><strong>Minimum Value</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>64</td>
</tr>
</tbody>
</table>

The number of thread groups in the thread pool. This is the most important parameter controlling thread pool performance. It affects how many statements can execute simultaneously. The default value is 16, with a range from 1 to 64 of permissible values. If a value outside this range is specified, the thread pool plugin does not load and the server writes a message to the error log.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, "MySQL Enterprise Thread Pool"

- **thread_pool_stall_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--thread-pool-stall-limit=#</code></td>
</tr>
<tr>
<td><strong>Introduced</strong></td>
<td>5.5.16</td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>thread_pool_stall_limit</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>Minimum Value</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>600</td>
</tr>
</tbody>
</table>

This variable affects executing statements. The value is the amount of time a statement has to finish after starting to execute before it becomes defined as stalled, at which point the thread pool permits the thread group to begin executing another statement. The value is measured in 10 millisecond units, so a value of 6 (the default) means 60ms. The range of values is 4 to 600 (40ms to 6s). Short wait values permit threads to start more quickly. Short values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, "MySQL Enterprise Thread Pool"

- **thread_stack**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--thread-stack=#</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>thread_stack</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
</tbody>
</table>
The stack size for each thread. Many of the limits detected by the `crash-me` test are dependent on this value. See Section 8.13.2, “The MySQL Benchmark Suite”. The default is large enough for normal operation. If the thread stack size is too small, it limits the complexity of the SQL statements that the server can handle, the recursion depth of stored procedures, and other memory-consuming actions.

- **time_format**

  This variable is unused.

- **time_zone**

  The current time zone. This variable is used to initialize the time zone for each client that connects. By default, the initial value of this is `'SYSTEM'` (which means, “use the value of `system_time_zone`”). The value can be specified explicitly at server startup with the `--default-time-zone` option. See Section 5.1.12, “MySQL Server Time Zone Support”.

  **Note**

  If set to `SYSTEM`, every MySQL function call that requires a time zone calculation makes a system library call to determine the current system time zone. This call may be protected by a global mutex, resulting in contention.

- **timed_mutexes**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--timed-mutexes[={OFF</td>
</tr>
<tr>
<td>Deprecated</td>
<td>5.5.39</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>timed_mutexes</code></td>
</tr>
</tbody>
</table>
**Server System Variables**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable is deprecated; it has no use. It will be removed in a future MySQL release.

- **timestamp**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>timestamp</td>
</tr>
<tr>
<td>Scope</td>
<td>Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>UNIX_TIMESTAMP()</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>2147483647</td>
</tr>
</tbody>
</table>

Set the time for this client. This is used to get the original timestamp if you use the binary log to restore rows. `timestamp_value` should be a Unix epoch timestamp (a value like that returned by `UNIX_TIMESTAMP()`, not a value in 'YYYY-MM-DD hh:mm:ss' format) or `DEFAULT`.

Setting `timestamp` to a constant value causes it to retain that value until it is changed again. Setting `timestamp` to `DEFAULT` causes its value to be the current date and time as of the time it is accessed. The maximum value corresponds to '2038-01-19 03:14:07' UTC, the same as for the `TIMESTAMP` data type.

`SET timestamp` affects the value returned by `NOW()` but not by `SYSDATE()`. This means that `timestamp` settings in the binary log have no effect on invocations of `SYSDATE()`. The server can be started with the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`, in which case `SET timestamp` affects both functions.

- **tmp_table_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--tmp-table-size=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>tmp_table_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>16777216</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>

The maximum size of internal in-memory temporary tables. This variable does not apply to user-created MEMORY tables.

The actual limit is determined from whichever of the values of `tmp_table_size` and `max_heap_table_size` is smaller. If an in-memory temporary table exceeds the limit, MySQL automatically converts it to an on-disk MyISAM table. Increase the value of `tmp_table_size` (and `max_heap_table_size` if necessary) if you do many advanced `GROUP BY` queries and you have lots of memory.

You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.

- **tmpdir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--tmpdir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td>tmpdir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

  The directory used for temporary files and temporary tables. This variable can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters (:) on Unix and semicolon characters (;) on Windows.

  The multiple-directory feature can be used to spread the load between several physical disks. If the MySQL server is acting as a replication slave, you should not set `tmpdir` to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA` operations. If files in the temporary file directory are lost when the server restarts, replication fails. You can set the slave's temporary directory using the `slave_load_tmpdir` variable. In that case, the slave will not use the general `tmpdir` value and you can set `tmpdir` to a nonpermanent location.

- **transaction_alloc_block_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--transaction-alloc-block-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>transaction_alloc_block_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8192</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Property</td>
<td>Value</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms, &lt;= 5.5.42)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms, &lt;= 5.5.42)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Maximum Value (&gt;= 5.5.43)</td>
<td>131072</td>
</tr>
<tr>
<td>Block Size</td>
<td>1024</td>
</tr>
</tbody>
</table>

The amount in bytes by which to increase a per-transaction memory pool which needs memory. See the description of `transaction_prealloc_size`.

- `transaction_prealloc_size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--transaction-prealloc-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>transaction_prealloc_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4096</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms, &lt;= 5.5.42)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms, &lt;= 5.5.42)</td>
<td>4294967295</td>
</tr>
<tr>
<td>Maximum Value (&gt;= 5.5.43)</td>
<td>131072</td>
</tr>
<tr>
<td>Block Size</td>
<td>1024</td>
</tr>
</tbody>
</table>

There is a per-transaction memory pool from which various transaction-related allocations take memory. The initial size of the pool in bytes is `transaction_prealloc_size`. For every allocation that cannot be satisfied from the pool because it has insufficient memory available, the pool is increased by `transaction_alloc_block_size` bytes. When the transaction ends, the pool is truncated to `transaction_prealloc_size` bytes.

By making `transaction_prealloc_size` sufficiently large to contain all statements within a single transaction, you can avoid many `malloc()` calls.

- `tx_isolation`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>tx_isolation</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>REPEATABLE-READ</code></td>
</tr>
<tr>
<td>Valid Values</td>
<td><code>READ-UNCOMMITTED</code></td>
</tr>
</tbody>
</table>
Server System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>READ-COMMITTED</td>
</tr>
<tr>
<td></td>
<td>REPEATABLE-READ</td>
</tr>
<tr>
<td></td>
<td>SERIALIZABLE</td>
</tr>
</tbody>
</table>

The transaction isolation level. The default is REPEATABLE-READ.

This variable can be set directly, or indirectly using the SET TRANSACTION statement. See Section 13.3.6, “SET TRANSACTION Statement”. If you set tx_isolation directly to an isolation level name that contains a space, the name should be enclosed within quotation marks, with the space replaced by a dash. For example:

```sql
SET tx_isolation = 'READ-COMMITTED';
```

The default transaction isolation level can also be set at startup using the `--transaction-isolation` server option.

- **unique_checks**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>unique_checks</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

If set to 1 (the default), uniqueness checks for secondary indexes in InnoDB tables are performed. If set to 0, storage engines are permitted to assume that duplicate keys are not present in input data. If you know for certain that your data does not contain uniqueness violations, you can set this to 0 to speed up large table imports to InnoDB.

Setting this variable to 0 does not require storage engines to ignore duplicate keys. An engine is still permitted to check for them and issue duplicate-key errors if it detects them.

- **updatable_views_with_limit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--updatable-views-with-limit[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>updatable_views_with_limit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
</tbody>
</table>

This variable controls whether updates to a view can be made when the view does not contain all columns of the primary key defined in the underlying table, if the update statement contains a LIMIT
Server System Variables

clause. (Such updates often are generated by GUI tools.) An update is an UPDATE or DELETE statement. Primary key here means a PRIMARY KEY, or a UNIQUE index in which no column can contain NULL.

The variable can have two values:

- 1 or YES: Issue a warning only (not an error message). This is the default value.
- 0 or NO: Prohibit the update.

version

The version number for the server. The value might also include a suffix indicating server build or configuration information. -log indicates that one or more of the general log, slow query log, or binary log are enabled. -debug indicates that the server was built with debugging support enabled.

version_comment

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>version_comment</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The cmake configuration program has a COMPILEATION_COMMENT option that permits a comment to be specified when building MySQL. This variable contains the value of that comment. See Section 2.9.7, "MySQL Source-Configuration Options".

version_compile_machine

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>version_compile_machine</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The type of machine or architecture on which MySQL was built.

version_compile_os

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>version_compile_os</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The type of operating system on which MySQL was built.

wait_timeout

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--wait-timeout=#</td>
</tr>
</tbody>
</table>
### Using System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>wait_timeout</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>28800</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>31536000 (Other)</td>
</tr>
<tr>
<td>Maximum Value (Windows)</td>
<td>2147483</td>
</tr>
</tbody>
</table>

The number of seconds the server waits for activity on a noninteractive connection before closing it.

On thread startup, the session `wait_timeout` value is initialized from the global `wait_timeout` value or from the global `interactive_timeout` value, depending on the type of client (as defined by the `CLIENT_INTERACTIVE` connect option to `mysql_real_connect()`). See also `interactive_timeout`.

- **warning_count**

  The number of errors, warnings, and notes that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.41, “SHOW WARNINGS Statement”.

#### 5.1.8 Using System Variables

The MySQL server maintains many system variables that configure its operation. Section 5.1.7, “Server System Variables”, describes the meaning of these variables. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically while the server is running by means of the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. You can also use system variable values in expressions.

Many system variables are built in. System variables implemented by a server plugin are exposed when the plugin is installed and have names that begin with the plugin name. For example, the `audit_log` plugin implements a system variable named `audit_log_policy`.

There are two scopes in which system variables exist. Global variables affect the overall operation of the server. Session variables affect its operation for individual client connections. A given system variable can have both a global and a session value. Global and session system variables are related as follows:

- When the server starts, it initializes each global variable to its default value. These defaults can be changed by options specified on the command line or in an option file. (See Section 4.2.2, “Specifying Program Options”.)

- The server also maintains a set of session variables for each client that connects. The client's session variables are initialized at connect time using the current values of the corresponding global variables. For example, a client's SQL mode is controlled by the session `sql_mode` value, which is initialized when the client connects to the value of the global `sql_mode` value.

  For some system variables, the session value is not initialized from the corresponding global value; if so, that is indicated in the variable description.

System variable values can be set globally at server startup by using options on the command line or in an option file. At startup, the syntax for system variables is the same as for command options,
Using System Variables

so within variable names, dashes and underscores may be used interchangeably. For example, \texttt{--general_log=ON} and \texttt{--general-log=ON} are equivalent.

When you use a startup option to set a variable that takes a numeric value, the value can be given with a suffix of \texttt{K}, \texttt{M}, or \texttt{G} (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3; that is, units of kilobytes, megabytes, or gigabytes, respectively. Thus, the following command starts the server with an \texttt{InnoDB} log file size of 16 megabytes and a maximum packet size of one gigabyte:

\begin{verbatim}
mysqld --innodb-log-file-size=16M --max-allowed-packet=1G
\end{verbatim}

Within an option file, those variables are set like this:

\begin{verbatim}
[mysqld]
innodb_log_file_size=16M
max_allowed_packet=1G
\end{verbatim}

The lettercase of suffix letters does not matter; \texttt{16M} and \texttt{16m} are equivalent, as are \texttt{1G} and \texttt{1g}.

To restrict the maximum value to which a system variable can be set at runtime with the \texttt{SET} statement, specify this maximum by using an option of the form \texttt{--maximum-var_name=value} at server startup. For example, to prevent the value of \texttt{innodb_log_file_size} from being increased to more than 32MB at runtime, use the option \texttt{--maximum-innodb-log-file-size=32M}.

Many system variables are dynamic and can be changed at runtime by using the \texttt{SET} statement. For a list, see Section 5.1.8.2, “Dynamic System Variables”. To change a system variable with \texttt{SET}, refer to it by name, optionally preceded by a modifier. At runtime, system variable names must be written using underscores, not dashes. The following examples briefly illustrate this syntax:

\begin{itemize}
  \item Set a global system variable:
    \begin{verbatim}
    SET GLOBAL max_connections = 1000;
    \end{verbatim}
  \end{itemize}

\begin{itemize}
  \item Set a session system variable:
    \begin{verbatim}
    SET SESSION sql_mode = 'TRADITIONAL';
    \end{verbatim}
  \end{itemize}

For complete details about \texttt{SET} syntax, see Section 13.7.4.1, “SET Syntax for Variable Assignment”. For a description of the privilege requirements for setting system variables, see Section 5.1.8.1, “System Variable Privileges”

Suffixes for specifying a value multiplier can be used when setting a variable at server startup, but not to set the value with \texttt{SET} at runtime. On the other hand, with \texttt{SET} you can assign a variable’s value using an expression, which is not true when you set a variable at server startup. For example, the first of the following lines is legal at server startup, but the second is not:

\begin{verbatim}
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
\end{verbatim}

Conversely, the second of the following lines is legal at runtime, but the first is not:

\begin{verbatim}
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
\end{verbatim}

\textbf{Note}

Some system variables can be enabled with the \texttt{SET} statement by setting them to \texttt{ON} or \texttt{1}, or disabled by setting them to \texttt{OFF} or \texttt{0}. However, to set such a variable
Using System Variables

On the command line or in an option file, you must set it to 1 or 0; setting it to ON or OFF will not work. For example, on the command line, `--delay_key_write=1` works but `--delay_key_write=ON` does not.

To display system variable names and values, use the `SHOW VARIABLES` statement:

```sql
mysql> SHOW VARIABLES;
+---------------------------------+-----------------------------------+
| Variable_name                   | Value                             |
+---------------------------------+-----------------------------------+
| auto_increment_increment        | 1                                 |
| auto_increment_offset           | 1                                 |
| automatic_sp_privileges         | ON                                |
| back_log                        | 50                                |
| basedir                         | /home/mysql/                      |
| binlog_cache_size               | 32768                             |
| bulk_insert_buffer_size         | 8388608                           |
| character_set_client            | utf8                              |
| character_set_connection        | utf8                              |
| character_set_database          | latin1                            |
| character_set_filesystem        | binary                            |
| character_set_results           | utf8                              |
| character_set_server            | latin1                            |
| character_sets_dir              | /home/mysql/share/mysql/charsets/ |
| collation_connection            | utf8_general_ci                   |
| collation_database              | latin1_swedish_ci                 |
| collation_server                | latin1_swedish_ci                 |
| ...                              |                                   |
| innodb_additional_mem_pool_size | 1048576                           |
| innodb_autoextend_increment     | 8                                 |
| innodb_buffer_pool_size         | 8388608                           |
| innodb_checksums                | ON                                |
| innodb_commit_concurrency       | 0                                 |
| innodb_concurrency_tickets      | 500                               |
| innodb_data_file_path           | ibdata1:10M:autoextend            |
| innodb_data_home_dir            |                                   |
| ...                              |                                   |
| version                         | 5.5.56-log                        |
| version_comment                 | Source distribution               |
| version_compile_machine         | i686                              |
| version_compile_os              | suse-linux                        |
| wait_timeout                    | 28800                             |
+---------------------------------+-----------------------------------+
```

With a `LIKE` clause, the statement displays only those variables that match the pattern. To obtain a specific variable name, use a `LIKE` clause as shown:

```sql
SHOW VARIABLES LIKE 'max_join_size';
SHOW SESSION VARIABLES LIKE 'max_join_size';
```

To get a list of variables whose name match a pattern, use the `%` wildcard character in a `LIKE` clause:

```sql
SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';
```

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because `_` is a wildcard that matches any single character, you should escape it as `\_` to match it literally. In practice, this is rarely necessary.

For `SHOW VARIABLES`, if you specify neither `GLOBAL` nor `SESSION`, MySQL returns `SESSION` values.

The reason for requiring the `GLOBAL` keyword when setting `GLOBAL`-only variables but not when retrieving them is to prevent problems in the future:
• Were a SESSION variable to be removed that has the same name as a GLOBAL variable, a client with privileges sufficient to modify global variables might accidentally change the GLOBAL variable rather than just the SESSION variable for its own session.

• Were a SESSION variable to be added with the same name as a GLOBAL variable, a client that intends to change the GLOBAL variable might find only its own SESSION variable changed.

5.1.8.1 System Variable Privileges

A system variable can have a global value that affects server operation as a whole, a session value that affects only the current session, or both. To modify system variable runtime values, use the SET statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”. This section describes the privileges required to assign values to system variables at runtime.

Setting a global system variable runtime value requires the SUPER privilege.

To set a session system variable runtime value, use the SET SESSION statement. In contrast to setting global runtime values, setting session runtime values normally requires no special privileges and can be done by any user to affect the current session. For some system variables, setting the session value may have effects outside the current session and thus is a restricted operation that can be done only by users who have the SUPER privilege. If a session system variable is restricted in this way, the variable description indicates that restriction. Examples include binlog_format and sql_log_bin. Setting the session value of these variables affects binary logging for the current session, but may also have wider implications for the integrity of server replication and backups.

5.1.8.2 Dynamic System Variables

Many server system variables are dynamic and can be set at runtime. See Section 13.7.4.1, “SET Syntax for Variable Assignment”. For a description of the privilege requirements for setting system variables, see Section 5.1.8.1, “System Variable Privileges”.

The following table lists all dynamic system variables applicable within mysqld.

The table lists each variable’s data type and scope. The last column indicates whether the scope for each variable is Global, Session, or both. Please see the corresponding item descriptions for details on setting and using the variables. Where appropriate, direct links to further information about the items are provided.

Variables that have a type of “string” take a string value. Variables that have a type of “numeric” take a numeric value. Variables that have a type of “boolean” can be set to 0, 1, ON or OFF. (If you set them on the command line or in an option file, use the numeric values.) Variables that are marked as “enumeration” normally should be set to one of the available values for the variable, but can also be set to the number that corresponds to the desired enumeration value. For enumerated system variables, the first enumeration value corresponds to 0. This differs from the ENUM data type used for table columns, for which the first enumeration value corresponds to 1.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Variable Type</th>
<th>Variable Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>audit_log_flush</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>audit_log_policy</td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td>audit_log_rotate_on_size</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>auto_increment_increment</td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td>auto_increment_offset</td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td>autocommit</td>
<td>Boolean</td>
<td>Varies</td>
</tr>
<tr>
<td>automatic_sp_privileges</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>Variable Name</td>
<td>Variable Type</td>
<td>Variable Scope</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td><code>big_tables</code></td>
<td>Boolean</td>
<td>Varies</td>
</tr>
<tr>
<td><code>binlog_cache_size</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>binlog_direct_non_transactional_updates</code></td>
<td>Boolean</td>
<td>Both</td>
</tr>
<tr>
<td><code>binlog_format</code></td>
<td>Enumeration</td>
<td>Both</td>
</tr>
<tr>
<td><code>binlog_stmt_cache_size</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>bulk_insert_buffer_size</code></td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_client</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_connection</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_database</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_filesystem</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_results</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>character_set_server</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>collation_connection</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>collation_database</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>collation_server</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>completion_type</code></td>
<td>Enumeration</td>
<td>Both</td>
</tr>
<tr>
<td><code>concurrent_insert</code></td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td><code>connect_timeout</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>debug</code></td>
<td>String</td>
<td>Both</td>
</tr>
<tr>
<td><code>debug_sync</code></td>
<td>String</td>
<td>Varies</td>
</tr>
<tr>
<td><code>default_storage_engine</code></td>
<td>Enumeration</td>
<td>Both</td>
</tr>
<tr>
<td><code>default_week_format</code></td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td><code>delay_key_write</code></td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td><code>delayed_insert_limit</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>delayed_insert_timeout</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>delayed_queue_size</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>div_precision_increment</code></td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td><code>engine_condition_pushdown</code></td>
<td>Boolean</td>
<td>Both</td>
</tr>
<tr>
<td><code>event_scheduler</code></td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td><code>expire_logs_days</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>flush</code></td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td><code>flush_time</code></td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td><code>foreign_key_checks</code></td>
<td>Boolean</td>
<td>Varies</td>
</tr>
<tr>
<td><code>ft_boolean_syntax</code></td>
<td>String</td>
<td>Global</td>
</tr>
<tr>
<td><code>general_log</code></td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td><code>general_log_file</code></td>
<td>File name</td>
<td>Global</td>
</tr>
<tr>
<td><code>group_concat_max_len</code></td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td><code>identity</code></td>
<td>Integer</td>
<td>Session</td>
</tr>
</tbody>
</table>
### Using System Variables

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Variable Type</th>
<th>Variable Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>init_connect</td>
<td>String</td>
<td>Global</td>
</tr>
<tr>
<td>init_slave</td>
<td>String</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_adaptive_flushing</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_adaptive_hash_index</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_autoextend_increment</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_change_buffering</td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_change_buffering_debug</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_commit_concurrency</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_concurrency_tickets</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_fast_shutdown</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_file_format</td>
<td>String</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_file_format_check</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_file_format_max</td>
<td>String</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_file_per_table</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_flush_log_at_trx_commit</td>
<td>Enumeration</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_io_capacity</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_large_prefix</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_limit_optimistic_insert_debug</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_lock_wait_timeout</td>
<td>Integer</td>
<td>Both</td>
</tr>
<tr>
<td>innodb_max_dirty_pages_pct</td>
<td>Numeric</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_max_purge_lag</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_old_blocks_pct</td>
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<td>Global</td>
</tr>
<tr>
<td>innodb_old_blocks_time</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_print_all_deadlocks</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_purge_batch_size</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_random_read_ahead</td>
<td>Boolean</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_read_ahead_threshold</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_replication_delay</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_rollback_segments</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
<td>innodb_spin_wait_delay</td>
<td>Integer</td>
<td>Global</td>
</tr>
<tr>
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<td>unique_checks</td>
<td>Boolean</td>
<td>Varies</td>
</tr>
<tr>
<td>updatable_views_with_limit</td>
<td>Boolean</td>
<td>Both</td>
</tr>
<tr>
<td>wait_timeout</td>
<td>Integer</td>
<td>Both</td>
</tr>
</tbody>
</table>

### 5.1.8.3 Structured System Variables

A structured variable differs from a regular system variable in two respects:

- Its value is a structure with components that specify server parameters considered to be closely related.
- There might be several instances of a given type of structured variable. Each one has a different name and refers to a different resource maintained by the server.

MySQL supports one structured variable type, which specifies parameters governing the operation of key caches. A key cache structured variable has these components:

- `key_buffer_size`
- `key_cache_block_size`
- `key_cache_division_limit`
- `key_cache_age_threshold`
This section describes the syntax for referring to structured variables. Key cache variables are used for syntax examples, but specific details about how key caches operate are found elsewhere, in Section 8.10.2, “The MyISAM Key Cache”.

To refer to a component of a structured variable instance, you can use a compound name in `instance_name.component_name` format. Examples:

```
hot_cache.key_buffer_size
hot_cache.key_cache_block_size
cold_cache.key_cache_block_size
```

For each structured system variable, an instance with the name of `default` is always predefined. If you refer to a component of a structured variable without any instance name, the `default` instance is used. Thus, `default.key_buffer_size` and `key_buffer_size` both refer to the same system variable.

Structured variable instances and components follow these naming rules:

- For a given type of structured variable, each instance must have a name that is unique within variables of that type. However, instance names need not be unique across structured variable types. For example, each structured variable has an instance named `default`, so `default` is not unique across variable types.

- The names of the components of each structured variable type must be unique across all system variable names. If this were not true (that is, if two different types of structured variables could share component member names), it would not be clear which default structured variable to use for references to member names that are not qualified by an instance name.

- If a structured variable instance name is not legal as an unquoted identifier, refer to it as a quoted identifier using backticks. For example, `hot-cache` is not legal, but ``hot-cache` is.

- `global`, `session`, and `local` are not legal instance names. This avoids a conflict with notation such as `@@GLOBAL.var_name` for referring to nonstructured system variables.

Currently, the first two rules have no possibility of being violated because the only structured variable type is the one for key caches. These rules will assume greater significance if some other type of structured variable is created in the future.

With one exception, you can refer to structured variable components using compound names in any context where simple variable names can occur. For example, you can assign a value to a structured variable using a command-line option:

```
shell> mysqld --hot_cache.key_buffer_size=64K
```

In an option file, use this syntax:

```
[mysqld]
hot_cache.key_buffer_size=64K
```

If you start the server with this option, it creates a key cache named `hot_cache` with a size of 64KB in addition to the default key cache that has a default size of 8MB.

Suppose that you start the server as follows:

```
shell> mysqld --key_buffer_size=256K
   --extra_cache.key_buffer_size=128K
   --extra_cache.key_cache_block_size=2048
```

In this case, the server sets the size of the default key cache to 256KB. (You could also have written `--default.key_buffer_size=256K`.) In addition, the server creates a second key cache named `extra_cache` that has a size of 128KB, with the size of block buffers for caching table index blocks set to 2048 bytes.
Server Status Variables

The following example starts the server with three different key caches having sizes in a 3:1:1 ratio:

```shell
shell> mysqld --key_buffer_size=6M
    --hot_cache.key_buffer_size=2M
    --cold_cache.key_buffer_size=2M
```

Structured variable values may be set and retrieved at runtime as well. For example, to set a key cache named `hot_cache` to a size of 10MB, use either of these statements:

```sql
mysql> SET GLOBAL hot_cache.key_buffer_size = 10*1024*1024;
mysql> SET @@GLOBAL.hot_cache.key_buffer_size = 10*1024*1024;
```

To retrieve the cache size, do this:

```sql
mysql> SELECT @@GLOBAL.hot_cache.key_buffer_size;
```

However, the following statement does not work. The variable is not interpreted as a compound name, but as a simple string for a `LIKE` pattern-matching operation:

```sql
mysql> SHOW GLOBAL VARIABLES LIKE 'hot_cache.key_buffer_size';
```

This is the exception to being able to use structured variable names anywhere a simple variable name may occur.

5.1.9 Server Status Variables

The MySQL server maintains many status variables that provide information about its operation. You can view these variables and their values by using the `SHOW [GLOBAL | SESSION] STATUS` statement (see Section 13.7.5.36, “SHOW STATUS Statement”). The optional `GLOBAL` keyword aggregates the values over all connections, and `SESSION` shows the values for the current connection.

```sql
mysql> SHOW GLOBAL STATUS;
+-----------------+------------+
| Variable_name   | Value      |
+-----------------+------------+
| Aborted_clients | 0          |
| Aborted_connects| 0          |
| Bytes_received  | 155372598  |
| Bytes_sent      | 1176560426 |
| ...             |            |
| Connections     | 30023      |
| Created_tmp_disk_tables | 0 |
| Created_tmp_files | 3       |
| Created_tmp_tables | 2        |
| ...             |            |
| Threads_created | 217        |
| Threads_running | 88         |
| Uptime          | 1389872    |
+-----------------+------------+
```

Many status variables are reset to 0 by the `FLUSH STATUS` statement.

This section provides a description of each status variable. For a status variable summary, see Section 5.1.5, “Server Status Variable Reference”.

The status variables have the following meanings. For meanings of status variables specific to NDB Cluster, see NDB Cluster Status Variables.

- **Aborted_clients**

  The number of connections that were aborted because the client died without closing the connection properly. See Section B.4.2.11, “Communication Errors and Aborted Connections”.
Server Status Variables

- **Aborted_connects**
  
The number of failed attempts to connect to the MySQL server. See Section B.4.2.11, “Communication Errors and Aborted Connections”.

- **Binlog_cache_disk_use**
  
The number of transactions that used the binary log cache but that exceeded the value of `binlog_cache_size` and used a temporary file to store changes from the transaction.

  In MySQL versions 5.5.3 through 5.5.8, this variable also included the number of nontransactional statements that caused the binary log transaction cache to be written to disk. Beginning with MySQL 5.5.9, the number of such nontransactional statements is tracked separately in the `Binlog_stmt_cache_disk_use` status variable.

- **Binlog_cache_use**
  
The number of transactions that used the binary log cache.

- **Binlog_stmt_cache_disk_use**
  
The number of nontransactional statements that used the binary log statement cache but that exceeded the value of `binlog_stmt_cache_size` and used a temporary file to store those statements.

- **Binlog_stmt_cache_use**
  
The number of nontransactional statements that used the binary log statement cache.

- **Bytes_received**
  
The number of bytes received from all clients.

- **Bytes_sent**
  
The number of bytes sent to all clients.

- **Com_***
  
The `Com_***` statement counter variables indicate the number of times each `***` statement has been executed. There is one status variable for each type of statement. For example, `Com_delete` and `Com_update` count `DELETE` and `UPDATE` statements, respectively. `Com_delete_multi` and `Com_update_multi` are similar but apply to `DELETE` and `UPDATE` statements that use multiple-table syntax.

  If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, “Query Cache Status and Maintenance”.

  All `Com_stmt_***` variables are increased even if a prepared statement argument is unknown or an error occurred during execution. In other words, their values correspond to the number of requests issued, not to the number of requests successfully completed.

  The `Com_stmt_***` status variables are as follows:

  - **Com_stmt_prepare**
  
  - **Com_stmt_execute**
  
  - **Com_stmt_fetch**
Server Status Variables

- **Com_stmt_send_long_data**
- **Com_stmt_reset**
- **Com_stmt_close**

Those variables stand for prepared statement commands. Their names refer to the `COM_xxx` command set used in the network layer. In other words, their values increase whenever prepared statement API calls such as `mysql_stmt_prepare()`, `mysql_stmt_execute()`, and so forth are executed. However, `Com_stmt_prepare`, `Com_stmt_execute` and `Com_stmt_close` also increase for `PREPARE`, `EXECUTE`, or `DEALLOCATE PREPARE`, respectively. Additionally, the values of the older statement counter variables `Com_prepare_sql`, `Com_execute_sql`, and `Com_dealloc_sql` increase for the `PREPARE`, `EXECUTE`, and `DEALLOCATE PREPARE` statements. `Com_stmt_fetch` stands for the total number of network round-trips issued when fetching from cursors.

`Com_stmt_reprepare` indicates the number of times statements were automatically reprepared by the server after metadata changes to tables or views referred to by the statement. A reprepare operation increments `Com_stmt_reprepare`, and also `Com_stmt_prepare`.

- **Compression**
  Whether the client connection uses compression in the client/server protocol.

- **Connections**
  The number of connection attempts (successful or not) to the MySQL server.

- **Created_tmp_disk_tables**
  The number of internal on-disk temporary tables created by the server while executing statements.

  If an internal temporary table is created initially as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is the minimum of the `tmp_table_size` and `max_heap_table_size` values. If `Created_tmp_disk_tables` is large, you may want to increase the `tmp_table_size` or `max_heap_table_size` value to lessen the likelihood that internal temporary tables in memory will be converted to on-disk tables.

  You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

  See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.

- **Created_tmp_files**
  How many temporary files `mysql` has created.

- **Created_tmp_tables**
  The number of internal temporary tables created by the server while executing statements.

  You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

  See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.
Each invocation of the SHOW STATUS statement uses an internal temporary table and increments the global Created_tmp_tables value.

- **Delayed_errors**
  The number of rows written with INSERT DELAYED for which some error occurred (probably duplicate key).

- **Delayed_insert_threads**
  The number of INSERT DELAYED handler threads in use.

- **Delayed_writes**
  The number of INSERT DELAYED rows written.

- **Flush_commands**
  The number of times the server flushes tables, whether because a user executed a FLUSH TABLES statement or due to internal server operation. It is also incremented by receipt of a COM_REFRESH packet. This is in contrast to Com_flush, which indicates how many FLUSH statements have been executed, whether FLUSH TABLES, FLUSH LOGS, and so forth.

- **Handler_commit**
  The number of internal COMMIT statements.

- **Handler_delete**
  The number of times that rows have been deleted from tables.

- **Handler_prepare**
  A counter for the prepare phase of two-phase commit operations.

- **Handler_read_first**
  The number of times the first entry in an index was read. If this value is high, it suggests that the server is doing a lot of full index scans (for example, SELECT col1 FROM foo, assuming that col1 is indexed).

- **Handler_read_key**
  The number of requests to read a row based on a key. If this value is high, it is a good indication that your tables are properly indexed for your queries.

- **Handler_read_last**
  The number of requests to read the last key in an index. With ORDER BY, the server will issue a first-key request followed by several next-key requests, whereas with ORDER BY DESC, the server will issue a last-key request followed by several previous-key requests.

- **Handler_read_next**
  The number of requests to read the next row in key order. This value is incremented if you are querying an index column with a range constraint or if you are doing an index scan.

- **Handler_read_prev**
Server Status Variables

The number of requests to read the previous row in key order. This read method is mainly used to optimize `ORDER BY ... DESC`.

- **Handler_read_rnd**

  The number of requests to read a row based on a fixed position. This value is high if you are doing a lot of queries that require sorting of the result. You probably have a lot of queries that require MySQL to scan entire tables or you have joins that do not use keys properly.

- **Handler_read_rnd_next**

  The number of requests to read the next row in the data file. This value is high if you are doing a lot of table scans. Generally this suggests that your tables are not properly indexed or that your queries are not written to take advantage of the indexes you have.

- **Handler_rollback**

  The number of requests for a storage engine to perform a rollback operation.

- **Handler_savepoint**

  The number of requests for a storage engine to place a savepoint.

- **Handler_savepoint_rollback**

  The number of requests for a storage engine to roll back to a savepoint.

- **Handler_update**

  The number of requests to update a row in a table.

- **Handler_write**

  The number of requests to insert a row in a table.

- **Innodb_buffer_pool_bytes_data**

  The total number of bytes in the InnoDB buffer pool containing data. The number includes both dirty and clean pages. For more accurate memory usage calculations than with `Innodb_buffer_pool_pages_data`, when compressed tables cause the buffer pool to hold pages of different sizes.

- **Innodb_buffer_pool_pages_data**

  The number of pages in the InnoDB buffer pool containing data. The number includes both dirty and clean pages. When using compressed tables, the reported `Innodb_buffer_pool_pages_data` value may be larger than `Innodb_buffer_pool_pages_total` (Bug #59550).

- **Innodb_buffer_pool_bytes_dirty**

  The total current number of bytes held in dirty pages in the InnoDB buffer pool. For more accurate memory usage calculations than with `Innodb_buffer_pool_pages_dirty`, when compressed tables cause the buffer pool to hold pages of different sizes.

- **Innodb_buffer_pool_pages_dirty**

  The number of pages currently dirty.
• **Innodb_buffer_pool_pages_flushed**
  
  The number of buffer pool page-flush requests.

• **Innodb_buffer_pool_pages_free**
  
  The number of free pages.

• **Innodb_buffer_pool_pages_latched**
  
  The number of latched pages in InnoDB buffer pool. These are pages currently being read or written or that cannot be flushed or removed for some other reason. Calculation of this variable is expensive, so it is available only when the UNIV_DEBUG system is defined at server build time.

• **Innodb_buffer_pool_pages_misc**
  
  The number of pages that are busy because they have been allocated for administrative overhead such as row locks or the adaptive hash index. This value can also be calculated as Innodb_buffer_pool_pages_total − Innodb_buffer_pool_pages_free − Innodb_buffer_pool_pages_data. When using compressed tables, Innodb_buffer_pool_pages_misc may report an out-of-bounds value (Bug #59550).

• **Innodb_buffer_pool_pages_total**
  
  The total size of the InnoDB buffer pool, in pages. When using compressed tables, the reported Innodb_buffer_pool_pages_data value may be larger than Innodb_buffer_pool_pages_total (Bug #59550).

• **Innodb_buffer_pool_read_ahead**
  
  The number of pages read into the InnoDB buffer pool by the read-ahead background thread.

• **Innodb_buffer_pool_read_ahead_evicted**
  
  The number of pages read into the InnoDB buffer pool by the read-ahead background thread that were subsequently evicted without having been accessed by queries.

• **Innodb_buffer_pool_read_ahead_rnd**
  
  The number of “random” read-aheads initiated by InnoDB. This happens when a query scans a large portion of a table but in random order.

• **Innodb_buffer_pool_read_requests**
  
  The number of logical read requests.

• **Innodb_buffer_pool_reads**
  
  The number of logical reads that InnoDB could not satisfy from the buffer pool, and had to read directly from the disk.

• **Innodb_buffer_pool_wait_free**
  
  Normally, writes to the InnoDB buffer pool happen in the background. However, if it is necessary to read or create a page and no clean pages are available, it is also necessary to wait for pages to be flushed first. This counter counts instances of these waits. If the buffer pool size has been set properly, this value should be small.

• **Innodb_buffer_pool_write_requests**
The number writes done to the InnoDB buffer pool.

- **Innodb_data_fsyncs**
  The number of `fsync()` operations so far.

- **Innodb_data_pending_fsyncs**
  The current number of pending `fsync()` operations.

- **Innodb_data_pending_reads**
  The current number of pending reads.

- **Innodb_data_pending_writes**
  The current number of pending writes.

- **Innodb_data_read**
  The amount of data read since the server was started (in bytes).

- **Innodb_data_reads**
  The total number of data reads (OS file reads).

- **Innodb_data_writes**
  The total number of data writes.

- **Innodb_data_written**
  The amount of data written so far, in bytes.

- **Innodb_dblwr_pages_written**
  The number of pages that have been written for doublewrite operations. See Section 14.15.1, “InnoDB Disk I/O”.

- **Innodb_dblwr_writes**
  The number of doublewrite operations that have been performed. See Section 14.15.1, “InnoDB Disk I/O”.

- **Innodb_have_atomic_builtins**
  Indicates whether the server was built with atomic instructions.

- **Innodb_log_waits**
  The number of times that the log buffer was too small and a wait was required for it to be flushed before continuing.

- **Innodb_log_write_requests**
  The number of log write requests.

- **Innodb_log_writes**
Server Status Variables

The number of physical writes to the log file.

• **Innodb_os_log_fsyncs**
  The number of `fsync()` writes done to the log file.

• **Innodb_os_log_pending_fsyncs**
  The number of pending log file `fsync()` operations.

• **Innodb_os_log_pending_writes**
  The number of pending log file writes.

• **Innodb_os_log_written**
  The number of bytes written to the log file.

• **Innodb_page_size**
  The compiled-in InnoDB page size (default 16KB). Many values are counted in pages; the page size enables them to be easily converted to bytes.

• **Innodb_pages_created**
  The number of pages created.

• **Innodb_pages_read**
  The number of pages read from the InnoDB buffer pool by operations on InnoDB tables.

• **Innodb_pages_written**
  The number of pages written.

• **Innodb_row_lock_current_waits**
  The number of row locks currently being waited for.

• **Innodb_row_lock_time**
  The total time spent in acquiring row locks, in milliseconds.

• **Innodb_row_lock_time_avg**
  The average time to acquire a row lock, in milliseconds.

• **Innodb_row_lock_time_max**
  The maximum time to acquire a row lock, in milliseconds.

• **Innodb_row_lock_waits**
  The number of times a row lock had to be waited for.

• **Innodb_rows_deleted**
  The number of rows deleted from InnoDB tables.
Server Status Variables

- **Innodb_rows_inserted**
  The number of rows inserted into InnoDB tables.

- **Innodb_rows_read**
  The number of rows read from InnoDB tables.

- **Innodb_rows_updated**
  The number of rows updated in InnoDB tables.

- **Innodb_truncated_status_writes**
  The number of times output from the `SHOW ENGINE INNODB STATUS` is truncated. Monitoring applications that parse the output from this command can test this value before and after issuing the `SHOW ENGINE` command, to confirm if the output is complete or not.

- **Key_blocks_not_flushed**
  The number of key blocks in the key cache that have changed but have not yet been flushed to disk.

- **Key_blocks_unused**
  The number of unused blocks in the key cache. You can use this value to determine how much of the key cache is in use; see the discussion of `key_buffer_size` in Section 5.1.7, “Server System Variables”.

- **Key_blocks_used**
  The number of used blocks in the key cache. This value is a high-water mark that indicates the maximum number of blocks that have ever been in use at one time.

- **Key_read_requests**
  The number of requests to read a key block from the cache.

- **Key_reads**
  The number of physical reads of a key block from disk. If `Key_reads` is large, then your `key_buffer_size` value is probably too small. The cache miss rate can be calculated as `Key_reads/Key_read_requests`.

- **Key_write_requests**
  The number of requests to write a key block to the cache.

- **Key_writes**
  The number of physical writes of a key block to disk.

- **Last_query_cost**
  The total cost of the last compiled query as computed by the query optimizer. This is useful for comparing the cost of different query plans for the same query. The default value of 0 means that no query has been compiled yet. The default value is 0. `Last_query_cost` has session scope.

`Last_query_cost` can be computed accurately only for simple, “flat” queries, but not for complex queries such as those containing subqueries or `UNION`. For the latter, the value is set to 0.
Server Status Variables

- **Max_used_connections**
  The maximum number of connections that have been in use simultaneously since the server started.

- **Not_flushed_delayed_rows**
  The number of rows waiting to be written in `INSERT DELAYED` queues.

- **Open_files**
  The number of files that are open. This count includes regular files opened by the server. It does not include other types of files such as sockets or pipes. Also, the count does not include files that storage engines open using their own internal functions rather than asking the server level to do so.

- **Open_streams**
  The number of streams that are open (used mainly for logging).

- **Open_table_definitions**
  The number of cached `.frm` files.

- **Open_tables**
  The number of tables that are open.

- **Opened_files**
  The number of files that have been opened with `my_open()` (a `mysys` library function). Parts of the server that open files without using this function do not increment the count.

- **Opened_table_definitions**
  The number of `.frm` files that have been cached.

- **Opened_tables**
  The number of tables that have been opened. If `Opened_tables` is big, your `table_open_cache` value is probably too small.

- **Performance_schema_xxx**
  Performance Schema status variables are listed in Section 22.13, “Performance Schema Status Variables”. These variables provide information about instrumentation that could not be loaded or created due to memory constraints.

- **Prepared_stmt_count**
  The current number of prepared statements. (The maximum number of statements is given by the `max_prepared_stmt_count` system variable.)

- **Qcache_free_blocks**
  The number of free memory blocks in the query cache.

- **Qcache_free_memory**
  The amount of free memory for the query cache.

- **Qcache_hits**

The number of query cache hits.

The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- **Qcache_inserts**
  The number of queries added to the query cache.

- **Qcache_lowmem_prunes**
  The number of queries that were deleted from the query cache because of low memory.

- **Qcache_not_cached**
  The number of noncached queries (not cacheable, or not cached due to the `query_cache_type` setting).

- **Qcache_queries_in_cache**
  The number of queries registered in the query cache.

- **Qcache_total_blocks**
  The total number of blocks in the query cache.

- **Queries**
  The number of statements executed by the server. This variable includes statements executed within stored programs, unlike the `Questions` variable. It does not count `COM_PING` or `COM_STATISTICS` commands.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- **Questions**
  The number of statements executed by the server. This includes only statements sent to the server by clients and not statements executed within stored programs, unlike the `Queries` variable. This variable does not count `COM_PING`, `COM_STATISTICS`, `COM_STMT_PREPARE`, `COM_STMT_CLOSE`, or `COM_STMT_RESET` commands.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- **Rpl_semi_sync_master_clients**
  The number of semisynchronous slaves.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- **Rpl_semi_sync_master_net_avg_wait_time**
  The average time in microseconds the master waited for a slave reply.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- **Rpl_semi_sync_master_net_wait_time**
Server Status Variables

The total time in microseconds the master waited for slave replies.
This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_net_waits**
  The total number of times the master waited for slave replies.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_no_times**
  The number of times the master turned off semisynchronous replication.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_no_tx**
  The number of commits that were not acknowledged successfully by a slave.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_status**
  Whether semisynchronous replication currently is operational on the master. The value is **ON** if the plugin has been enabled and a commit acknowledgment has occurred. It is **OFF** if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_timefunc_failures**
  The number of times the master failed when calling time functions such as `gettimeofday()`.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_tx_avg_wait_time**
  The average time in microseconds the master waited for each transaction.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_tx_wait_time**
  The total time in microseconds the master waited for transactions.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_tx_waits**
  The total number of times the master waited for transactions.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

• **Rpl_semi_sync_master_wait_pos_backtraverse**
  The total number of times the master waited for an event with binary coordinates lower than events waited for previously. This can occur when the order in which transactions start waiting for a reply is different from the order in which their binary log events are written.
Server Status Variables

This variable is available only if the master-side semisynchronous replication plugin is installed.

- **Rpl_semi_sync_master_wait_sessions**
  The number of sessions currently waiting for slave replies.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

- **Rpl_semi_sync_master_yes_tx**
  The number of commits that were acknowledged successfully by a slave.
  This variable is available only if the master-side semisynchronous replication plugin is installed.

- **Rpl_semi_sync_slave_status**
  Whether semisynchronous replication currently is operational on the slave. This is **ON** if the plugin has been enabled and the slave I/O thread is running, **OFF** otherwise.
  This variable is available only if the slave-side semisynchronous replication plugin is installed.

- **Rpl_status**
  The status of fail-safe replication (not implemented). This variable is unused and is removed in MySQL 5.6.

- **Select_full_join**
  The number of joins that perform table scans because they do not use indexes. If this value is not 0, you should carefully check the indexes of your tables.

- **Select_full_range_join**
  The number of joins that used a range search on a reference table.

- **Select_range**
  The number of joins that used ranges on the first table. This is normally not a critical issue even if the value is quite large.

- **Select_range_check**
  The number of joins without keys that check for key usage after each row. If this is not 0, you should carefully check the indexes of your tables.

- **Select_scan**
  The number of joins that did a full scan of the first table.

- **Slave_heartbeat_period**
  Shows the replication heartbeat interval (in seconds) on a replication slave.

- **Slave_open_temp_tables**
  The number of temporary tables that the slave SQL thread currently has open. If the value is greater than zero, it is not safe to shut down the slave; see Section 17.4.1.30, “Replication and Temporary Tables”.
Server Status Variables

- **Slave_received_heartbeats**
  This counter increments with each replication heartbeat received by a replication slave since the last time that the slave was restarted or reset, or a `CHANGE MASTER TO` statement was issued.

- **Slave_retried_transactions**
  The total number of times since startup that the replication slave SQL thread has retried transactions.

- **Slave_running**
  This is **ON** if this server is a replication slave that is connected to a replication master, and both the I/O and SQL threads are running; otherwise, it is **OFF**.

- **Slow_launch_threads**
  The number of threads that have taken more than `slow_launch_time` seconds to create.

- **Slow_queries**
  The number of queries that have taken more than `long_query_time` seconds. This counter increments regardless of whether the slow query log is enabled. For information about that log, see Section 5.4.5, "The Slow Query Log".

- **Sort_merge_passes**
  The number of merge passes that the sort algorithm has had to do. If this value is large, you should consider increasing the value of the `sort_buffer_size` system variable.

- **Sort_range**
  The number of sorts that were done using ranges.

- **Sort_rows**
  The number of sorted rows.

- **Sort_scan**
  The number of sorts that were done by scanning the table.

- **Ssl_accept_renegotiates**
  The number of renegotiates needed to establish the connection.

- **Ssl_accepts**
  The number of accepted SSL connections.

- **Ssl_callback_cache_hits**
  The number of callback cache hits.

- **Ssl_cipher**
  The current encryption cipher (empty for unencrypted connections).

- **Ssl_cipher_list**
  The list of possible SSL ciphers (empty for non-SSL connections).
Server Status Variables

- **Ssl_client_connects**
  The number of SSL connection attempts to an SSL-enabled master.

- **Ssl_connect_renegotiates**
  The number of renegotiates needed to establish the connection to an SSL-enabled master.

- **Ssl_ctx_verify_depth**
  The SSL context verification depth (how many certificates in the chain are tested).

- **Ssl_ctx_verify_mode**
  The SSL context verification mode.

- **Ssl_default_timeout**
  The default SSL timeout.

- **Ssl_finished_accepts**
  The number of successful SSL connections to the server.

- **Ssl_finished_connects**
  The number of successful slave connections to an SSL-enabled master.

- **Ssl_session_cache_hits**
  The number of SSL session cache hits.

- **Ssl_session_cache_misses**
  The number of SSL session cache misses.

- **Ssl_session_cache_mode**
  The SSL session cache mode.

- **Ssl_session_cache_overflows**
  The number of SSL session cache overflows.

- **Ssl_session_cache_size**
  The SSL session cache size.

- **Ssl_session_cache_timeouts**
  The number of SSL session cache timeouts.

- **Ssl_sessions_reused**
  How many SSL connections were reused from the cache.

- **Ssl_used_session_cache_entries**
  How many SSL session cache entries were used.

- **Ssl_verify_depth**
The verification depth for replication SSL connections.

- **Ssl_verify_mode**

  The verification mode used by the server for a connection that uses SSL. The value is a bitmask; bits are defined in the `openssl/ssl.h` header file:

  ```
  # define SSL_VERIFY_NONE                 0x00
  # define SSL_VERIFY_PEER                 0x01
  # define SSL_VERIFY_FAIL_IF_NO_PEER_CERT 0x02
  # define SSL_VERIFY_CLIENT_ONCE          0x04
  ```

  **SSL_VERIFY_PEER** indicates that the server asks for a client certificate. If the client supplies one, the server performs verification and proceeds only if verification is successful. **SSL_VERIFY_CLIENT_ONCE** indicates that a request for the client certificate will be done only in the initial handshake.

- **Ssl_version**

  The SSL protocol version of the connection (for example, TLSv1). If the connection is not encrypted, the value is empty.

- **Table_locks_immediate**

  The number of times that a request for a table lock could be granted immediately.

- **Table_locks_waited**

  The number of times that a request for a table lock could not be granted immediately and a wait was needed. If this is high and you have performance problems, you should first optimize your queries, and then either split your table or tables or use replication.

- **Tc_log_max_pages_used**

  For the memory-mapped implementation of the log that is used by `mysqld` when it acts as the transaction coordinator for recovery of internal XA transactions, this variable indicates the largest number of pages used for the log since the server started. If the product of `Tc_log_max_pages_used` and `Tc_log_page_size` is always significantly less than the log size, the size is larger than necessary and can be reduced. (The size is set by the `--log-tc-size` option. This variable is unused: It is unneeded for binary log-based recovery, and the memory-mapped recovery log method is not used unless the number of storage engines that are capable of two-phase commit and that support XA transactions is greater than one. (InnoDB is the only applicable engine.)

- **Tc_log_page_size**

  The page size used for the memory-mapped implementation of the XA recovery log. The default value is determined using `getpagesize()`. This variable is unused for the same reasons as described for `Tc_log_max_pages_used`.

- **Tc_log_page_waits**

  For the memory-mapped implementation of the recovery log, this variable increments each time the server was not able to commit a transaction and had to wait for a free page in the log. If this value is large, you might want to increase the log size (with the `--log-tc-size` option). For binary log-based recovery, this variable increments each time the binary log cannot be closed because there are two-phase commits in progress. (The close operation waits until all such transactions are finished.)

- **Threads_cached**
The number of threads in the thread cache.

- **Threads_connected**
  The number of currently open connections.

- **Threads_created**
  The number of threads created to handle connections. If `Threads_created` is big, you may want to increase the `thread_cache_size` value. The cache miss rate can be calculated as `Threads_created/Connections`.

- **Threads_running**
  The number of threads that are not sleeping.

- **Uptime**
  The number of seconds that the server has been up.

- **Uptime_since_flush_status**
  The number of seconds since the most recent `FLUSH STATUS` statement.

### 5.1.10 Server SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the `sql_mode` system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

- **Setting the SQL Mode**
- **The Most Important SQL Modes**
- **Full List of SQL Modes**
- **Combination SQL Modes**
- **Strict SQL Mode**

For answers to questions often asked about server SQL modes in MySQL, see Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”.

When working with InnoDB tables, consider also the `innodb_strict_mode` system variable. It enables additional error checks for InnoDB tables.

**Setting the SQL Mode**

The default SQL mode is empty (no modes set).

To set the SQL mode at server startup, use the `--sql-mode="modes"` option on the command line, or `sql-mode="modes"` in an option file such as `my.cnf` (Unix operating systems) or `my.ini` (Windows).
Server SQL Modes

"modes" is a list of different modes separated by commas. To clear the SQL mode explicitly, set it to an empty string using `--sql-mode=""` on the command line, or `sql-mode=""` in an option file.

**Note**

MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

To change the SQL mode at runtime, set the global or session `sql_mode` system variable using a `SET` statement:

```sql
SET GLOBAL sql_mode = 'modes';
SET SESSION sql_mode = 'modes';
```

Setting the `GLOBAL` variable requires the `SUPER` privilege and affects the operation of all clients that connect from that time on. Setting the `SESSION` variable affects only the current client. Each client can change its session `sql_mode` value at any time.

To determine the current global or session `sql_mode` setting, select its value:

```sql
SELECT @@GLOBAL.sql_mode;
SELECT @@SESSION.sql_mode;
```

**Important**

**SQL mode and user-defined partitioning.** Changing the server SQL mode after creating and inserting data into partitioned tables can cause major changes in the behavior of such tables, and could lead to loss or corruption of data. It is strongly recommended that you never change the SQL mode once you have created tables employing user-defined partitioning.

When replicating partitioned tables, differing SQL modes on the master and slave can also lead to problems. For best results, you should always use the same server SQL mode on the master and slave.

For more information, see Section 19.5, “Restrictions and Limitations on Partitioning”.

### The Most Important SQL Modes

The most important `sql_mode` values are probably these:

- **ANSI**

  This mode changes syntax and behavior to conform more closely to standard SQL. It is one of the special combination modes listed at the end of this section.

- **STRICT_TRANS_TABLES**

  If a value could not be inserted as given into a transactional table, abort the statement. For a nontransactional table, abort the statement if the value occurs in a single-row statement or the first row of a multiple-row statement. More details are given later in this section.

- **TRADITIONAL**

  Make MySQL behave like a “traditional” SQL database system. A simple description of this mode is “give an error instead of a warning” when inserting an incorrect value into a column. It is one of the special combination modes listed at the end of this section.
Note

With TRADITIONAL mode enabled, an INSERT or UPDATE aborts as soon as an error occurs. If you are using a nontransactional storage engine, this may not be what you want because data changes made prior to the error may not be rolled back, resulting in a “partially done” update.

When this manual refers to “strict mode,” it means a mode with either or both STRICT_TRANS_TABLES or STRICT_ALL_TABLES enabled.

Full List of SQL Modes

The following list describes all supported SQL modes:

- **ALLOW_INVALID_DATES**
  
  Do not perform full checking of dates. Check only that the month is in the range from 1 to 12 and the day is in the range from 1 to 31. This may be useful for Web applications that obtain year, month, and day in three different fields and store exactly what the user inserted, without date validation. This mode applies to DATE and DATETIME columns. It does not apply to TIMESTAMP columns, which always require a valid date.

  With ALLOW_INVALID_DATES disabled, the server requires that month and day values be legal, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as '2004-04-31' are converted to '0000-00-00' and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable ALLOW_INVALID_DATES.

- **ANSI_QUOTES**

  Treat " as an identifier quote character (like the ` quote character) and not as a string quote character. You can still use ` to quote identifiers with this mode enabled. With ANSI_QUOTES enabled, you cannot use double quotation marks to quote literal strings because they are interpreted as identifiers.

- **ERROR_FOR_DIVISION_BY_ZERO**

  The ERROR_FOR_DIVISION_BY_ZERO mode affects handling of division by zero, which includes MOD($n, 0). For data-change operations (INSERT, UPDATE), its effect also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, division by zero inserts NULL and produces no warning.
  
  - If this mode is enabled, division by zero inserts NULL and produces a warning.
  
  - If this mode and strict mode are enabled, division by zero produces an error, unless IGNORE is given as well. For INSERT IGNORE and UPDATE IGNORE, division by zero inserts NULL and produces a warning.

  For SELECT, division by zero returns NULL. Enabling ERROR_FOR_DIVISION_BY_ZERO causes a warning to be produced as well, regardless of whether strict mode is enabled.

- **HIGH_NOT_PRECEDENCE**

  The precedence of the NOT operator is such that expressions such as NOT $a$ BETWEEN $b$ AND $c$ are parsed as NOT ($a$ BETWEEN $b$ AND $c$). In some older versions of MySQL, the expression was parsed as (NOT $a$) BETWEEN $b$ AND $c$. The old higher-precedence behavior can be obtained by enabling the HIGH_NOT_PRECEDENCE SQL mode.
Server SQL Modes

• **IGNORE_SPACE**

Permit spaces between a function name and the ( character. This causes built-in function names to be treated as reserved words. As a result, identifiers that are the same as function names must be quoted as described in Section 9.2, “Schema Object Names”. For example, because there is a `COUNT()` function, the use of `count` as a table name in the following statement causes an error:

```sql
mysql> CREATE TABLE count (i INT);
ERROR 1064 (42000): You have an error in your SQL syntax
```

The table name should be quoted:

```sql
mysql> CREATE TABLE `count` (i INT);
Query OK, 0 rows affected (0.00 sec)
```

The **IGNORE_SPACE** SQL mode applies to built-in functions, not to user-defined functions or stored functions. It is always permissible to have spaces after a UDF or stored function name, regardless of whether **IGNORE_SPACE** is enabled.

For further discussion of **IGNORE_SPACE**, see Section 9.2.5, “Function Name Parsing and Resolution”.

• **NO_AUTO_CREATE_USER**

Prevent the **GRANT** statement from automatically creating new users if it would otherwise do so, unless authentication information is specified. The statement must specify a nonempty password using **IDENTIFIED BY** or an authentication plugin using **IDENTIFIED WITH**.

• **NO_AUTO_VALUE_ON_ZERO**

**NO_AUTO_VALUE_ON_ZERO** affects handling of **AUTO_INCREMENT** columns. Normally, you generate the next sequence number for the column by inserting either `NULL` or `0` into it. **NO_AUTO_VALUE_ON_ZERO** suppresses this behavior for `0` so that only `NULL` generates the next sequence number.

This mode can be useful if `0` has been stored in a table's **AUTO_INCREMENT** column. (Storing `0` is not a recommended practice, by the way.) For example, if you dump the table with **mysqldump** and then reload it, MySQL normally generates new sequence numbers when it encounters the `0` values, resulting in a table with contents different from the one that was dumped. Enabling **NO_AUTO_VALUE_ON_ZERO** before reloading the dump file solves this problem. For this reason, **mysqldump** automatically includes in its output a statement that enables **NO_AUTO_VALUE_ON_ZERO**.

• **NO_BACKSLASH_ESCAPES**

Disable the use of the backslash character (`\`) as an escape character within strings and identifiers. With this mode enabled, backslash becomes an ordinary character like any other.

• **NO_DIR_IN_CREATE**

When creating a table, ignore all **INDEX DIRECTORY** and **DATA DIRECTORY** directives. This option is useful on slave replication servers.

• **NO_ENGINE_SUBSTITUTION**
Control automatic substitution of the default storage engine when a statement such as `CREATE TABLE` or `ALTER TABLE` specifies a storage engine that is disabled or not compiled in.

Because storage engines can be pluggable at runtime, unavailable engines are treated the same way:

With `NO_ENGINE_SUBSTITUTION` disabled, for `CREATE TABLE` the default engine is used and a warning occurs if the desired engine is unavailable. For `ALTER TABLE`, a warning occurs and the table is not altered.

With `NO_ENGINE_SUBSTITUTION` enabled, an error occurs and the table is not created or altered if the desired engine is unavailable.

- **NO_FIELD_OPTIONS**

  Do not print MySQL-specific column options in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- **NO_KEY_OPTIONS**

  Do not print MySQL-specific index options in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- **NO_TABLE_OPTIONS**

  Do not print MySQL-specific table options (such as `ENGINE`) in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- **NO_UNSIGNED_SUBTRACTION**

  Subtraction between integer values, where one is of type `UNSIGNED`, produces an unsigned result by default. Prior to MySQL 5.5.5, if the result would otherwise have been negative, it becomes the maximum integer value:

  ```sql
  mysql> SET sql_mode = '';
mynsql> SELECT CAST(0 AS UNSIGNED) - 1;
  +-------------------------+
  | CAST(0 AS UNSIGNED) - 1 |
  +-------------------------+
  | 18446744073709551615 |
  +-------------------------+
  ``

  As of MySQL 5.5.5, if the result would otherwise have been negative, an error results:

  ```sql
  mysql> SET sql_mode = '';
  Query OK, 0 rows affected (0.00 sec)
  mysql> SELECT CAST(0 AS UNSIGNED) - 1;
  ERROR 1690 (22003): BIGINT UNSIGNED value is out of range in '(cast(0 as unsigned) - 1)'
  ``

  If the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled, the result is negative:

  ```sql
  mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mynsql> SELECT CAST(0 AS UNSIGNED) - 1;
  +-------------------------+
  | CAST(0 AS UNSIGNED) - 1 |
  +-------------------------+
  | -1 |
  +-------------------------+
  ```
If the result of such an operation is used to update an \texttt{UNSIGNED} integer column, the result is clipped to the maximum value for the column type, or clipped to 0 if \texttt{NO_UNSIGNED_SUBTRACTION} is enabled. With strict SQL mode enabled, an error occurs and the column remains unchanged.

When \texttt{NO_UNSIGNED_SUBTRACTION} is enabled, the subtraction result is signed, \textit{even if any operand is unsigned}. For example, compare the type of column \texttt{c2} in table \texttt{t1} with that of column \texttt{c2} in table \texttt{t2}:

\begin{verbatim}
mysql> SET sql_mode='';
mysql> CREATE TABLE test (c1 BIGINT UNSIGNED NOT NULL);
mysql> CREATE TABLE t1 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t1;
+-------+---------------------+------+-----+---------+-------+
| Field | Type                | Null | Key | Default | Extra |
|-------+---------------------+------+-----+---------+-------+
| c2    | bigint(21) unsigned | NO   |     | 0       |       |
+-------+---------------------+------+-----+---------+-------+
mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
mysql> CREATE TABLE t2 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t2;
+-------+------------+------+-----+---------+-------+
| Field | Type       | Null | Key | Default | Extra |
|-------+------------+------+-----+---------+-------+
| c2    | bigint(21) | NO   |     | 0       |       |
+-------+------------+------+-----+---------+-------+
\end{verbatim}

This means that \texttt{BIGINT UNSIGNED} is not 100\% usable in all contexts. See Section 12.10, "Cast Functions and Operators".

- \texttt{NO_ZERO_DATE}

The \texttt{NO_ZERO_DATE} mode affects whether the server permits \texttt{'0000-00-00'} as a valid date. Its effect also depends on whether strict SQL mode is enabled.

- If this mode is not enabled, \texttt{'0000-00-00'} is permitted and inserts produce no warning.

- If this mode is enabled, \texttt{'0000-00-00'} is permitted and inserts produce a warning.

- If this mode and strict mode are enabled, \texttt{'0000-00-00'} is not permitted and inserts produce an error, unless \texttt{IGNORE} is given as well. For \texttt{INSERT IGNORE} and \texttt{UPDATE IGNORE}, \texttt{'0000-00-00'} is permitted and inserts produce a warning.

- \texttt{NO_ZERO_IN_DATE}

The \texttt{NO_ZERO_IN_DATE} mode affects whether the server permits dates in which the year part is nonzero but the month or day part is 0. (This mode affects dates such as \texttt{'2010-00-01'} or \texttt{'2010-01-00'}, but not \texttt{'0000-00-00'}. To control whether the server permits \texttt{'0000-00-00'}, use the \texttt{NO_ZERO_DATE} mode.) The effect of \texttt{NO_ZERO_IN_DATE} also depends on whether strict SQL mode is enabled.

- If this mode is not enabled, dates with zero parts are permitted and inserts produce no warning.

- If this mode is enabled, dates with zero parts are inserted as \texttt{'0000-00-00'} and produce a warning.

- If this mode and strict mode are enabled, dates with zero parts are not permitted and inserts produce an error, unless \texttt{IGNORE} is given as well. For \texttt{INSERT IGNORE} and \texttt{UPDATE IGNORE}, dates with zero parts are inserted as \texttt{'0000-00-00'} and produce a warning.
**Server SQL Modes**

- **ONLY_FULL_GROUP_BY**

  Reject queries for which the select list or **HAVING** condition refer to nonaggregated columns that are not named in the **GROUP BY** clause.

  A MySQL extension to standard SQL permits references in the **HAVING** clause to aliased expressions in the select list. Enabling **ONLY_FULL_GROUP_BY** disables this extension, thus requiring the **HAVING** clause to be written using unaliased expressions.

  For additional discussion and examples, see *Section 12.17.3, “MySQL Handling of GROUP BY”*.  

- **PAD_CHAR_TO_FULL_LENGTH**

  By default, trailing spaces are trimmed from **CHAR** column values on retrieval. If **PAD_CHAR_TO_FULL_LENGTH** is enabled, trimming does not occur and retrieved **CHAR** values are padded to their full length. This mode does not apply to **VARCHAR** columns, for which trailing spaces are retained on retrieval.

    ```
    mysql> CREATE TABLE t1 (c1 CHAR(10));
    Query OK, 0 rows affected (0.37 sec)
    mysql> INSERT INTO t1 (c1) VALUES('xy');
    Query OK, 1 row affected (0.01 sec)
    mysql> SET sql_mode = '';
    Query OK, 0 rows affected (0.00 sec)
    mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
    +------+-----------------+
    | c1   | CHAR_LENGTH(c1) |
    +------+-----------------+
    | xy   |               2 |
    +------+-----------------+
    1 row in set (0.00 sec)
    mysql> SET sql_mode = 'PAD_CHAR_TO_FULL_LENGTH';
    Query OK, 0 rows affected (0.00 sec)
    mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
    +------------+-----------------+
    | c1         | CHAR_LENGTH(c1) |
    +------------+-----------------+
    | xy         |              10 |
    +------------+-----------------+
    1 row in set (0.00 sec)
    ```

- **PIPES_AS_CONCAT**

  Treat `||` as a string concatenation operator (same as **CONCAT()**) rather than as a synonym for **OR**.

- **REAL_AS_FLOAT**

  Treat **REAL** as a synonym for **FLOAT**. By default, MySQL treats **REAL** as a synonym for **DOUBLE**.

- **STRICT_ALL_TABLES**

  Enable strict SQL mode for all storage engines. Invalid data values are rejected. For details, see *Strict SQL Mode*.
Server SQL Modes

- **STRTRANSL_TABLES**

  Enable strict SQL mode for transactional storage engines, and when possible for nontransactional storage engines. For details, see Strict SQL Mode.

Combination SQL Modes

The following special modes are provided as shorthand for combinations of mode values from the preceding list.

- **ANSI**

  Equivalent to `REAL_AS_FLOAT, PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE`.

  **ANSI** mode also causes the server to return an error for queries where a set function \( S \) with an outer reference \( S(outer_ref) \) cannot be aggregated in the outer query against which the outer reference has been resolved. This is such a query:

  ```sql
  SELECT * FROM t1 WHERE t1.a IN (SELECT MAX(t1.b) FROM t2 WHERE ...);
  ```

  Here, \( MAX(t1.b) \) cannot aggregated in the outer query because it appears in the WHERE clause of that query. Standard SQL requires an error in this situation. If **ANSI** mode is not enabled, the server treats \( S(outer_ref) \) in such queries the same way that it would interpret \( S(const) \).

  See Section 1.7, “MySQL Standards Compliance”.

- **DB2**

  Equivalent to `PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE, NO_KEY_OPTIONS, NO_TABLE_OPTIONS, NO_FIELD_OPTIONS`.

- **MAXDB**

  Equivalent to `PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE, NO_KEY_OPTIONS, NO_TABLE_OPTIONS, NO_FIELD_OPTIONS, NO_AUTO_CREATE_USER`.

- **MSSQL**

  Equivalent to `PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE, NO_KEY_OPTIONS, NO_TABLE_OPTIONS, NO_FIELD_OPTIONS`.

- **MYSQL323**

  Equivalent to `MYSQL323, HIGH_NOT_PRECEDENCE`. This means `HIGH_NOT_PRECEDENCE` plus some `SHOW CREATE TABLE` behaviors specific to **MYSQL323**:

  - **TIMESTAMP** column display does not include `DEFAULT` or `ON UPDATE` attributes.
  - String column display does not include character set and collation attributes. For **CHAR** and **VARCHAR** columns, if the collation is binary, **BINARY** is appended to the column type.
  - The **ENGINE=engine_name** table option displays as **TYPE=engine_name**.
  - For **MEMORY** tables, the storage engine is displayed as **HEAP**.

- **MYSQL40**
Equivalent to MySQL40, HIGH_NOT_PRECEDENCE. This means HIGH_NOT_PRECEDENCE plus some behaviors specific to MySQL40. These are the same as for MySQL323, except that SHOW CREATE TABLE does not display HEAP as the storage engine for MEMORY tables.

- **ORACLE**

  Equivalent to PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE, NO_KEY_OPTIONS, NO_TABLE_OPTIONS, NO_FIELD_OPTIONS, NO_AUTO_CREATE_USER.

- **POSTGRESQL**

  Equivalent to PIPES_AS_CONCAT, ANSI_QUOTES, IGNORE_SPACE, NO_KEY_OPTIONS, NO_TABLE_OPTIONS, NO_FIELD_OPTIONS.

- **TRADITIONAL**

  Equivalent to STRICT_TRANS_TABLES, STRICT_ALL_TABLES, NO_ZERO_IN_DATE, NO_ZERO_DATE, ERROR_FOR_DIVISION_BY_ZERO, NO_AUTO_CREATE_USER, and NO_ENGINE_SUBSTITUTION.

**Strict SQL Mode**

Strict mode controls how MySQL handles invalid or missing values in data-change statements such as INSERT or UPDATE. A value can be invalid for several reasons. For example, it might have the wrong data type for the column, or it might be out of range. A value is missing when a new row to be inserted does not contain a value for a non-NULL column that has no explicit DEFAULT clause in its definition. (For a NULL column, NULL is inserted if the value is missing.)

If strict mode is not in effect, MySQL inserts adjusted values for invalid or missing values and produces warnings (see Section 13.7.5.41, "SHOW WARNINGS Statement"). In strict mode, you can produce this behavior by using INSERT IGNORE or UPDATE IGNORE.

For statements such as SELECT that do not change data, invalid values generate a warning in strict mode, not an error.

Strict mode does not affect whether foreign key constraints are checked. foreign_key_checks can be used for that. (See Section 5.1.7, “Server System Variables").

Strict SQL mode is in effect if either STRICT_ALL_TABLES or STRICT_TRANS_TABLES is enabled, although the effects of these modes differ somewhat:

- For transactional tables, an error occurs for invalid or missing values in a data-change statement when either STRICT_ALL_TABLES or STRICT_TRANS_TABLES is enabled. The statement is aborted and rolled back.

- For nontransactional tables, the behavior is the same for either mode if the bad value occurs in the first row to be inserted or updated: The statement is aborted and the table remains unchanged. If the statement inserts or modifies multiple rows and the bad value occurs in the second or later row, the result depends on which strict mode is enabled:
  - For STRICT_ALL_TABLES, MySQL returns an error and ignores the rest of the rows. However, because the earlier rows have been inserted or updated, the result is a partial update. To avoid this, use single-row statements, which can be aborted without changing the table.
  - For STRICT_TRANS_TABLES, MySQL converts an invalid value to the closest valid value for the column and inserts the adjusted value. If a value is missing, MySQL inserts the implicit default value for the column data type. In either case, MySQL generates a warning rather than an error and
IPv6 Support

continues processing the statement. Implicit defaults are described in Section 11.5, “Data Type Default Values”.

Strict mode also affects handling of division by zero, zero dates, and zeros in dates, in conjunction with the \texttt{ERROR\_FOR\_DIVISION\_BY\_ZERO}, \texttt{NO\_ZERO\_DATE}, and \texttt{NO\_ZERO\_IN\_DATE} modes. For details, see the descriptions of those modes.

5.1.11 IPv6 Support

Support for IPv6 includes these capabilities:

- MySQL Server can accept TCP/IP connections from clients connecting over IPv6. For example, this command connects over IPv6 to the MySQL server on the local host:
  
  \texttt{shell> mysql -h ::1}

  To use this capability, two things must be true:

  - Your system must be configured to support IPv6. See Section 5.1.11.1, “Verifying System Support for IPv6”.

  - The default MySQL server configuration permits only IPv4 connections, so the server must be configured for IPv6 connections. To permit IPv6 connections in addition to or instead of IPv4 connections, start the server with an appropriate \texttt{--bind-address} option. See Section 5.1.7, “Server System Variables”.

- MySQL account names permit IPv6 addresses to enable DBAs to specify privileges for clients that connect to the server over IPv6. See Section 6.2.4, “Specifying Account Names”. IPv6 addresses can be specified in account names in statements such as \texttt{CREATE USER}, \texttt{GRANT}, and \texttt{REVOKE}. For example:

  \texttt{mysql> CREATE USER 'bill'@'::1' IDENTIFIED BY 'secret';}

  \texttt{mysql> GRANT SELECT ON mydb.* TO 'bill'@'::1';}

The following sections describe how to set up MySQL so that clients can connect to the server over IPv6.

5.1.11.1 Verifying System Support for IPv6

Before MySQL Server can accept IPv6 connections, the operating system on your server host must support IPv6. As a simple test to determine whether that is true, try this command:

\texttt{shell> ping6 ::1}

16 bytes from ::1, icmp_seq=0 hlim=64 time=0.171 ms
16 bytes from ::1, icmp_seq=1 hlim=64 time=0.077 ms
...

To produce a description of your system’s network interfaces, invoke \texttt{ifconfig -a} and look for IPv6 addresses in the output.

If your host does not support IPv6, consult your system documentation for instructions on enabling it. It might be that you need only reconfigure an existing network interface to add an IPv6 address. Or a more extensive change might be needed, such as rebuilding the kernel with IPv6 options enabled.

These links may be helpful in setting up IPv6 on various platforms:

- Windows XP
- Gentoo Linux
- Ubuntu Linux
IPv6 Support

- Linux (Generic)
- macOS

5.1.11.2 Configuring the MySQL Server to Permit IPv6 Connections

The MySQL server listens on a single network socket for TCP/IP connections. This socket is bound to a single address, but it is possible for an address to map onto multiple network interfaces. To specify an address, use the `--bind-address=addr` option at server startup, where `addr` is an IPv4 or IPv6 address or a host name. For details, see the `--bind-address` description in Section 5.1.6, “Server Command Options”.

5.1.11.3 Connecting Using the IPv6 Local Host Address

The following procedure shows how to configure MySQL to permit IPv6 connections by clients that connect to the local server using the `::1` local host address. The instructions given here assume that your system supports IPv6.

1. Start the MySQL server with an appropriate `--bind-address` option to permit it to accept IPv6 connections. For example, put the following lines in the server option file and restart the server:

   ```
   [mysqld]
   bind-address = ::
   ```

   Alternatively, you can bind the server to `::1`, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single address and rejects IPv4 connections. For more information, see the `--bind-address` description in Section 5.1.6, “Server Command Options”.

2. As an administrator, connect to the server and create an account for a local user who will connect from the `::1` local IPv6 host address:

   ```
   mysql>
   CREATE USER 'ipv6user'@'::1' IDENTIFIED BY 'ipv6pass';
   ```

   For the permitted syntax of IPv6 addresses in account names, see Section 6.2.4, “Specifying Account Names”. In addition to the `CREATE USER` statement, you can issue `GRANT` statements that give specific privileges to the account, although that is not necessary for the remaining steps in this procedure.

3. Invoke the `mysql` client to connect to the server using the new account:

   ```
   shell>
   mysql -h ::1 -u ipv6user -pipv6pass
   ```

4. Try some simple statements that show connection information:

   ```
   mysql>
   STATUS
   ...
   Connection: ::1 via TCP/IP
   ...
   ```

   ```
   mysql>
   SELECT CURRENT_USER();
   +----------------+
   | CURRENT_USER() |
   +----------------+
   | ipv6user@::1    |
   +----------------+
   ```

5.1.11.4 Connecting Using IPv6 Nonlocal Host Addresses

The following procedure shows how to configure MySQL to permit IPv6 connections by remote clients. It is similar to the preceding procedure for local clients, but the server and client hosts are distinct and each has its own nonlocal IPv6 address. The example uses these addresses:
IPv6 Support

Server host: 2001:db8:0:f101::1
Client host: 2001:db8:0:f101::2

These addresses are chosen from the nonroutable address range recommended by IANA for documentation purposes and suffice for testing on your local network. To accept IPv6 connections from clients outside the local network, the server host must have a public address. If your network provider assigns you an IPv6 address, you can use that. Otherwise, another way to obtain an address is to use an IPv6 broker; see Section 5.1.11.5, “Obtaining an IPv6 Address from a Broker”.

1. Start the MySQL server with an appropriate `--bind-address` option to permit it to accept IPv6 connections. For example, put the following lines in the server option file and restart the server:

   ```
   [mysqld]
   bind-address = ::
   ```

   Alternatively, you can bind the server to 2001:db8:0:f101::1, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single address and rejects IPv4 connections. For more information, see the `--bind-address` description in Section 5.1.6, “Server Command Options”.

2. On the server host (2001:db8:0:f101::1), create an account for a user who will connect from the client host (2001:db8:0:f101::2):

   ```
   mysql> CREATE USER 'remoteipv6user'@'2001:db8:0:f101::2' IDENTIFIED BY 'remoteipv6pass';
   ```

3. On the client host (2001:db8:0:f101::2), invoke the `mysql` client to connect to the server using the new account:

   ```
   shell> mysql -h 2001:db8:0:f101::1 -u remoteipv6user -premoteipv6pass
   ```

4. Try some simple statements that show connection information:

   ```
   mysql> STATUS
   ...
   Connection: 2001:db8:0:f101::1 via TCP/IP
   ...
   mysql> SELECT CURRENT_USER();
   +-----------------------------------+
   | CURRENT_USER()                    |
   +-----------------------------------+
   | remoteipv6user@2001:db8:0:f101::2 |
   +-----------------------------------+
   ```

5.1.11.5 Obtaining an IPv6 Address from a Broker

If you do not have a public IPv6 address that enables your system to communicate over IPv6 outside your local network, you can obtain one from an IPv6 broker. The Wikipedia IPv6 Tunnel Broker page lists several brokers and their features, such as whether they provide static addresses and the supported routing protocols.

After configuring your server host to use a broker-supplied IPv6 address, start the MySQL server with an appropriate `--bind-address` option to permit the server to accept IPv6 connections. For example, put the following lines in the server option file and restart the server:

```
   [mysqld]
   bind-address = ::
   ```

Alternatively, you can bind the server to the specific IPv6 address provided by the broker, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single
address and rejects IPv4 connections. For more information, see the `--bind-address` description in Section 5.1.6, "Server Command Options". In addition, if the broker allocates dynamic addresses, the address provided for your system might change the next time you connect to the broker. If so, any accounts you create that name the original address become invalid. To bind to a specific address but avoid this change-of-address problem, you may be able to arrange with the broker for a static IPv6 address.

The following example shows how to use Freenet6 as the broker and the `gogoc` IPv6 client package on Gentoo Linux.

1. Create an account at Freenet6 by visiting this URL and signing up:

    http://gogonet.gogo6.com

2. After creating the account, go to this URL, sign in, and create a user ID and password for the IPv6 broker:

    http://gogonet.gogo6.com/page/freenet6-registration

3. As `root`, install `gogoc`:

    shell> emerge gogoc

4. Edit `/etc/gogoc/gogoc.conf` to set the `userid` and `password` values. For example:

    userid=gogouser
    passwd=gogopass

5. Start `gogoc`:

    shell> /etc/init.d/gogoc start

To start `gogoc` each time your system boots, execute this command:

    shell> rc-update add gogoc default

6. Use `ping6` to try to ping a host:

    shell> ping6 ipv6.google.com

7. To see your IPv6 address:

    shell> ifconfig tun

**5.1.12 MySQL Server Time Zone Support**

This section describes the time zone settings maintained by MySQL, how to load the system tables required for named time support, how to stay current with time zone changes, and how to enable leap-second support.

- **Time Zone Variables**
- **Populating the Time Zone Tables**
- **Staying Current with Time Zone Changes**
- **Time Zone Leap Second Support**

For information about time zone settings in replication setups, please see Section 17.4.1, "Replication Features and Issues".
MySQL Server maintains several time zone settings:

- The system time zone. When the server starts, it attempts to determine the time zone of the host machine automatically and uses it to set the `system_time_zone` system variable. The value does not change thereafter.

  To explicitly specify the system time zone for MySQL Server at startup, set the `TZ` environment variable before you start `mysqld`. If you start the server using `mysqld_safe`, its `--timezone` option provides another way to set the system time zone. The permissible values for `TZ` and `--timezone` are system dependent. Consult your operating system documentation to see what values are acceptable.

- The server current time zone. The global `time_zone` system variable indicates the time zone the server currently is operating in. The initial `time_zone` value is `'SYSTEM'`, which indicates that the server time zone is the same as the system time zone.

  If set to `SYSTEM`, every MySQL function call that requires a time zone calculation makes a system library call to determine the current system time zone. This call may be protected by a global mutex, resulting in contention.

  The initial global server time zone value can be specified explicitly at startup with the `--default-time-zone` option on the command line, or you can use the following line in an option file:

  ```
  default-time-zone='timezone'
  ```

  If you have the `SUPER` privilege, you can set the global server time zone value at runtime with this statement:

  ```
  SET GLOBAL time_zone = timezone;
  ```

- Per-session time zones. Each client that connects has its own session time zone setting, given by the `session_time_zone` variable. Initially, the session variable takes its value from the global `time_zone` variable, but the client can change its own time zone with this statement:

  ```
  SET session_time_zone = timezone;
  ```

  The session time zone setting affects display and storage of time values that are zone-sensitive. This includes the values displayed by functions such as `NOW()` or `CURTIME()`, and values stored in and retrieved from `TIMESTAMP` columns. Values for `TIMESTAMP` columns are converted from the session time zone to UTC for storage, and from UTC to the session time zone for retrieval.

  The session time zone setting does not affect values displayed by functions such as `UTC_TIMESTAMP()` or values in `DATE`, `TIME`, or `DATETIME` columns. Nor are values in those data types stored in UTC; the time zone applies for them only when converting from `TIMESTAMP` values. If you want locale-specific arithmetic for `DATE`, `TIME`, or `DATETIME` values, convert them to UTC, perform the arithmetic, and then convert back.

  The current global and session time zone values can be retrieved like this:

  ```
  SELECT @@GLOBAL.time_zone, @@SESSION.time_zone;
  ```

  `timezone` values can be given in several formats, none of which are case-sensitive:

  - As the value `'SYSTEM'`, indicating that the server time zone is the same as the system time zone.
MySQL Server Time Zone Support

- As a string indicating an offset from UTC of the form \[H:]H:MM, prefixed with a + or -, such as '+10:00', '-6:00', or '+05:30'. A leading zero can optionally be used for hours values less than 10; MySQL prepends a leading zero when storing and retrieving the value in such cases. MySQL converts '-00:00' or '-0:00' to '+00:00'.

A time zone offset must be in the range '-12:59' to '+13:00', inclusive.

- As a named time zone, such as 'Europe/Helsinki', 'US/Eastern', or 'MET'. Named time zones can be used only if the time zone information tables in the mysql database have been created and populated.

### Populating the Time Zone Tables

Several tables in the mysql system database exist to store time zone information (see Section 5.3, “The mysql System Database”). The MySQL installation procedure creates the time zone tables, but does not load them. To do so manually, use the following instructions.

**Note**

Loading the time zone information is not necessarily a one-time operation because the information changes occasionally. When such changes occur, applications that use the old rules become out of date and you may find it necessary to reload the time zone tables to keep the information used by your MySQL server current. See Staying Current with Time Zone Changes.

If your system has its own zoneinfo database (the set of files describing time zones), use the mysql_tzinfo_to_sql program to load the time zone tables. Examples of such systems are Linux, macOS, FreeBSD, and Solaris. One likely location for these files is the /usr/share/zoneinfo directory. If your system has no zoneinfo database, you can use a downloadable package, as described later in this section.

To load the time zone tables from the command line, pass the zoneinfo directory path name to mysql_tzinfo_to_sql and send the output into the mysql program. For example:

```
mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root -p mysql
```

The mysql command shown here assumes that you connect to the server using an account such as root that has privileges for modifying tables in the mysql system database. Adjust the connection parameters as required.

mysql_tzinfo_to_sql reads your system's time zone files and generates SQL statements from them.

mysql processes those statements to load the time zone tables.

mysql_tzinfo_to_sql also can be used to load a single time zone file or generate leap second information:

- To load a single time zone file tz_file that corresponds to a time zone name tz_name, invoke mysql_tzinfo_to_sql like this:

  ```
  mysql_tzinfo_to_sql tz_file tz_name | mysql -u root -p mysql
  ```

  With this approach, you must execute a separate command to load the time zone file for each named zone that the server needs to know about.

- If your time zone must account for leap seconds, initialize leap second information like this, where tz_file is the name of your time zone file:

  ```
  mysql_tzinfo_to_sql tz_file | mysql -u root -p mysql
  ```
MySQL Server Time Zone Support

After running `mysql_tzinfo_to_sql`, restart the server so that it does not continue to use any previously cached time zone data.

If your system has no zoneinfo database (for example, Windows), you can use a package that is available for download at the MySQL Developer Zone:

[https://dev.mysql.com/downloads/timezones.html](https://dev.mysql.com/downloads/timezones.html)

**Warning**

Do *not* use a downloadable time zone package if your system has a zoneinfo database. Use the `mysql_tzinfo_to_sql` utility instead. Otherwise, you may cause a difference in datetime handling between MySQL and other applications on your system.

You can use either a package that contains SQL statements to populate your existing time zone tables, or a package that contains pre-built MyISAM time zone tables to replace your existing tables:

- To use a time zone package that contains SQL statements, download and unpack it, then load the unpacked file contents into your existing time zone tables:

  ```
  mysql -u root -p mysql < file_name
  ```

  Then restart the server.

- To use a time zone package that contains .frm, .MYD, and .MYI files for the MyISAM time zone tables, download and unpack it. These table files are part of the mysql database, so you should place the files in the mysql subdirectory of your MySQL server's data directory. Stop the server before doing this and restart it afterward.

### Staying Current with Time Zone Changes

When time zone rules change, applications that use the old rules become out of date. To stay current, it is necessary to make sure that your system uses current time zone information is used. For MySQL, there are multiple factors to consider in staying current:

- The operating system time affects the value that the MySQL server uses for times if its time zone is set to SYSTEM. Make sure that your operating system is using the latest time zone information. For most operating systems, the latest update or service pack prepares your system for the time changes. Check the website for your operating system vendor for an update that addresses the time changes.

- If you replace the system's /etc/localtime time zone file with a version that uses rules differing from those in effect at mysqld startup, restart mysqld so that it uses the updated rules. Otherwise, mysqld might not notice when the system changes its time.

- If you use named time zones with MySQL, make sure that the time zone tables in the mysql database are up to date:
  - If your system has its own zoneinfo database, reload the MySQL time zone tables whenever the zoneinfo database is updated.
  - For systems that do not have their own zoneinfo database, check the MySQL Developer Zone for updates. When a new update is available, download it and use it to replace the content of your current time zone tables.
MySQL Server Time Zone Support

For instructions for both methods, see Populating the Time Zone Tables. `mysqld` caches time zone information that it looks up, so after updating the time zone tables, restart `mysqld` to make sure that it does not continue to serve outdated time zone data.

If you are uncertain whether named time zones are available, for use either as the server's time zone setting or by clients that set their own time zone, check whether your time zone tables are empty. The following query determines whether the table that contains time zone names has any rows:

```sql
SELECT COUNT(*) FROM mysql.time_zone_name;
```

```
+----------+
| COUNT(*) |
+----------+
|        0 |
+----------+
```

A count of zero indicates that the table is empty. In this case, no applications currently are using named time zones, and you need not update the tables (unless you want to enable named time zone support). A count greater than zero indicates that the table is not empty and that its contents are available to be used for named time zone support. In this case, be sure to reload your time zone tables so that applications that use named time zones will obtain correct query results.

To check whether your MySQL installation is updated properly for a change in Daylight Saving Time rules, use a test like the one following. The example uses values that are appropriate for the 2007 DST 1-hour change that occurs in the United States on March 11 at 2 a.m.

The test uses this query:

```sql
SELECT
  CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central') AS time1,
  CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central') AS time2;
```

The two time values indicate the times at which the DST change occurs, and the use of named time zones requires that the time zone tables be used. The desired result is that both queries return the same result (the input time, converted to the equivalent value in the 'US/Central' time zone).

Before updating the time zone tables, you see an incorrect result like this:

```
| time1               | time2               |
+---------------------+---------------------+
| 2007-03-11 01:00:00 | 2007-03-11 02:00:00 |
+---------------------+---------------------+
```

After updating the tables, you should see the correct result:

```
| time1               | time2               |
+---------------------+---------------------+
| 2007-03-11 01:00:00 | 2007-03-11 01:00:00 |
+---------------------+---------------------+
```

**Time Zone Leap Second Support**

Leap second values are returned with a time part that ends with `:59:59`. This means that a function such as `NOW()` can return the same value for two or three consecutive seconds during the leap second. It remains true that literal temporal values having a time part that ends with `:59:60` or `:59:61` are considered invalid.

If it is necessary to search for `TIMESTAMP` values one second before the leap second, anomalous results may be obtained if you use a comparison with `'YYYY-MM-DD hh:mm:ss'` values. The following example
demonstrates this. It changes the session time zone to UTC so there is no difference between internal
\texttt{TIMESTAMP} values (which are in UTC) and displayed values (which have time zone correction applied).

```sql
mysql> CREATE TABLE t1 (a INT, ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP, PRIMARY KEY (ts));
Query OK, 0 rows affected (0.01 sec)

mysql> -- change to UTC
mysql> SET time_zone = '+00:00';
Query OK, 0 rows affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:59'
mysql> SET timestamp = 1230767999;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (1);
Query OK, 1 row affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:60'
mysql> SET timestamp = 1230768000;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (2);
Query OK, 1 row affected (0.00 sec)

mysql> -- values differ internally but display the same
mysql> SELECT a, ts, UNIX_TIMESTAMP(ts) FROM t1;
+------+---------------------+--------------------+
<table>
<thead>
<tr>
<th>a</th>
<th>ts</th>
<th>UNIX_TIMESTAMP(ts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2008-12-31 23:59:59</td>
<td>1230767999</td>
</tr>
<tr>
<td>2</td>
<td>2008-12-31 23:59:59</td>
<td>1230768000</td>
</tr>
</tbody>
</table>
+------+---------------------+--------------------+
2 rows in set (0.00 sec)

mysql> -- only the non-leap value matches
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:59';
+---------------------+
<table>
<thead>
<tr>
<th>a</th>
<th>ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2008-12-31 23:59:59</td>
</tr>
</tbody>
</table>
+---------------------+
1 row in set (0.00 sec)

mysql> -- the leap value with seconds=60 is invalid
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:60';
Empty set, 2 warnings (0.00 sec)

To work around this, you can use a comparison based on the UTC value actually stored in the column,
which has the leap second correction applied:

```sql
mysql> -- selecting using UNIX_TIMESTAMP value return leap value
mysql> SELECT * FROM t1 WHERE UNIX_TIMESTAMP(ts) = 1230768000;
+---------------------+
<table>
<thead>
<tr>
<th>a</th>
<th>ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2008-12-31 23:59:59</td>
</tr>
</tbody>
</table>
+---------------------+
1 row in set (0.00 sec)

5.1.13 Server-Side Help Support
MySQL Server supports a **HELP** statement that returns information from the MySQL Reference Manual (see Section 13.8.3, “HELP Statement”). This information is stored in several tables in the **mysql** database (see Section 5.3, “The mysql System Database”). Proper operation of the **HELP** statement requires that these help tables be initialized.

For a new installation of MySQL using a binary or source distribution on Unix, help-table content initialization occurs when you initialize the data directory (see Section 2.10.1, “Initializing the Data Directory”). For an RPM distribution on Linux or binary distribution on Windows, content initialization occurs as part of the MySQL installation process.

For a MySQL upgrade using a binary distribution, help-table content is not upgraded automatically, but you can upgrade it manually. Locate the `fill_help_tables.sql` file in the `share` or `share/mysql` directory. Change location into that directory and process the file with the `mysql` client as follows (enter the command on one line):

```
mysql -u root -p
  --init-command="SET sql_log_bin=OFF"
mysql < fill_help_tables.sql
```

The command shown here assumes that you connect to the server using an account such as **root** that has privileges for modifying tables in the **mysql** database. Adjust the connection parameters as required.

If you are working with Git and a MySQL development source tree, the source tree contains only a “stub” version of `fill_help_tables.sql`. To obtain a non-stub copy, use one from a source or binary distribution.

**Note**

Each MySQL series has its own series-specific reference manual, so help-table content is series specific as well. This has implications for replication because help-table content should match the MySQL series. If you load MySQL 5.5 help content into a MySQL 5.5 master server, it does not make sense to replicate that content to a slave server from a different MySQL series and for which that content is not appropriate. For this reason, as you upgrade individual servers in a replication scenario, you should upgrade each server’s help tables, using the instructions given earlier.

### 5.1.14 The Server Shutdown Process

The server shutdown process takes place as follows:

1. **The shutdown process is initiated.**
   
   This can occur initiated several ways. For example, a user with the **SHUTDOWN** privilege can execute a `mysqladmin shutdown` command. `mysqladmin` can be used on any platform supported by MySQL. Other operating system-specific shutdown initiation methods are possible as well: The server shuts down on Unix when it receives a **SIGTERM** signal. A server running as a service on Windows shuts down when the services manager tells it to.

2. **The server creates a shutdown thread if necessary.**
   
   Depending on how shutdown was initiated, the server might create a thread to handle the shutdown process. If shutdown was requested by a client, a shutdown thread is created. If shutdown is the result of receiving a **SIGTERM** signal, the signal thread might handle shutdown itself, or it might create a separate thread to do so. If the server tries to create a shutdown thread and cannot (for example, if memory is exhausted), it issues a diagnostic message that appears in the error log:
3. The server stops accepting new connections.

To prevent new activity from being initiated during shutdown, the server stops accepting new client connections by closing the handlers for the network interfaces to which it normally listens for connections: the TCP/IP port, the Unix socket file, the Windows named pipe, and shared memory on Windows.

4. The server terminates current activity.

For each thread associated with a client connection, the server breaks the connection to the client and marks the thread as killed. Threads die when they notice that they are so marked. Threads for idle connections die quickly. Threads that currently are processing statements check their state periodically and take longer to die. For additional information about thread termination, see Section 13.7.6.4, “KILL Statement”, in particular for the instructions about killed REPAIR TABLE or OPTIMIZE TABLE operations on MyISAM tables.

For threads that have an open transaction, the transaction is rolled back. If a thread is updating a nontransactional table, an operation such as a multiple-row UPDATE or INSERT may leave the table partially updated because the operation can terminate before completion.

If the server is a master replication server, it treats threads associated with currently connected slaves like other client threads. That is, each one is marked as killed and exits when it next checks its state.

If the server is a slave replication server, it stops the I/O and SQL threads, if they are active, before marking client threads as killed. The SQL thread is permitted to finish its current statement (to avoid causing replication problems), and then stops. If the SQL thread is in the middle of a transaction at this point, the server waits until the current replication event group (if any) has finished executing, or until the user issues a KILL QUERY or KILL CONNECTION statement. See also Section 13.4.2.6, “STOP SLAVE Statement”.

If the slave is updating a nontransactional table when it is forcibly killed, the slave’s data may become inconsistent with the master.

5. The server shuts down or closes storage engines.

At this stage, the server flushes the table cache and closes all open tables.

Each storage engine performs any actions necessary for tables that it manages. For example, MyISAM flushes any pending index writes for a table. InnoDB flushes its buffer pool to disk (unless innodb_fast_shutdown is 2), writes the current LSN to the tablespace, and terminates its own internal threads.

6. The server exits.

5.2 The MySQL Data Directory

Information managed by the MySQL server is stored under a directory known as the data directory. The following list briefly describes the items typically found in the data directory, with cross references for additional information:

- Data directory subdirectories. Each subdirectory of the data directory is a database directory and corresponds to a database managed by the server. All MySQL installations have certain standard databases:
• The `mysql` directory corresponds to the `mysql` system database, which contains information required by the MySQL server as it runs. See Section 5.3, “The mysql System Database”.

• The `performance_schema` directory corresponds to the Performance Schema, which provides information used to inspect the internal execution of the server at runtime. See Chapter 22, MySQL Performance Schema.

• The `ndbinfo` directory corresponds to the `ndbinfo` database that stores information specific to NDB Cluster (present only for installations built to include NDB Cluster). See Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

Other subdirectories correspond to databases created by users or applications.

**Note**

INFORMATION_SCHEMA is a standard database, but its implementation uses no corresponding database directory.

• Log files written by the server. See Section 5.4, “MySQL Server Logs”.

• InnoDB tablespace and log files. See Chapter 14, The InnoDB Storage Engine.

• The server process ID file (while the server is running).

Some items in the preceding list can be relocated elsewhere by reconfiguring the server. In addition, the `--datadir` option enables the location of the data directory itself to be changed. For a given MySQL installation, check the server configuration to determine whether items have been moved.

5.3 The mysql System Database

The `mysql` database is the system database. It contains tables that store information required by the MySQL server as it runs.

Tables in the `mysql` database fall into these categories:

• Grant System Tables

• Object Information System Tables

• Log System Tables

• Server-Side Help System Tables

• Time Zone System Tables

• Replication System Tables

• Miscellaneous System Tables

The remainder of this section enumerates the tables in each category, with cross references for additional information. System tables use the MyISAM storage engine.

**Warning**

Do not convert MySQL system tables in the `mysql` database from MyISAM to InnoDB tables. This is an unsupported operation. If you do this, MySQL does not
Grant System Tables

These system tables contain grant information about user accounts and the privileges held by them:

- **user**: User accounts, global privileges, and other nonprivilege columns.
- **db**: Database-level privileges.
- **host**: Obsolete.
- **tables_priv**: Table-level privileges.
- **columns_priv**: Column-level privileges.
- **procs_priv**: Stored procedure and function privileges.
- **proxies_priv**: Proxy-user privileges.

For more information about the structure, contents, and purpose of the grant tables, see Section 6.2.3, “Grant Tables”.

Object Information System Tables

These system tables contain information about stored programs, user-defined functions, and server-side plugins:

- **event**: Information about Event Scheduler events. See Section 20.4, “Using the Event Scheduler”. The server loads events listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.

- **func**: Information about user-defined functions (UDFs). See Section 24.4, “Adding Functions to MySQL”. The server loads UDFs listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.

- **plugin**: Information about server-side plugins. See Section 5.5.1, “Installing and Uninstalling Plugins”, and Section 24.2, “The MySQL Plugin API”. The server loads plugins listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.

- **proc**: Information about stored procedures and functions. See Section 20.2, “Using Stored Routines”.

Log System Tables

The server uses these system tables for logging:

- **general_log**: The general query log table.
- **slow_log**: The slow query log table.

Log tables use the CSV storage engine.

For more information, see Section 5.4, “MySQL Server Logs”.

Server-Side Help System Tables
These system tables contain server-side help information:

- **help_category**: Information about help categories.
- **help_keyword**: Keywords associated with help topics.
- **help_relation**: Mappings between help keywords and topics.
- **help_topic**: Help topic contents.

For more information, see Section 5.1.13, “Server-Side Help Support”.

**Time Zone System Tables**

These system tables contain time zone information:

- **time_zone**: Time zone IDs and whether they use leap seconds.
- **time_zone_leap_second**: When leap seconds occur.
- **time_zone_name**: Mappings between time zone IDs and names.
- **time_zone_transition, time_zone_transition_type**: Time zone descriptions.

For more information, see Section 5.1.12, “MySQL Server Time Zone Support”.

**Replication System Tables**

The server uses the `ndb_binlog_index` system table to store binary log information for NDB Cluster replication. See Section 18.6.4, “NDB Cluster Replication Schema and Tables”.

**Miscellaneous System Tables**

Other system tables do not fall into the preceding categories:

- **servers**: Used by the FEDERATED storage engine. See Section 15.9.2.2, “Creating a FEDERATED Table Using CREATE SERVER”.

**5.4 MySQL Server Logs**

MySQL Server has several logs that can help you find out what activity is taking place.

<table>
<thead>
<tr>
<th>Log Type</th>
<th>Information Written to Log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error log</td>
<td>Problems encountered starting, running, or stopping <code>mysqld</code></td>
</tr>
<tr>
<td>General query log</td>
<td>Established client connections and statements received from clients</td>
</tr>
<tr>
<td>Binary log</td>
<td>Statements that change data (also used for replication)</td>
</tr>
<tr>
<td>Relay log</td>
<td>Data changes received from a replication master server</td>
</tr>
<tr>
<td>Slow query log</td>
<td>Queries that took more than <code>long_query_time</code> seconds to execute</td>
</tr>
<tr>
<td>DDL log (metadata log)</td>
<td>Metadata operations performed by DDL statements</td>
</tr>
</tbody>
</table>

By default, no logs are enabled, except the error log on Windows. (The DDL log is always created when required, and has no user-configurable options; see Section 5.4.6, “The DDL Log”.) The following log-specific sections provide information about the server options that enable logging.
By default, the server writes files for all enabled logs in the data directory. You can force the server to close and reopen the log files (or in some cases switch to a new log file) by flushing the logs. Log flushing occurs when you issue a `FLUSH LOGS` statement; execute `mysqladmin` with a `flush-logs` or `refresh` argument; or execute `mysqldump` with a `--flush-logs` or `--master-data` option. See Section 13.7.6.3, “FLUSH Statement”, Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”, and Section 4.5.4, “mysqldump — A Database Backup Program”. In addition, the binary log is flushed when its size reaches the value of the `max_binlog_size` system variable.

You can control the general query and slow query logs during runtime. You can enable or disable logging, or change the log file name. You can tell the server to write general query and slow query entries to log tables, log files, or both. For details, see Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”, Section 5.4.3, “The General Query Log”, and Section 5.4.5, “The Slow Query Log”.

The relay log is used only on slave replication servers, to hold data changes from the master server that must also be made on the slave. For discussion of relay log contents and configuration, see Section 17.2.2.1, “The Slave Relay Log”.

For information about log maintenance operations such as expiration of old log files, see Section 5.4.7, “Server Log Maintenance”.

For information about keeping logs secure, see Section 6.1.2.3, “Passwords and Logging”.

5.4.1 Selecting General Query Log and Slow Query Log Output Destinations

MySQL Server provides flexible control over the destination of output written to the general query log and the slow query log, if those logs are enabled. Possible destinations for log entries are log files or the `general_log` and `slow_log` tables in the `mysql` system database. File output, table output, or both can be selected.

- Log Control at Server Startup
- Log Control at Runtime
- Log Table Benefits and Characteristics

Log Control at Server Startup

The `log_output` system variable specifies the destination for log output. Setting this variable does not in itself enable the logs; they must be enabled separately.

- If `log_output` is not specified at startup, the default logging destination is `FILE`.

- If `log_output` is specified at startup, its value is a list one or more comma-separated words chosen from `TABLE` (log to tables), `FILE` (log to files), or `NONE` (do not log to tables or files). `NONE`, if present, takes precedence over any other specifiers.

The `general_log` system variable controls logging to the general query log for the selected log destinations. If specified at server startup, `general_log` takes an optional argument of 1 or 0 to enable or disable the log. To specify a file name other than the default for file logging, set the `general_log_file` variable. Similarly, the `slow_query_log` variable controls logging to the slow query log for the selected destinations and setting `slow_query_log_file` specifies a file name for file logging. If either log is enabled, the server opens the corresponding log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected.

Examples:
Selecting General Query Log and Slow Query Log Output Destinations

- To write general query log entries to the log table and the log file, use `--log_output=TABLE,FILE` to select both log destinations and `--general_log` to enable the general query log.

- To write general and slow query log entries only to the log tables, use `--log_output=TABLE` to select tables as the log destination and `--general_log` and `--slow_query_log` to enable both logs.

- To write slow query log entries only to the log file, use `--log_output=FILE` to select files as the log destination and `--slow_query_log` to enable the slow query log. In this case, because the default log destination is FILE, you could omit the `log_output` setting.

Log Control at Runtime

The system variables associated with log tables and files enable runtime control over logging:

- The `log_output` variable indicates the current logging destination. It can be modified at runtime to change the destination.

- The `general_log` and `slow_query_log` variables indicate whether the general query log and slow query log are enabled (ON) or disabled (OFF). You can set these variables at runtime to control whether the logs are enabled.

- The `general_log_file` and `slow_query_log_file` variables indicate the names of the general query log and slow query log files. You can set these variables at server startup or at runtime to change the names of the log files.

- To disable or enable general query logging for the current session, set the session `sql_log_off` variable to ON or OFF. (This assumes that the general query log itself is enabled.)

Log Table Benefits and Characteristics

The use of tables for log output offers the following benefits:

- Log entries have a standard format. To display the current structure of the log tables, use these statements:

  ```
  SHOW CREATE TABLE mysql.general_log;
  SHOW CREATE TABLE mysql.slow_log;
  ```

- Log contents are accessible through SQL statements. This enables the use of queries that select only those log entries that satisfy specific criteria. For example, to select log contents associated with a particular client (which can be useful for identifying problematic queries from that client), it is easier to do this using a log table than a log file.

- Logs are accessible remotely through any client that can connect to the server and issue queries (if the client has the appropriate log table privileges). It is not necessary to log in to the server host and directly access the file system.

The log table implementation has the following characteristics:

- In general, the primary purpose of log tables is to provide an interface for users to observe the runtime execution of the server, not to interfere with its runtime execution.

- `CREATE TABLE`, `ALTER TABLE`, and `DROP TABLE` are valid operations on a log table. For `ALTER TABLE` and `DROP TABLE`, the log table cannot be in use and must be disabled, as described later.

- By default, the log tables use the CSV storage engine that writes data in comma-separated values format. For users who have access to the .CSV files that contain log table data, the files are easy to import into other programs such as spreadsheets that can process CSV input.
The Error Log

The log tables can be altered to use the MyISAM storage engine. You cannot use `ALTER TABLE` to alter a log table that is in use. The log must be disabled first. No engines other than CSV or MyISAM are legal for the log tables.

- To disable logging so that you can alter (or drop) a log table, you can use the following strategy. The example uses the general query log; the procedure for the slow query log is similar but uses the `slow_log` table and `slow_query_log` system variable.

  ```sql
  SET @old_log_state = @@GLOBAL.general_log;
  SET GLOBAL general_log = 'OFF';
  ALTER TABLE mysql.general_log ENGINE = MyISAM;
  SET GLOBAL general_log = @old_log_state;
  ```

- **TRUNCATE TABLE** is a valid operation on a log table. It can be used to expire log entries.

- **RENAME TABLE** is a valid operation on a log table. You can atomically rename a log table (to perform log rotation, for example) using the following strategy:

  ```sql
  USE mysql;
  DROP TABLE IF EXISTS general_log2;
  CREATE TABLE general_log2 LIKE general_log;
  RENAME TABLE general_log TO general_log_backup, general_log2 TO general_log;
  ```

- **CHECK TABLE** is a valid operation on a log table.

- **LOCK TABLES** cannot be used on a log table.

- **INSERT, DELETE, and UPDATE** cannot be used on a log table. These operations are permitted only internally to the server itself.

- **FLUSH TABLES WITH READ LOCK** and the state of the `read_only` system variable have no effect on log tables. The server can always write to the log tables.

- Entries written to the log tables are not written to the binary log and thus are not replicated to slave servers.

- To flush the log tables or log files, use `FLUSH TABLES` or `FLUSH LOGS`, respectively.

- Partitioning of log tables is not permitted.

- Before MySQL 5.5.25, mysqldump does not dump the `general_log` or `slow_query_log` tables for dumps of the `mysql` database. As of 5.5.25, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

5.4.2 The Error Log

This section discusses how to configure the MySQL server for logging of diagnostic messages to the error log. For information about selecting the error message character set or language, see Section 10.6, “Error Message Character Set”, or Section 10.12, “Setting the Error Message Language”.

The error log contains a record of mysqld startup and shutdown times. It also contains diagnostic messages such as errors, warnings, and notes that occur during server startup and shutdown, and while the server is running. For example, if mysqld notices that a table needs to be automatically checked or repaired, it writes a message to the error log.

On some operating systems, the error log contains a stack trace if mysqld exits abnormally. The trace can be used to determine where mysqld exited. See Section 24.5, “Debugging and Porting MySQL”. 
If used to start `mysqld`, `mysqld_safe` may write messages to the error log. For example, when `mysqld_safe` notices abnormal `mysqld` exits, it restarts `mysqld` and writes a `mysqld restarted` message to the error log.

The following sections discuss aspects of configuring error logging. In the discussion, “console” means `stderr`, the standard error output. This is your terminal or console window unless the standard error output has been redirected to a different destination.

The server interprets options that determine where to write error messages somewhat differently for Windows and Unix systems. Be sure to configure error logging using the information appropriate to your platform.

### 5.4.2.1 Error Logging on Windows

On Windows, `mysqld` uses the `--log-error`, `--pid-file`, and `--console` options to determine whether `mysqld` writes the error log to the console or a file, and, if to a file, the file name:

- If `--console` is given, `mysqld` writes the error log to the console, unless `--log-error` is also given. `--log-error` takes precedence over `--console` if both are given.
- If `--log-error` is not given, or is given without naming a file, `mysqld` writes the error log to a file named `host_name.err` in the data directory, unless the `--pid-file` option is specified. In that case, the file name is the PID file base name with a suffix of `.err` in the data directory.
- If `--log-error` is given to name a file, `mysqld` writes the error log to that file (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.

If the server writes the error log to a file, the `log_error` system variable indicates the error log file name.

In addition, the server by default writes events and error messages to the Windows Event Log within the Application log:

- Entries marked as `Error`, `Warning`, and `Note` are written to the Event Log, but not messages such as information statements from individual storage engines.
- Event Log entries have a source of `MySQL`.
- You cannot disable writing information to the Windows Event Log.

### 5.4.2.2 Error Logging on Unix and Unix-Like Systems

On Unix and Unix-like systems, `mysqld` uses the `--log-error` option to determine whether `mysqld` writes the error log to the console or a file, and, if to a file, the file name:

- If `--log-error` is not given, `mysqld` writes the error log to the console.
- If `--log-error` is given without naming a file, `mysqld` writes the error log to a file named `host_name.err` in the data directory.
- If `--log-error` is given to name a file, `mysqld` writes the error log to that file (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.
- If `--log-error` is given in an option file in a `[mysqld]`, `[server]`, or `[mysqld_safe]` section, `mysqld_safe` finds and uses the option, and passes it to `mysqld`. 
The General Query Log

Note

It is common for Yum or APT package installations to configure an error log file location under /var/log with an option like log-error=/var/log/mysqld.log in a server configuration file. Removing the file name from the option causes the host_name.err file in the data directory to be used.

If the server writes the error log to a file, the log_error system variable indicates the error log file name.

5.4.2.3 Error Logging to the System Log

If you use mysqld_safe to start mysqld, mysqld_safe arranges for mysqld to write error messages to a log file or to syslog. mysqld_safe has three error-logging options, --syslog, --skip-syslog, and --log-error. The default with no logging options or with --skip-syslog is to use the default log file. To explicitly specify use of an error log file, specify --log-error=file_name to mysqld_safe, which then arranges for mysqld to write messages to a log file. To use syslog instead, specify the --syslog option.

5.4.2.4 Error Log Filtering

The --log-warnings option or log_warnings system variable controls warning logging to the error log. The default value is enabled (1). To disable warning logging, set --log-warnings or log_warnings to 0. If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.4.2.11, “Communication Errors and Aborted Connections”.

5.4.2.5 Error Log File Flushing and Renaming

If you flush the error log using FLUSH ERROR LOGS, FLUSH LOGS, or mysqladmin flush-logs, the server closes and reopens any error log file to which it is writing. To rename an error log file, do so manually before flushing. Flushing the logs then opens a new file with the original file name. For example, assuming a log file name of host_name.err, to rename the file and create a new one, use the following commands:

mv host_name.err host_name.err-old
mysqladmin flush-logs
mv host_name.err-old backup-directory

On Windows, use rename rather than mv.

If the location of the error log file is not writable by the server, the log-flushing operation fails to create a new log file. For example, on Linux, the server might write the error log to the /var/log/mysqld.log file, where the /var/log directory is owned by root and is not writable by mysqld. For information about handling this case, see Section 5.4.7, “Server Log Maintenance”.

If the server is not writing to a named error log file, no error log file renaming occurs when the error log is flushed.

5.4.3 The General Query Log

The general query log is a general record of what mysqld is doing. The server writes information to this log when clients connect or disconnect, and it logs each SQL statement received from clients. The general query log can be very useful when you suspect an error in a client and want to know exactly what the client sent to mysqld.

mysqld writes statements to the query log in the order that it receives them, which might differ from the order in which they are executed. This logging order is in contrast with that of the binary log, for which
The General Query Log

statements are written after they are executed but before any locks are released. In addition, the query log may contain statements that only select data while such statements are never written to the binary log.

When using statement-based binary logging on a replication master server, statements received by its slaves are written to the query log of each slave. Statements are written to the query log of the master server if a client reads events with the `mysqlbinlog` utility and passes them to the server.

However, when using row-based binary logging, updates are sent as row changes rather than SQL statements, and thus these statements are never written to the query log when `binlog_format` is `ROW`. A given update also might not be written to the query log when this variable is set to `MIXED`, depending on the statement used. See Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”, for more information.

By default, the general query log is disabled. To specify the initial general query log state explicitly, use `--general_log=[0|1]`. With no argument or an argument of 1, `--general_log` enables the log. With an argument of 0, this option disables the log. To specify a log file name, use `--general_log_file=file_name`. To specify the log destination, use the `log_output` system variable (as described in Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”). The older options to enable the general query log, `--log` and `-l`, are deprecated.

If you specify no name for the general query log file, the default name is `host_name.log`. The server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the general query log or change the log file name at runtime, use the global `general_log` and `general_log_file` system variables. Set `general_log` to 0 (or `OFF`) to disable the log or to 1 (or `ON`) to enable it. Set `general_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

When the general query log is enabled, the server writes output to any destinations specified by the `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the general log is enabled. Setting the log file name has no effect on logging if the log destination value does not contain `FILE`.

Server restarts and log flushing do not cause a new general query log file to be generated (although flushing closes and reopens it). To rename the file and create a new one, use the following commands:

```
shell> mv host_name.log host_name-old.log
shell> mysqladmin flush-logs
shell> mv host_name-old.log backup-directory
```

On Windows, use `rename` rather than `mv`.

You can also rename the general query log file at runtime by disabling the log:

```
SET GLOBAL general_log = 'OFF';
```

With the log disabled, rename the log file externally (for example, from the command line). Then enable the log again:

```
SET GLOBAL general_log = 'ON';
```

This method works on any platform and does not require a server restart.

To disable or enable general query logging for the current session, set the session `sql_log_off` variable to `ON` or `OFF`. (This assumes that the general query log itself is enabled.)
The general query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

5.4.4 The Binary Log

The binary log contains “events” that describe database changes such as table creation operations or changes to table data. It also contains events for statements that potentially could have made changes (for example, a DELETE which matched no rows), unless row-based logging is used. The binary log also contains information about how long each statement took that updated data. The binary log has two important purposes:

• For replication, the binary log on a master replication server provides a record of the data changes to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 17.2, “Replication Implementation”.

• Certain data recovery operations require use of the binary log. After a backup has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events bring databases up to date from the point of the backup. See Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

The binary log is not used for statements such as SELECT or SHOW that do not modify data. To log all statements (for example, to identify a problem query), use the general query log. See Section 5.4.3, “The General Query Log”.

Running a server with binary logging enabled makes performance slightly slower. However, the benefits of the binary log in enabling you to set up replication and for restore operations generally outweigh this minor performance decrement.

The binary log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

The following discussion describes some of the server options and variables that affect the operation of binary logging. For a complete list, see Section 17.1.3.4, “Binary Log Options and Variables”.

To enable the binary log, start the server with the --log-bin [=base_name] option. If no base_name value is given, the default name is the value of the --pid-file option (which by default is the name of host machine) followed by -bin. If the base name is given, the server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. It is recommended that you specify a base name explicitly rather than using the default of the host name; see Section B.4.7, “Known Issues in MySQL”, for the reason.

If you supply an extension in the log name (for example, --log-bin=base_name.extension), the extension is silently removed and ignored.

mysqld appends a numeric extension to the binary log base name to generate binary log file names. The number increases each time the server creates a new log file, thus creating an ordered series of files. The server creates a new file in the series each time it starts or flushes the logs. The server also creates a new binary log file automatically after the current log's size reaches max_binlog_size. A binary log file may become larger than max_binlog_size if you are using large transactions because a transaction is written to the file in one piece, never split between files.

To keep track of which binary log files have been used, mysqld also creates a binary log index file that contains the names of the binary log files. By default, this has the same base name as the binary log file, with the extension '.index'. You can change the name of the binary log index file with the --log-bin-index [=file_name] option. You should not manually edit this file while mysqld is running; doing so would confuse mysqld.
The Binary Log

The term “binary log file" generally denotes an individual numbered file containing database events. The term “binary log" collectively denotes the set of numbered binary log files plus the index file.

A client that has privileges sufficient to set restricted session system variables (see Section 5.1.8.1, “System Variable Privileges") can disable binary logging of its own statements by using a `SET sql_log_bin=OFF` statement.

The format of the events recorded in the binary log is dependent on the binary logging format. Three format types are supported, row-based logging, statement-based logging and mixed-base logging. The binary logging format used depends on the MySQL version. For general descriptions of the logging formats, see Section 5.4.4.1, “Binary Logging Formats". For detailed information about the format of the binary log, see MySQL Internals: The Binary Log.

The server evaluates the `--binlog-do-db` and `--binlog-ignore-db` options in the same way as it does the `--replicate-do-db` and `--replicate-ignore-db` options. For information about how this is done, see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options".

If you are replicating from an NDB Cluster to a standalone MySQL Server, you should be aware that the NDB storage engine uses default values for some binary logging options (including options specific to NDB such as `--ndb-log-update-as-write`) that differ from those used by other storage engines. If not corrected for, these differences can lead to divergence of the master's and slave's binary logs. For more information, see Replication from NDB to other storage engines. In particular, if you are using a nontransactional storage engine such as MyISAM on the slave, see Replication from NDB to a nontransactional storage engine.

A replication slave server by default does not write to its own binary log any data modifications that are received from the replication master. To log these modifications, start the slave with the `--log-slave-updates` option in addition to the `--log-bin` option (see Section 17.1.3.3, “Replication Slave Options and Variables"). This is done when a slave is also to act as a master to other slaves in chained replication.

You can delete all binary log files with the `RESET MASTER` statement, or a subset of them with `PURGE BINARY LOGS`. See Section 13.7.6.6, “RESET Statement", and Section 13.4.1.1, “PURGE BINARY LOGS Statement".

If you are using replication, you should not delete old binary log files on the master until you are sure that no slave still needs to use them. For example, if your slaves never run more than three days behind, once a day you can execute `mysqladmin flush-logs` on the master and then remove any logs that are more than three days old. You can remove the files manually, but it is preferable to use `PURGE BINARY LOGS`, which also safely updates the binary log index file for you (and which can take a date argument). See Section 13.4.1.1, “PURGE BINARY LOGS Statement".

You can display the contents of binary log files with the `mysqlbinlog` utility. This can be useful when you want to reprocess statements in the log for a recovery operation. For example, you can update a MySQL server from the binary log as follows:

```
shell> mysqlbinlog log_file | mysql -h server_name
```

`mysqlbinlog` also can be used to display replication slave relay log file contents because they are written using the same format as binary log files. For more information on the `mysqlbinlog` utility and how to use it, see Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files". For more information about the binary log and recovery operations, see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log".

Binary logging is done immediately after a statement or transaction completes but before any locks are released or any commit is done. This ensures that the log is logged in commit order.

Updates to nontransactional tables are stored in the binary log immediately after execution.
Within an uncommitted transaction, all updates (UPDATE, DELETE, or INSERT) that change transactional tables such as InnoDB tables are cached until a COMMIT statement is received by the server. At that point, mysqld writes the entire transaction to the binary log before the COMMIT is executed.

Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a ROLLBACK statement at the end to ensure that the modifications to those tables are replicated.

When a thread that handles the transaction starts, it allocates a buffer of binlog_cache_size to buffer statements. If a statement is bigger than this, the thread opens a temporary file to store the transaction. The temporary file is deleted when the thread ends.

The Binlog_cache_use status variable shows the number of transactions that used this buffer (and possibly a temporary file) for storing statements. The Binlog_cache_disk_use status variable shows how many of those transactions actually had to use a temporary file. These two variables can be used for tuning binlog_cache_size to a large enough value that avoids the use of temporary files.

The max_binlog_cache_size system variable (default 4GB, which is also the maximum) can be used to restrict the total size used to cache a multiple-statement transaction. If a transaction is larger than this many bytes, it fails and rolls back. The minimum value is 4096.

If you are using the binary log and row based logging, concurrent inserts are converted to normal inserts for CREATE ... SELECT or INSERT ... SELECT statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. If you are using statement-based logging, the original statement is written to the log.

The binary log format has some known limitations that can affect recovery from backups. See Section 17.4.1, “Replication Features and Issues”.

Binary logging for stored programs is done as described in Section 20.7, “Stored Program Binary Logging”.

Note that the binary log format differs in MySQL 5.5 from previous versions of MySQL, due to enhancements in replication. See Section 17.4.2, “Replication Compatibility Between MySQL Versions”.

Writes to the binary log file and binary log index file are handled in the same way as writes to MyISAM tables. See Section B.4.3.4, “How MySQL Handles a Full Disk”.

By default, the binary log is not synchronized to disk at each write. So if the operating system or machine (not only the MySQL server) crashes, there is a chance that the last statements of the binary log are lost. To prevent this, you can make the binary log be synchronized to disk after every N writes to the binary log, with the sync_binlog system variable. See Section 5.1.7, “Server System Variables”. 1 is the safest value for sync_binlog, but also the slowest. Even with sync_binlog set to 1, there is still the chance of an inconsistency between the table content and binary log content in case of a crash. For example, if you are using InnoDB tables and the MySQL server processes a COMMIT statement, it writes the whole transaction to the binary log and then commits this transaction into InnoDB. If the server crashes between those two operations, the transaction is rolled back by InnoDB at restart but still exists in the binary log. To resolve this, you should set --innodb_support_xa to 1. Although this option is related to the support of XA transactions in InnoDB, it also ensures that the binary log and InnoDB data files are synchronized.

For this option to provide a greater degree of safety, the MySQL server should also be configured to synchronize the binary log and the InnoDB logs to disk at every transaction. The InnoDB logs are synchronized by default, and sync_binlog=1 can be used to synchronize the binary log. The effect of this option is that at restart after a crash, after doing a rollback of transactions, the MySQL server scans the latest binary log file to collect transaction xid values and calculate the last valid position in the binary log file. The MySQL server then tells InnoDB to complete any prepared transactions that were successfully
written to the binary log, and truncates the binary log to the last valid position. This ensures that the binary log reflects the exact data of InnoDB tables, and so, that the slave remains in synchrony with the master (not receiving a statement which has been rolled back).

If the MySQL server discovers at crash recovery that the binary log is shorter than it should have been, it lacks at least one successfully committed InnoDB transaction. This should not happen if sync_binlog=1 and the disk/file system do an actual sync when they are requested to (some do not), so the server prints an error message The binary log file_name is shorter than its expected size. In this case, this binary log is not correct and replication should be restarted from a fresh snapshot of the master's data.

The session values of the following system variables are written to the binary log and honored by the replication slave when parsing the binary log:

- `sql_mode` (except that the NO_DIR_IN_CREATE mode is not replicated; see Section 17.4.1.37, “Replication and Variables”)
- `foreign_key_checks`
- `unique_checks`
- `character_set_client`
- `collation_connection`
- `collation_database`
- `collation_server`
- `sql_auto_is_null`

### 5.4.4.1 Binary Logging Formats

The server uses several logging formats to record information in the binary log. The exact format employed depends on the version of MySQL being used. There are three logging formats:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called statement-based logging. You can cause this format to be used by starting the server with `--binlog-format=STATEMENT`.

- In row-based logging, the master writes events to the binary log that indicate how individual table rows are affected. You can cause the server to use row-based logging by starting it with `--binlog-format=ROW`.

- A third option is also available: mixed logging. With mixed logging, statement-based logging is used by default, but the logging mode switches automatically to row-based in certain cases as described below. You can cause MySQL to use mixed logging explicitly by starting `mysqld` with the option `--binlog-format=MIXED`.

In MySQL 5.5, the default binary logging format is `STATEMENT`.

The logging format can also be set or limited by the storage engine being used. This helps to eliminate issues when replicating certain statements between a master and slave which are using different storage engines.

With statement-based replication, there may be issues with replicating nondeterministic statements. In deciding whether or not a given statement is safe for statement-based replication, MySQL determines
whether it can guarantee that the statement can be replicated using statement-based logging. If MySQL cannot make this guarantee, it marks the statement as potentially unreliable and issues the warning, *Statement may not be safe to log in statement format.*

You can avoid these issues by using MySQL’s row-based replication instead.

### 5.4.4.2 Setting The Binary Log Format

You can select the binary logging format explicitly by starting the MySQL server with `--binlog-format=type`. The supported values for `type` are:

- **STATEMENT** causes logging to be statement based.
- **ROW** causes logging to be row based.
- **MIXED** causes logging to use mixed format.

In MySQL 5.5, the default binary logging format is **STATEMENT**. This includes MySQL NDB Cluster 7.2.1 and later MySQL NDB Cluster 7.2 releases, which are based on MySQL 5.5.

The logging format also can be switched at runtime. Set the global value of the `binlog_format` system variable to specify the format for clients that connect subsequent to the change:

```sql
mysql> SET GLOBAL binlog_format = 'STATEMENT';
mysql> SET GLOBAL binlog_format = 'ROW';
mysql> SET GLOBAL binlog_format = 'MIXED';
```

An individual client can control the logging format for its own statements by setting the session value of `binlog_format`:

```sql
mysql> SET SESSION binlog_format = 'STATEMENT';
mysql> SET SESSION binlog_format = 'ROW';
mysql> SET SESSION binlog_format = 'MIXED';
```

**Note**

Each MySQL Server can set its own and only its own binary logging format (true whether `binlog_format` is set with global or session scope). This means that changing the logging format on a replication master does not cause a slave to change its logging format to match. (When using **STATEMENT** mode, the `binlog_format` system variable is not replicated; when using **MIXED** or **ROW** logging mode, it is replicated but is ignored by the slave.) Changing the binary logging format on the master while replication is ongoing, or without also changing it on the slave can cause replication to fail with errors such as `Error executing row event: 'Cannot execute statement: impossible to write to binary log since statement is in row format and BINLOG_FORMAT = STATEMENT.'`

Changing the global `binlog_format` value requires privileges sufficient to set global system variables. Changing the session `binlog_format` value requires privileges sufficient to set restricted session system variables. See Section 5.1.8.1, “System Variable Privileges”.

There are several reasons why a client might want to set binary logging on a per-session basis:

- A session that makes many small changes to the database might want to use row-based logging.
- A session that performs updates that match many rows in the **WHERE** clause might want to use statement-based logging because it will be more efficient to log a few statements than many rows.
The Binary Log

• Some statements require a lot of execution time on the master, but result in just a few rows being modified. It might therefore be beneficial to replicate them using row-based logging.

There are exceptions when you cannot switch the replication format at runtime:

• From within a stored function or a trigger

• If the NDCLUSTER storage engine is enabled

• If the session is currently in row-based replication mode and has open temporary tables

Trying to switch the format in any of these cases results in an error.

If you are using InnoDB tables and the transaction isolation level is READ COMMITTED or READ UNCOMMITTED, only row-based logging can be used. It is possible to change the logging format to STATEMENT, but doing so at runtime leads very rapidly to errors because InnoDB can no longer perform inserts.

Switching the replication format at runtime is not recommended when any temporary tables exist, because temporary tables are logged only when using statement-based replication, whereas with row-based replication they are not logged. With mixed replication, temporary tables are usually logged; exceptions happen with user-defined functions (UDFs) and with the UUID() function.

With the binary log format set to ROW, many changes are written to the binary log using the row-based format. Some changes, however, still use the statement-based format. Examples include all DDL (data definition language) statements such as CREATE TABLE, ALTER TABLE, or DROP TABLE.

The --binlog-row-event-max-size option is available for servers that are capable of row-based replication. Rows are stored into the binary log in chunks having a size in bytes not exceeding the value of this option. The value must be a multiple of 256. The default value is 1024.

Warning

When using statement-based logging for replication, it is possible for the data on the master and slave to become different if a statement is designed in such a way that the data modification is nondeterministic; that is, it is left to the will of the query optimizer. In general, this is not a good practice even outside of replication. For a detailed explanation of this issue, see Section B.4.7, “Known Issues in MySQL”.

5.4.4.3 Mixed Binary Logging Format

When running in MIXED logging format, the server automatically switches from statement-based to row-based logging under the following conditions:

• When a DML statement updates an NDCLUSTER table.

• When a function contains UUID().

• When one or more tables with AUTO_INCREMENT columns are updated and a trigger or stored function is invoked. Like all other unsafe statements, this generates a warning if binlog_format = STATEMENT.

For more information, see Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

• When any INSERT DELAYED is executed.

• When the body of a view requires row-based replication, the statement creating the view also uses it. For example, this occurs when the statement creating a view uses the UUID() function.
The Binary Log

- When a call to a UDF is involved.

- If a statement is logged by row and the session that executed the statement has any temporary tables, logging by row is used for all subsequent statements (except for those accessing temporary tables) until all temporary tables in use by that session are dropped.

This is true whether or not any temporary tables are actually logged.

Temporary tables cannot be logged using row-based format; thus, once row-based logging is used, all subsequent statements using that table are unsafe. The server approximates this condition by treating all statements executed during the session as unsafe until the session no longer holds any temporary tables.

- When `FOUND_ROWS()` or `ROW_COUNT()` is used. (Bug #12092, Bug #30244)

- When `USER()`, `CURRENT_USER()`, or `CURRENT_USER` is used. (Bug #28086)

- When a statement refers to one or more system variables. (Bug #31168)

**Exception.** The following system variables, when used with session scope (only), do not cause the logging format to switch:

- `auto_increment_increment`
- `auto_increment_offset`
- `character_set_client`
- `character_set_connection`
- `character_set_database`
- `character_set_server`
- `collation_connection`
- `collation_database`
- `collation_server`
- `foreign_key_checks`
- `identity`
- `last_insert_id`
- `lc_time_names`
- `pseudo_thread_id`
- `sql_auto_is_null`
- `time_zone`
- `timestamp`
- `unique_checks`

For information about determining system variable scope, see Section 5.1.8, “Using System Variables”. 
For information about how replication treats `sql_mode`, see Section 17.4.1.37, “Replication and Variables”.

- When one of the tables involved is a log table in the `mysql` database.
- When the `LOAD_FILE()` function is used. (Bug #39701)

Note

A warning is generated if you try to execute a statement using statement-based logging that should be written using row-based logging. The warning is shown both in the client (in the output of `SHOW WARNINGS`) and through the `mysqld` error log. A warning is added to the `SHOW WARNINGS` table each time such a statement is executed. However, only the first statement that generated the warning for each client session is written to the error log to prevent flooding the log.

In addition to the decisions above, individual engines can also determine the logging format used when information in a table is updated. The logging capabilities of an individual engine can be defined as follows:

- If an engine supports row-based logging, the engine is said to be `row-logging capable`.
- If an engine supports statement-based logging, the engine is said to be `statement-logging capable`.

A given storage engine can support either or both logging formats. The following table lists the formats supported by each engine.

<table>
<thead>
<tr>
<th>Storage Engine</th>
<th>Row Logging Supported</th>
<th>Statement Logging Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCHIVE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BLACKHOLE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CSV</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>EXAMPLE</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>FEDERATED</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HEAP</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>InnoDB</td>
<td>Yes</td>
<td>Yes when the transaction isolation level is <code>REPEATABLE_READ</code> or <code>SERIALIZABLE</code>; No otherwise.</td>
</tr>
<tr>
<td>MyISAM</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MERGE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>NDBCLUSTER</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Whether a statement is to be logged and the logging mode to be used is determined according to the type of statement (safe, unsafe, or binary injected), the binary logging format (`STATEMENT`, `ROW`, or `MIXED`), and the logging capabilities of the storage engine (statement capable, row capable, both, or neither). (Binary injection refers to logging a change that must be logged using `ROW` format.)

Statements may be logged with or without a warning; failed statements are not logged, but generate errors in the log. This is shown in the following decision table. `Type`, `binlog_format`, `SLC`, and `RLC` columns
The Binary Log

Outline the conditions, and **Error / Warning** and **Logged as** columns represent the corresponding actions. **SLC** stands for “statement-logging capable”, and **RLC** stands for “row-logging capable”.

<table>
<thead>
<tr>
<th>Type</th>
<th>binlog_format</th>
<th>SLC</th>
<th>RLC</th>
<th>Error / Warning</th>
<th>Logged as</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>*</td>
<td>No</td>
<td>No</td>
<td>Error: Cannot execute statement: Binary logging is impossible since at least one engine is involved that is both row-incapable and statement-incapable.</td>
<td>-</td>
</tr>
<tr>
<td>Safe</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>No</td>
<td>-</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Safe</td>
<td>MIXED</td>
<td>Yes</td>
<td>No</td>
<td>-</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Safe</td>
<td>ROW</td>
<td>Yes</td>
<td>No</td>
<td>Error: Cannot execute statement: Binary logging is impossible since <strong>BINLOG_FORMAT = ROW</strong> and at least one table uses a storage engine that is not capable of row-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Unsafe</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>No</td>
<td>Warning: Unsafe statement binlogged in statement format, since <strong>BINLOG_FORMAT = STATEMENT</strong></td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Unsafe</td>
<td>MIXED</td>
<td>Yes</td>
<td>No</td>
<td>Error: Cannot execute statement: Binary logging of an unsafe statement is impossible when the storage engine is limited to statement-based logging, even if <strong>BINLOG_FORMAT = MIXED</strong>.</td>
<td>-</td>
</tr>
<tr>
<td>Unsafe</td>
<td>ROW</td>
<td>Yes</td>
<td>No</td>
<td>Error: Cannot execute statement: Binary logging is impossible since</td>
<td>-</td>
</tr>
<tr>
<td>Type</td>
<td>binlog_format</td>
<td>SLC</td>
<td>RLC</td>
<td>Error / Warning</td>
<td>Logged as</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>-----</td>
<td>-----</td>
<td>-----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Row Injection</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>No</td>
<td><strong>Error: Cannot execute row injection</strong>: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Row Injection</td>
<td>MIXED</td>
<td>Yes</td>
<td>No</td>
<td><strong>Error: Cannot execute row injection</strong>: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Row Injection</td>
<td>ROW</td>
<td>Yes</td>
<td>No</td>
<td><strong>Error: Cannot execute row injection</strong>: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Safe Injection</td>
<td>STATEMENT</td>
<td>No</td>
<td>Yes</td>
<td><strong>Error: Cannot execute statement</strong>: Binary logging is impossible since ( \text{BINLOG_FORMAT = STATEMENT} ) and at least one table uses a storage engine that is not capable of statement-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Safe Injection</td>
<td>MIXED</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Safe Injection</td>
<td>ROW</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## The Binary Log

<table>
<thead>
<tr>
<th>Type</th>
<th>binlog_format</th>
<th>SLC</th>
<th>RLC</th>
<th>Error / Warning</th>
<th>Logged as</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsafe</td>
<td>STATEMENT</td>
<td>No</td>
<td>Yes</td>
<td>Error: Cannot execute statement: Binary logging is impossible since BINLOG_FORMAT = STATEMENT and at least one table uses a storage engine that is not capable of statement-based logging.</td>
<td>-</td>
</tr>
<tr>
<td>Unsafe</td>
<td>MIXED</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Unsafe</td>
<td>ROW</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Row Injection</td>
<td>STATEMENT</td>
<td>No</td>
<td>Yes</td>
<td>Error: Cannot execute row injection: Binary logging is not possible since BINLOG_FORMAT = STATEMENT.</td>
<td>-</td>
</tr>
<tr>
<td>Row Injection</td>
<td>MIXED</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Row Injection</td>
<td>ROW</td>
<td>No</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Safe</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Safe</td>
<td>MIXED</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Safe</td>
<td>ROW</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Unsafe</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>Yes</td>
<td>Warning: Unsafe statement binlogged in statement format since BINLOG_FORMAT = STATEMENT.</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Unsafe</td>
<td>MIXED</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Unsafe</td>
<td>ROW</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
<tr>
<td>Row Injection</td>
<td>STATEMENT</td>
<td>Yes</td>
<td>Yes</td>
<td>Error: Cannot execute row injection: Binary logging is not possible because BINLOG_FORMAT = STATEMENT.</td>
<td>-</td>
</tr>
<tr>
<td>Row Injection</td>
<td>MIXED</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
</tbody>
</table>
The Slow Query Log

<table>
<thead>
<tr>
<th>Type</th>
<th>binlog_format</th>
<th>SLC</th>
<th>RLC</th>
<th>Error / Warning</th>
<th>Logged as</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Injection</td>
<td>ROW</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>ROW</td>
</tr>
</tbody>
</table>

When a warning is produced by the determination, a standard MySQL warning is produced (and is available using `SHOW WARNINGS`). The information is also written to the `mysqld` error log. Only one error for each error instance per client connection is logged to prevent flooding the log. The log message includes the SQL statement that was attempted.

If a slave server was started with `--log-warnings` enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth.

5.4.4.4 Logging Format for Changes to mysql Database Tables

The contents of the grant tables in the `mysql` database can be modified directly (for example, with `INSERT` or `DELETE`) or indirectly (for example, with `GRANT` or `CREATE USER`). Statements that affect `mysql` database tables are written to the binary log using the following rules:

- Data manipulation statements that change data in `mysql` database tables directly are logged according to the setting of the `binlog_format` system variable. This pertains to statements such as `INSERT`, `UPDATE`, `DELETE`, `REPLACE`, `DO`, `LOAD DATA`, `SELECT`, and `TRUNCATE TABLE`.

- Statements that change the `mysql` database indirectly are logged as statements regardless of the value of `binlog_format`. This pertains to statements such as `GRANT`, `REVOKE`, `SET PASSWORD`, `RENAME USER`, `CREATE` (all forms except `CREATE TABLE ... SELECT`), `ALTER` (all forms), and `DROP` (all forms).

`CREATE TABLE ... SELECT` is a combination of data definition and data manipulation. The `CREATE TABLE` part is logged using statement format and the `SELECT` part is logged according to the value of `binlog_format`.

5.4.5 The Slow Query Log

The slow query log consists of SQL statements that take more than `long_query_time` seconds to execute and require at least `min_examined_row_limit` rows to be examined. The slow query log can be used to find queries that take a long time to execute and are therefore candidates for optimization. However, examining a long slow query log can be a time-consuming task. To make this easier, you can use the `mysqldumpslow` command to process a slow query log file and summarize its contents. See Section 4.6.8, "mysqldumpslow — Summarize Slow Query Log Files".

The time to acquire the initial locks is not counted as execution time. `mysqld` writes a statement to the slow query log after it has been executed and after all locks have been released, so log order might differ from execution order.

The slow query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

- Slow Query Log Parameters
- Slow Query Log Contents

Slow Query Log Parameters

The minimum and default values of `long_query_time` are 0 and 10, respectively. The value can be specified to a resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored.
By default, administrative statements are not logged, nor are queries that do not use indexes for lookups. This behavior can be changed using `--log-slow-admin-statements` and `log_queries_not_using_indexes`, as described later.

By default, the slow query log is disabled. To specify the initial slow query log state explicitly, use `--slow_query_log[={0|1}]`. With no argument or an argument of 1, `--slow_query_log` enables the log. With an argument of 0, this option disables the log. To specify a log file name, use `--slow_query_log_file=file_name`. To specify the log destination, use the `log_output` system variable (as described in Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”). The older system variable to enable the slow query log file, `log_slow_queries`, is deprecated.

If you specify no name for the slow query log file, the default name is `host_name-slow.log`. The server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the slow query log or change the log file name at runtime, use the global `slow_query_log` and `slow_query_log_file` system variables. Set `slow_query_log` to 0 to disable the log or to 1 to enable it. Set `slow_query_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

The server writes less information to the slow query log if you use the `--log-short-format` option.

To include slow administrative statements in the slow query log, use the `--log-slow-admin-statements` server option. Administrative statements include `ALTER TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE INDEX`, `DROP INDEX`, `OPTIMIZE TABLE`, and `REPAIR TABLE`.

To include queries that do not use indexes for row lookups in the statements written to the slow query log, enable the `log_queries_not_using_indexes` system variable. (Even with that variable enabled, the server does not log queries that would not benefit from the presence of an index due to the table having fewer than two rows.) When queries that do not use an index are logged, the slow query log may grow quickly.

The server uses the controlling parameters in the following order to determine whether to write a query to the slow query log:

1. The query must either not be an administrative statement, or `--log-slow-admin-statements` must have been specified.
2. The query must have taken at least `long_query_time` seconds, or `log_queries_not_using_indexes` must be enabled and the query used no indexes for row lookups.
3. The query must have examined at least `min_examined_row_limit` rows.

The server does not log queries handled by the query cache.

By default, a replication slave does not write replicated queries to the slow query log. To change this, use the `--log-slow-slave-statements` server option.

**Slow Query Log Contents**

When the slow query log is enabled, the server writes output to any destinations specified by the `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the slow query log is enabled. Setting the log file name has no effect on logging if `FILE` is not selected as an output destination.
If the slow query log is enabled and `FILE` is selected as an output destination, each statement written to the log is preceded by a line that begins with a `#` character and has these fields (with all fields on a single line):

- **Query_time**: duration
  The statement execution time in seconds.
- **Lock_time**: duration
  The time to acquire locks in seconds.
- **Rows_sent**: N
  The number of rows sent to the client.
- **Rows_examined**:
  The number of rows examined by the server layer (not counting any processing internal to storage engines).

Each statement written to the slow query log file is preceded by a `SET` statement that includes a timestamp indicating when the slow statement was logged (which occurs after the statement finishes executing).

### 5.4.6 The DDL Log

The DDL log, or metadata log, records metadata operations generated by data definition statements such as `DROP TABLE` and `ALTER TABLE`. MySQL uses this log to recover from crashes occurring in the middle of a metadata operation. When executing the statement `DROP TABLE t1, t2`, we need to ensure that both `t1` and `t2` are dropped, and that each table drop is complete. Another example of this type of SQL statement is `ALTER TABLE t3 DROP PARTITION p2`, where we must make certain that the partition is completely dropped and that its definition is removed from the list of partitions for table `t3`.

A record of metadata operations such as those just described are written to the file `ddl_log.log`, in the MySQL data directory. This is a binary file; it is not intended to be human-readable, and you should not attempt to modify its contents in any way.

`ddl_log.log` is not created until it is actually needed for recording metadata statements, and is removed following a successful start of `mysqld`. Thus, it is possible for this file not to be present on a MySQL server that is functioning in a completely normal manner.

Currently, `ddl_log.log` can hold up to 1048573 entries, equivalent to 4 GB in size. Once this limit is exceeded, you must rename or remove the file before it is possible to execute any additional DDL statements. This is a known issue which we are working to resolve (Bug #83708).

There are no user-configurable server options or variables associated with this file.

### 5.4.7 Server Log Maintenance

As described in Section 5.4, “MySQL Server Logs”, MySQL Server can create several different log files to help you see what activity is taking place. However, you must clean up these files regularly to ensure that the logs do not take up too much disk space.

When using MySQL with logging enabled, you may want to back up and remove old log files from time to time and tell MySQL to start logging to new files. See Section 7.2, “Database Backup Methods”.

On a Linux (Red Hat) installation, you can use the `mysql-log-rotate` script for log maintenance. If you installed MySQL from an RPM distribution, this script should have been installed automatically. Be careful
with this script if you are using the binary log for replication. You should not remove binary logs until you are certain that their contents have been processed by all slaves.

On other systems, you must install a short script yourself that you start from `cron` (or its equivalent) for handling log files.

For the binary log, you can set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.7, “Server System Variables”). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master. To remove binary logs on demand, use the `PURGE BINARY LOGS` statement (see Section 13.4.1.1, “PURGE BINARY LOGS Statement”).

To force MySQL to start using new log files, flush the logs. Log flushing occurs when you execute a `FLUSH LOGS` statement or a `mysqladmin flush-logs, mysqladmin refresh, mysqldump --flush-logs, or mysqldump --master-data` command. See Section 13.7.6.3, “FLUSH Statement”, Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”, and Section 4.5.4, “mysqldump — A Database Backup Program”. In addition, the server flushes the binary log automatically when current binary log file size reaches the value of the `max_binlog_size` system variable.

`FLUSH LOGS` supports optional modifiers to enable selective flushing of individual logs (for example, `FLUSH BINARY LOGS`). See Section 13.7.6.3, “FLUSH Statement”.

A log-flushing operation has the following effects:

- If binary logging is enabled, the server closes the current binary log file and opens a new log file with the next sequence number.
- If general query logging or slow query logging to a log file is enabled, the server closes and reopens the log file.
- If the server was started with the `--log-error` option to cause the error log to be written to a file, the server closes and reopens the log file.

Execution of log-flushing statements or commands requires connecting to the server using an account that has the `RELOAD` privilege. On Unix and Unix-like systems, another way to flush the logs is to send a `SIGHUP` signal to the server, which can be done by `root` or the account that owns the server process. Signals enable log flushing to be performed without having to connect to the server. However, `SIGHUP` has additional effects other than log flushing that might be undesirable. For details, see Section 4.10, “Unix Signal Handling in MySQL”.

As mentioned previously, flushing the binary log creates a new binary log file, whereas flushing the general query log, slow query log, or error log just closes and reopens the log file. For the latter logs, to cause a new log file to be created on Unix, rename the current log file first before flushing it. At flush time, the server opens the new log file with the original name. For example, if the general query log, slow query log, and error log files are named `mysql.log, mysql-slow.log, and err.log`, you can use a series of commands like this from the command line:

```bash
cd mysql-data-directory
mv mysql.log mysql.log.old
mv mysql-slow.log mysql-slow.log.old
mv err.log err.log.old
mysqladmin flush-logs
```

On Windows, use `rename` rather than `mv`.

At this point, you can make a backup of `mysql.log.old, mysql-slow.log.old, and err.log.old,` then remove them from disk.
To rename the general query log or slow query log at runtime, first connect to the server and disable the log:

```sql
SET GLOBAL general_log = 'OFF';
SET GLOBAL slow_query_log = 'OFF';
```

With the logs disabled, rename the log files externally (for example, from the command line). Then enable the logs again:

```sql
SET GLOBAL general_log = 'ON';
SET GLOBAL slow_query_log = 'ON';
```

This method works on any platform and does not require a server restart.

---

**Note**

For the server to recreate a given log file after you have renamed the file externally, the file location must be writable by the server. This may not always be the case. For example, on Linux, the server might write the error log as `/var/log/mysqld.log`, where `/var/log` is owned by `root` and not writable by `mysqld`. In this case, log-flushing operations fail to create a new log file.

To handle this situation, you must manually create the new log file with the proper ownership after renaming the original log file. For example, execute these commands as `root`:

```sh
mv /var/log/mysqld.log /var/log/mysqld.log.old
install -omysql -gmysql -m0644 /dev/null /var/log/mysqld.log
```

---

5.5 MySQL Server Plugins

MySQL supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The components supported by this interface include, but are not limited to, storage engines, `INFORMATION_SCHEMA` tables, full-text parser plugins, partitioning support, and server extensions.

MySQL distributions include several plugins that implement server extensions:

- Plugins for authenticating attempts by clients to connect to MySQL Server. Plugins are available for several authentication protocols. See Section 6.2.10, “Pluggable Authentication”.
- Semisynchronous replication plugins implement an interface to replication capabilities that permit the master to proceed as long as at least one slave has responded to each transaction. See Section 17.3.8, “Semisynchronous Replication”.
- MySQL Enterprise Edition includes a thread pool plugin that manages connection threads to increase server performance by efficiently managing statement execution threads for large numbers of client connections. See Section 5.5.3, “MySQL Enterprise Thread Pool”.
- MySQL Enterprise Edition includes an audit plugin for monitoring and logging of connection and query activity. See Section 6.4.2, “MySQL Enterprise Audit”.

The following sections describe how to install and uninstall plugins, and how to determine at runtime which plugins are installed and obtain information about them. For information about writing plugins, see Section 24.2, “The MySQL Plugin API”.

5.5.1 Installing and Uninstalling Plugins
Installing and Uninstalling Plugins

Server plugins must be loaded into the server before they can be used. MySQL supports plugin loading at server startup and runtime. It is also possible to control the activation state of loaded plugins at startup, and to unload them at runtime.

While a plugin is loaded, information about it is available from the `INFORMATION_SCHEMA.PLUGINS` table and the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

- Installing Plugins
- Controlling Plugin Activation State
- Uninstalling Plugins

Installing Plugins

Before a server plugin can be used, it must be installed using one of the following methods. In the descriptions, `plugin_name` stands for a plugin name such as `innodb` or `csv`.

**Built-in plugins:**

A built-in plugin is known by the server automatically. Normally, the server enables the plugin at startup. Some built-in plugins permit this to be changed with the `--plugin_name[=activation_state]` option.

**Plugins registered in the `mysql.plugin` system table:**

The `plugin` table in the `mysql` system database serves as a registry of plugins (other than built-in plugins, which need not be registered). At startup, the server loads each plugin listed in the table. Normally, for a plugin loaded from the `mysql.plugin` table, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.plugin` table and does not load the plugins listed there.

**Plugins named with the `--plugin-load` option:**

A plugin located in a plugin library file can be loaded at server startup with the `--plugin-load` option. Normally, for a plugin loaded at startup, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

The value of each plugin-loading option is a semicolon-separated list of `name=plugin_library` and `plugin_library` values. Each `name` is the name of a plugin to load, and `plugin_library` is the name of the library file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the `plugin_dir` system variable.

Plugin-loading options do not register any plugin in the `mysql.plugin` table. For subsequent restarts, the server loads the plugin again only if `--plugin-load` is given again. That is, the option produces a one-time plugin-installation operation that persists for a single server invocation.

`--plugin-load` enables plugins to be loaded even when `--skip-grant-tables` is given (which causes the server to ignore the `mysql.plugin` table). `--plugin-load` also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

**Plugins installed with the `INSTALL PLUGIN` statement:**

A plugin located in a plugin library file can be loaded at runtime with the `INSTALL PLUGIN` statement. The statement also registers the plugin in the `mysql.plugin` table to cause the server to load it.
Installing and Uninstalling Plugins

on subsequent restarts. For this reason, `INSTALL PLUGIN` requires the `INSERT` privilege for the `mysql.plugin` table.

The plugin library file base name depends on your platform. Common suffixes are `.so` for Unix and Unix-like systems, `.dll` for Windows.

Example: The `--plugin-load` option installs a plugin at server startup. To install a plugin named `myplugin` from a plugin library file named `somepluglib.so`, use these lines in a `my.cnf` file:

```
[mysqld]
plugin-load=myplugin=somepluglib.so
```

In this case, the plugin is not registered in `mysql.plugin`. Restarting the server without the `--plugin-load` option causes the plugin not to be loaded at startup.

Alternatively, the `INSTALL PLUGIN` statement causes the server to load the plugin code from the library file at runtime:

```
INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
```

`INSTALL PLUGIN` also causes “permanent” plugin registration: The plugin is listed in the `mysql.plugin` table to ensure that the server loads it on subsequent restarts.

Many plugins can be loaded either at server startup or at runtime. However, if a plugin is designed such that it must be loaded and initialized during server startup, attempts to load it at runtime using `INSTALL PLUGIN` produce an error:

```
mysql> INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
ERROR 1721 (HY000): Plugin 'myplugin' is marked as not dynamically installable. You have to stop the server to install it.
```

In this case, you must use `--plugin-load`.

Many plugins can be loaded either at server startup or at runtime. However, if a plugin is designed such that it must be loaded and initialized during server startup, use `--plugin-load` rather than `INSTALL PLUGIN`.

If a plugin is named both using a `--plugin-load` option and (as a result of an earlier `INSTALL PLUGIN` statement) in the `mysql.plugin` table, the server starts but writes these messages to the error log:

```
[ERROR] Function 'plugin_name' already exists
[Warning] Couldn't load plugin named 'plugin_name'
with soname 'plugin_object_file'.
```

Controlling Plugin Activation State

If the server knows about a plugin when it starts (for example, because the plugin is named using a `--plugin-load` option or is registered in the `mysql.plugin` table), the server loads and enables the plugin by default. It is possible to control activation state for such a plugin using a `--plugin_name[=activation_state]` startup option, where `plugin_name` is the name of the plugin to affect, such as `innodb` or `csv`. As with other options, dashes and underscores are interchangeable in option names. Also, activation state values are not case-sensitive. For example, `--my_plugin=ON` and `--my-plugin=on` are equivalent.

- `--plugin_name=OFF`
  
  Tells the server to disable the plugin. This may not be possible for certain built-in plugins, such as `mysql_native_password`.

- `--plugin_name[=ON]`
Installing and Uninstalling Plugins

Tells the server to enable the plugin. (Specifying the option as `--plugin_name` without a value has the same effect.) If the plugin fails to initialize, the server runs with the plugin disabled.

- `--plugin_name=FORCE`

  Tells the server to enable the plugin, but if plugin initialization fails, the server does not start. In other words, this option forces the server to run with the plugin enabled or not at all.

- `--plugin_name=FORCE_PLUS_PERMANENT`

  Like `FORCE`, but in addition prevents the plugin from being unloaded at runtime. If a user attempts to do so with `UNINSTALL PLUGIN`, an error occurs. This value is available as of MySQL 5.5.7.

Plugin activation states are visible in the `LOAD_OPTION` column of the `INFORMATION_SCHEMA.PLUGINS` table.

Suppose that `CSV`, `BLACKHOLE`, and `ARCHIVE` are built-in pluggable storage engines and that you want the server to load them at startup, subject to these conditions: The server is permitted to run if `CSV` initialization fails, must require that `BLACKHOLE` initialization succeeds, and should disable `ARCHIVE`. To accomplish that, use these lines in an option file:

```
[mysqld]
csv=ON
blackhole=FORCE
archive=OFF
```

The `--enable-plugin_name` option format is a synonym for `--plugin_name=ON`. The `--disable-plugin_name` and `--skip-plugin_name` option formats are synonyms for `--plugin_name=OFF`.

Before MySQL 5.1.36, plugin options are boolean options (see Section 4.2.2.4, “Program Option Modifiers”). That is, any of these options enable the plugin:

- `--plugin_name`
- `--plugin_name=1`
- `--enable-plugin_name`

And these options disable the plugin:

- `--plugin_name=0`
- `--disable-plugin_name`
- `--skip-plugin_name`

If you upgrade to MySQL 5.5 from a version older than 5.1.36 and previously used options of the form `--plugin_name=0` or `--plugin_name=1`, the equivalent options are now `--plugin_name=OFF` and `--plugin_name=ON`, respectively. You also have the choice of requiring plugins to start successfully by using `--plugin_name=FORCE` or `--plugin_name=FORCE_PLUS_PERMANENT`.

If a plugin is disabled, either explicitly with `OFF` or implicitly because it was enabled with `ON` but fails to initialize, aspects of server operation that require the plugin will change. For example, if the plugin implements a storage engine, existing tables for the storage engine become inaccessible, and attempts to create new tables for the storage engine result in tables that use the default storage engine unless the `NO_ENGINE_SUBSTITUTION` SQL mode is enabled to cause an error to occur instead.

Disabling a plugin may require adjustment to other options. For example, if you start the server using `--skip-innodb` to disable InnoDB, other `innodb_xxx` options likely will need to be omitted at startup. In addition, because InnoDB is the default storage engine, it will not start unless you also change the `default_storage_engine` system variable to set the default to some other available engine.
Uninstalling Plugins

At runtime, the `UNINSTALL PLUGIN` statement disables and uninstalls a plugin known to the server. The statement unloads the plugin and removes it from the `mysql.plugin` system table, if it is registered there. For this reason, `UNINSTALL PLUGIN` statement requires the `DELETE` privilege for the `mysql.plugin` table. With the plugin no longer registered in the table, the server does not load the plugin automatically for subsequent restarts.

`UNINSTALL PLUGIN` can unload a plugin regardless of whether it was loaded at runtime with `INSTALL PLUGIN` or at startup with a plugin-loading option, subject to these conditions:

- It cannot unload plugins that are built in to the server. These can be identified as those that have a library name of `NULL` in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`.
- It cannot unload plugins for which the server was started with `--plugin_name=FORCE_PLUS_PERMANENT`, which prevents plugin unloading at runtime. These can be identified from the `LOAD_OPTION` column of the `INFORMATION_SCHEMA.PLUGINS` table.

To uninstall a plugin that currently is loaded at server startup with a plugin-loading option, use this procedure.

1. Remove any options related to the plugin from the `my.cnf` file.
2. Restart the server.
3. Plugins normally are installed using either a plugin-loading option at startup or with `INSTALL PLUGIN` at runtime, but not both. However, removing options for a plugin from the `my.cnf` file may not be sufficient to uninstall it if at some point `INSTALL PLUGIN` has also been used. If the plugin still appears in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`, use `UNINSTALL PLUGIN` to remove it from the `mysql.plugin` table. Then restart the server again.

5.5.2 Obtaining Server Plugin Information

There are several ways to determine which plugins are installed in the server:

- The `INFORMATION_SCHEMA.PLUGINS` table contains a row for each loaded plugin. Any that have a `PLUGIN_LIBRARY` value of `NULL` are built in and cannot be unloaded.

```
mysql> SELECT * FROM INFORMATION_SCHEMA.PLUGINS\G
*************************** 1. row ***************************
PLUGIN_NAME: binlog
PLUGIN_VERSION: 1.0
PLUGIN_STATUS: ACTIVE
PLUGIN_TYPE: STORAGE ENGINE
PLUGIN_TYPE_VERSION: 50158.0
PLUGIN_LIBRARY: NULL
PLUGIN_LIBRARY_VERSION: NULL
PLUGIN_AUTHOR: MySQL AB
PLUGIN_DESCRIPTION: This is a pseudo storage engine to represent the binlog in a transaction
PLUGIN_LICENSE: GPL
LOAD_OPTION: FORCE
...
*************************** 10. row ***************************
PLUGIN_NAME: InnoDB
PLUGIN_VERSION: 1.0
PLUGIN_STATUS: ACTIVE
PLUGIN_TYPE: STORAGE ENGINE
PLUGIN_TYPE_VERSION: 50158.0
PLUGIN_LIBRARY: ha_innodb_plugin.so
PLUGIN_LIBRARY_VERSION: 1.0
PLUGIN_AUTHOR: Innobase Oy
```
MySQL Enterprise Thread Pool

**PLUGIN_DESCRIPTION:** Supports transactions, row-level locking, and foreign keys

**PLUGIN_LICENSE:** GPL

**LOAD_OPTION:** ON

---

- The `SHOW PLUGINS` statement displays a row for each loaded plugin. Any that have a *Library* value of `NULL` are built in and cannot be unloaded.

```sql
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
  Name: binlog
  Status: ACTIVE
  Type: STORAGE ENGINE
  Library: NULL
  License: GPL
...
*************************** 10. row ***************************
  Name: InnoDB
  Status: ACTIVE
  Type: STORAGE ENGINE
  Library: ha_innodb_plugin.so
  License: GPL
...
```

- The `mysql.plugin` table shows which plugins have been registered with `INSTALL PLUGIN`. The table contains only plugin names and library file names, so it does not provide as much information as the `PLUGINS` table or the `SHOW PLUGINS` statement.

**5.5.3 MySQL Enterprise Thread Pool**

**Note**

MySQL Enterprise Thread Pool is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, [https://www.mysql.com/products/](https://www.mysql.com/products/).

As of MySQL 5.5.16, MySQL Enterprise Edition includes MySQL Enterprise Thread Pool, implemented using a server plugin. The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. The thread pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections.

The thread pool addresses several problems of the model that uses one thread per connection:

- Too many thread stacks make CPU caches almost useless in highly parallel execution workloads. The thread pool promotes thread stack reuse to minimize the CPU cache footprint.

- With too many threads executing in parallel, context switching overhead is high. This also presents a challenging task to the operating system scheduler. The thread pool controls the number of active threads to keep the parallelism within the MySQL server at a level that it can handle and that is appropriate for the server host on which MySQL is executing.

- Too many transactions executing in parallel increases resource contention. In InnoDB, this increases the time spent holding central mutexes. The thread pool controls when transactions start to ensure that not too many execute in parallel.

**Additional Resources**

Section A.15, "MySQL 5.5 FAQ: MySQL Enterprise Thread Pool"
5.5.3.1 Thread Pool Components

The thread pool feature comprises these components:

- A plugin library file implements a plugin for the thread pool code as well as several associated monitoring tables that provide information about thread pool operation.

For a detailed description of how the thread pool works, see Section 5.5.3.3, “Thread Pool Operation”.

The INFORMATION_SCHEMA tables are named TP_THREAD_STATE, TP_THREAD_GROUP_STATE, and TP_THREAD_GROUP_STATS. These tables provide information about thread pool operation. For more information, see Section 21.31, “INFORMATION_SCHEMA Thread Pool Tables”.

- Several system variables are related to the thread pool. The thread_handling system variable has a value of loaded-dynamically when the server successfully loads the thread pool plugin.

The other related variables are implemented by the thread pool plugin; they are not available unless it is enabled:

- thread_pool_algorithm: The concurrency algorithm to use for scheduling.
- thread_pool_high_priority_connection: How to schedule statement execution for a session.
- thread_pool_prio_kickup_timer: How long before the thread pool moves a statement awaiting execution from the low-priority queue to the high-priority queue.
- thread_pool_max_unused_threads: How many sleeping threads to permit.
- thread_pool_size: The number of thread groups in the thread pool. This is the most important parameter controlling thread pool performance.
- thread_pool_stall_limit: The time before an executing statement is considered to be stalled.

If any variable implemented by the plugin is set to an illegal value at startup, plugin initialization fails and the plugin does not load.

For information about setting thread pool parameters, see Section 5.5.3.4, “Thread Pool Tuning”.

- The Performance Schema has instruments that expose information about the thread pool and may be used to investigate operational performance. To identify them, use this query:

```sql
SELECT * FROM performance_schema.setup_instruments
WHERE NAME LIKE '%thread_pool%';
```

For more information, see Chapter 22, MySQL Performance Schema.

5.5.3.2 Thread Pool Installation

This section describes how to install MySQL Enterprise Thread Pool. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the plugin_dir system variable). If necessary, configure the plugin directory location by setting the value of plugin_dir at server startup.

The plugin library file base name is thread_pool. The file name suffix differs per platform (for example, .so for Unix and Unix-like systems, .dll for Windows).
To enable thread pool capability, load the plugins to be used by starting the server with the `--plugin-load` option. For example, if you name just the plugin library file, the server loads all plugins that it contains (that is, the thread pool plugin and all the `INFORMATION_SCHEMA` tables). To do this, put these lines in the server `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=thread_pool.so
```

That is equivalent to loading all thread pool plugins by naming them individually:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so;tp_thread_state=thread_pool.so;tp_thread_group_state=thread_pool.so;tp_thread_group_stats=thread_pool.so
```

If desired, you can load individual plugins from the library file. To load the thread pool plugin but not the `INFORMATION_SCHEMA` tables, use an option like this:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so
```

To load the thread pool plugin and only the `TP_THREAD_STATE INFORMATION_SCHEMA` table, use an option like this:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so;tp_thread_state=thread_pool.so
```

**Note**

If you do not load all the `INFORMATION_SCHEMA` tables, some or all MySQL Enterprise Monitor thread pool graphs will be empty.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS WHERE PLUGIN_NAME LIKE 'thread%' OR PLUGIN_NAME LIKE 'tp%';
+-----------------------+---------------+
<table>
<thead>
<tr>
<th>PLUGIN_NAME</th>
<th>PLUGIN_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>thread_pool</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>TP_THREAD_STATE</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>TP_THREAD_GROUP_STATE</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>TP_THREAD_GROUP_STATS</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>
+-----------------------+---------------+
```

If the server loads the thread pool plugin successfully, it sets the `thread_handling` system variable to `loaded-dynamically`.

If a plugin fails to initialize, check the server error log for diagnostic messages.

### 5.5.3.3 Thread Pool Operation

The thread pool consists of a number of thread groups, each of which manages a set of client connections. As connections are established, the thread pool assigns them to thread groups in round-robin fashion.

The number of thread groups is configurable using the `thread_pool_size` system variable. The default number of groups is 16. For guidelines on setting this variable, see Section 5.5.3.4, “Thread Pool Tuning”.

The maximum number of threads per group is 4096 (or 4095 on some systems where one thread is used internally).
The thread pool separates connections and threads, so there is no fixed relationship between connections and the threads that execute statements received from those connections. This differs from the default thread-handling model that associates one thread with one connection such that a given thread executes all statements from its connection.

The thread pool tries to ensure a maximum of one thread executing in each group at any time, but sometimes permits more threads to execute temporarily for best performance. The algorithm works in the following manner:

- Each thread group has a listener thread that listens for incoming statements from the connections assigned to the group. When a statement arrives, the thread group either begins executing it immediately or queues it for later execution:
  - Immediate execution occurs if the statement is the only one received and no statements are queued or currently executing.
  - Queuing occurs if the statement cannot begin executing immediately.

- If immediate execution occurs, execution is performed by the listener thread. (This means that temporarily no thread in the group is listening.) If the statement finishes quickly, the executing thread returns to listening for statements. Otherwise, the thread pool considers the statement stalled and starts another thread as a listener thread (creating it if necessary). To ensure that no thread group becomes blocked by stalled statements, the thread pool has a background thread that regularly monitors thread group states.

By using the listening thread to execute a statement that can begin immediately, there is no need to create an additional thread if the statement finishes quickly. This ensures the most efficient execution possible in the case of a low number of concurrent threads.

When the thread pool plugin starts, it creates one thread per group (the listener thread), plus the background thread. Additional threads are created as necessary to execute statements.

- The value of the `thread_pool_stall_limit` system variable determines the meaning of “finishes quickly” in the previous item. The default time before threads are considered stalled is 60ms but can be set to a maximum of 6s. This parameter is configurable to enable you to strike a balance appropriate for the server work load. Short wait values permit threads to start more quickly. Short values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

- The thread pool focuses on limiting the number of concurrent short-running statements. Before an executing statement reaches the stall time, it prevents other statements from beginning to execute. If the statement executes past the stall time, it is permitted to continue but no longer prevents other statements from starting. In this way, the thread pool tries to ensure that in each thread group there is never more than one short-running statement, although there might be multiple long-running statements. It is undesirable to let long-running statements prevent other statements from executing because there is no limit on the amount of waiting that might be necessary. For example, on a replication master, a thread that is sending binary log events to a slave effectively runs forever.

- A statement becomes blocked if it encounters a disk I/O operation or a user level lock (row lock or table lock). The block would cause the thread group to become unused, so there are callbacks to the thread pool to ensure that the thread pool can immediately start a new thread in this group to execute another statement. When a blocked thread returns, the thread pool permits it to restart immediately.

- There are two queues, a high-priority queue and a low-priority queue. The first statement in a transaction goes to the low-priority queue. Any following statements for the transaction go to the high-priority queue if the transaction is ongoing (statements for it have begun executing),
MySQL Enterprise Thread Pool

or to the low-priority queue otherwise. Queue assignment can be affected by enabling the
`thread_pool_high_priority_connection` system variable, which causes all queued statements
for a session to go into the high-priority queue.

Statements for a nontransactional storage engine, or a transactional engine if `autocommit` is enabled,
are treated as low-priority statements because in this case each statement is a transaction. Thus, given
a mix of statements for InnoDB and MyISAM tables, the thread pool prioritizes those for InnoDB over
those for MyISAM unless `autocommit` is enabled. With `autocommit` enabled, all statements will be low
priority.

• When the thread group selects a queued statement for execution, it first looks in the high-priority
queue, then in the low-priority queue. If a statement is found, it is removed from its queue and begins to
execute.

• If a statement stays in the low-priority queue too long, the thread pool moves to the high-priority queue.
The value of the `thread_pool_prio_kickup_timer` system variable controls the time before
movement. For each thread group, a maximum of one statement per 10ms or 100 per second will be
moved from the low-priority queue to the high-priority queue.

• The thread pool reuses the most active threads to obtain a much better use of CPU caches. This is a
small adjustment that has a great impact on performance.

• While a thread executes a statement from a user connection, Performance Schema instrumentation
accounts thread activity to the user connection. Otherwise, Performance Schema accounts activity to the
thread pool.

Here are examples of conditions under which a thread group might have multiple threads started to
execute statements:

• One thread begins executing a statement, but runs long enough to be considered stalled. The thread
group permits another thread to begin executing another statement even through the first thread is still
executing.

• One thread begins executing a statement, then becomes blocked and reports this back to the thread
pool. The thread group permits another thread to begin executing another statement.

• One thread begins executing a statement, becomes blocked, but does not report back that it is blocked
because the block does not occur in code that has been instrumented with thread pool callbacks. In
this case, the thread appears to the thread group to be still running. If the block lasts long enough for
the statement to be considered stalled, the group permits another thread to begin executing another
statement.

The thread pool is designed to be scalable across an increasing number of connections. It is also designed
to avoid deadlocks that can arise from limiting the number of actively executing statements. It is important
that threads that do not report back to the thread pool do not prevent other statements from executing and
thus cause the thread pool to become deadlocked. Examples of such statements follow:

• Long-running statements. These would lead to all resources used by only a few statements and they
could prevent all others from accessing the server.

• Binary log dump threads that read the binary log and send it to slaves. This is a kind of long-running
“statement” that runs for a very long time, and that should not prevent other statements from executing.

• Statements blocked on a row lock, table lock, sleep, or any other blocking activity that has not been
reported back to the thread pool by MySQL Server or a storage engine.

In each case, to prevent deadlock, the statement is moved to the stalled category when it does not
complete quickly, so that the thread group can permit another statement to begin executing. With this
design, when a thread executes or becomes blocked for an extended time, the thread pool moves the thread to the stalled category and for the rest of the statement's execution, it does not prevent other statements from executing.

The maximum number of threads that can occur is the sum of `max_connections` and `thread_pool_size`. This can happen in a situation where all connections are in execution mode and an extra thread is created per group to listen for more statements. This is not necessarily a state that happens often, but it is theoretically possible.

### 5.5.3.4 Thread Pool Tuning

This section provides guidelines on setting thread pool system variables for best performance, measured using a metric such as transactions per second.

`thread_pool_size` is the most important parameter controlling thread pool performance. It can be set only at server startup. Our experience in testing the thread pool indicates the following:

- If the primary storage engine is InnoDB, the optimal `thread_pool_size` setting is likely to be between 16 and 36, with the most common optimal values tending to be from 24 to 36. We have not seen any situation where the setting has been optimal beyond 36. There may be special cases where a value smaller than 16 is optimal.
  
  For workloads such as DBT2 and Sysbench, the optimum for InnoDB seems to be usually around 36. For very write-intensive workloads, the optimal setting can sometimes be lower.

- If the primary storage engine is MyISAM, the `thread_pool_size` setting should be fairly low. Optimal performance is often seen with values from 4 to 8. Higher values tend to have a slightly negative but not dramatic impact on performance.

Another system variable, `thread_pool_stall_limit`, is important for handling of blocked and long-running statements. If all calls that block the MySQL Server are reported to the thread pool, it would always know when execution threads are blocked. However, this may not always be true. For example, blocks could occur in code that has not been instrumented with thread pool callbacks. For such cases, the thread pool must be able to identify threads that appear to be blocked. This is done by means of a timeout, the length of which can be tuned using the `thread_pool_stall_limit` system variable. This parameter ensures that the server does not become completely blocked. The value of `thread_pool_stall_limit` has an upper limit of 6 seconds to prevent the risk of a deadlocked server.

`thread_pool_stall_limit` also enables the thread pool to handle long-running statements. If a long-running statement was permitted to block a thread group, all other connections assigned to the group would be blocked and unable to start execution until the long-running statement completed. In the worst case, this could take hours or even days.

The value of `thread_pool_stall_limit` should be chosen such that statements that execute longer than its value are considered stalled. Stalled statements generate a lot of extra overhead since they involve extra context switches and in some cases even extra thread creations. On the other hand, setting the `thread_pool_stall_limit` parameter too high means that long-running statements will block a number of short-running statements for longer than necessary. Short wait values permit threads to start more quickly. Short values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

Suppose a server executes a workload where 99.9% of the statements complete within 100ms even when the server is loaded, and the remaining statements take between 100ms and 2 hours fairly evenly spread. In this case, it would make sense to set `thread_pool_stall_limit` to 10 (meaning 100ms). The default value of 60ms is suitable for servers that primarily execute very simple statements.
The **thread_pool_stall_limit** parameter can be changed at runtime to enable you to strike a balance appropriate for the server work load. Assuming that the **TP_THREAD_GROUP_STATS** table is enabled, you can use the following query to determine the fraction of executed statements that stalled:

```
SELECT SUM(STALLED_QUERIES_EXECUTED) / SUM(QUERIES_EXECUTED)
FROM INFORMATION_SCHEMA.TP_THREAD_GROUP_STATS;
```

This number should be as low as possible. To decrease the likelihood of statements stalling, increase the value of **thread_pool_stall_limit**.

When a statement arrives, what is the maximum time it can be delayed before it actually starts executing? Suppose that the following conditions apply:

- There are 200 statements queued in the low-priority queue.
- There are 10 statements queued in the high-priority queue.
- **thread_pool_prio_kickup_timer** is set to 10000 (10 seconds).
- **thread_pool_stall_limit** is set to 100 (1 second).

In the worst case, the 10 high-priority statements represent 10 transactions that continue executing for a long time. Thus, in the worst case, no statements will be moved to the high-priority queue because it will always already contain statements awaiting execution. After 10 seconds, the new statement is eligible to be moved to the high-priority queue. However, before it can be moved, all the statements before it must be moved as well. This could take another 2 seconds because a maximum of 100 statements per second are moved to the high-priority queue. Now when the statement reaches the high-priority queue, there could potentially be many long-running statements ahead of it. In the worst case, every one of those will become stalled and it will take 1 second for each statement before the next statement is retrieved from the high-priority queue. Thus, in this scenario, it will take 222 seconds before the new statement starts executing.

This example shows a worst case for an application. How to handle it depends on the application. If the application has high requirements for the response time, it should most likely throttle users at a higher level itself. Otherwise, it can use the thread pool configuration parameters to set some kind of a maximum waiting time.

### 5.6 MySQL Server User-Defined Functions

MySQL Server enables user-defined functions (UDFs) to be created and loaded into the server to extend server capabilities. Server capabilities can be implemented in whole or in part using UDFs. In addition, you can write your own UDFs.

The following sections describe how to install and uninstall UDFs, and how to determine at runtime which UDFs are installed and obtain information about them. For information about writing UDFs, see Section 24.4, “Adding Functions to MySQL”.

#### 5.6.1 Installing and Uninstalling User-Defined Functions

User-defined functions (UDFs) must be loaded into the server before they can be used. MySQL supports UDF loading at runtime.

To load a UDF, use the **CREATE FUNCTION** statement. For example:

```
CREATE FUNCTION metaphon
RETURNS STRING
SONAME 'udf_example.so';
```

The UDF file base name depends on your platform. Common suffixes are `.so` for Unix and Unix-like systems, `.dll` for Windows.
While a UDF is loaded, information about it is available from the `mysql.func` system table. See Section 5.6.2, “Obtaining User-Defined Function Information”.

`CREATE FUNCTION` also registers the UDF in the `mysql.func` system table to cause the server to load it on subsequent restarts. For this reason, `CREATE FUNCTION` requires the `INSERT` privilege for the `mysql` system database.

To remove a UDF, use the `DROP FUNCTION` statement. For example:

```
DROP FUNCTION metaphon;
```

`DROP FUNCTION` unloads the UDF and removes it from the `mysql.func` system table. For this reason, `DROP FUNCTION` requires the `DELETE` privilege for the `mysql` system database. With the UDF no longer registered in the table, the server does not load the UDF automatically for subsequent restarts.

You cannot use `CREATE FUNCTION` to reinstall a function that has previously been installed. To reinstall a function, first remove it with `DROP FUNCTION`, then install it again with `CREATE FUNCTION`. You would need to do this, for example, if you upgrade to a new version of MySQL that provides an updated implementation of the function, or you recompile a new version of a function that you have written. Otherwise, the server continues to use the old version.

If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.func` table and does not load the UDFs listed there.

### 5.6.2 Obtaining User-Defined Function Information

The `func` table in the `mysql` system database shows which UDFs have been registered with `CREATE FUNCTION`:

```
SELECT * FROM mysql.func;
```

The `func` table has these columns:

- **name**
  The UDF name as referred to in SQL statements.

- **ret**
  The UDF return value type. Permitted values are 0 (**STRING**), 1 (**REAL**), 2 (**INTEGER**), 3 (**ROW**), or 4 (**DECIMAL**).

- **dl**
  The name of the UDF library file containing the executable UDF code. The file is located in the directory named by the `plugin_dir` system variable.

- **type**
  The UDF type, either **function** (scalar) or **aggregate**.

### 5.7 Running Multiple MySQL Instances on One Machine

In some cases, you might want to run multiple instances of MySQL on a single machine. You might want to test a new MySQL release while leaving an existing production setup undisturbed. Or you might want to give different users access to different `mysqld` servers that they manage themselves. (For example, you might be an Internet Service Provider that wants to provide independent MySQL installations for different customers.)
It is possible to use a different MySQL server binary per instance, or use the same binary for multiple instances, or any combination of the two approaches. For example, you might run a server from MySQL 5.1 and one from MySQL 5.5, to see how different versions handle a given workload. Or you might run multiple instances of the current production version, each managing a different set of databases.

Whether or not you use distinct server binaries, each instance that you run must be configured with unique values for several operating parameters. This eliminates the potential for conflict between instances. Parameters can be set on the command line, in option files, or by setting environment variables. See Section 4.2.2, “Specifying Program Options”. To see the values used by a given instance, connect to it and execute a `SHOW VARIABLES` statement.

The primary resource managed by a MySQL instance is the data directory. Each instance should use a different data directory, the location of which is specified using the `--datadir=dir_name` option. For methods of configuring each instance with its own data directory, and warnings about the dangers of failing to do so, see Section 5.7.1, “Setting Up Multiple Data Directories”.

In addition to using different data directories, several other options must have different values for each server instance:

- `--port=port_num`
  `--port` controls the port number for TCP/IP connections. Alternatively, if the host has multiple network addresses, you can use `--bind-address` to cause each server to listen to a different address.

- `--socket={file_name|pipe_name}`
  `--socket` controls the Unix socket file path on Unix or the named-pipe name on Windows. On Windows, it is necessary to specify distinct pipe names only for those servers configured to permit named-pipe connections.

- `--shared-memory-base-name=name`
  This option is used only on Windows. It designates the shared-memory name used by a Windows server to permit clients to connect using shared memory. It is necessary to specify distinct shared-memory names only for those servers configured to permit shared-memory connections.

- `--pid-file=file_name`
  This option indicates the path name of the file in which the server writes its process ID.

If you use the following log file options, their values must differ for each server:

- `--general_log_file=file_name`
- `--log-bin[=file_name]`
- `--slow_query_log_file=file_name`
- `--log-error[=file_name]`

For further discussion of log file options, see Section 5.4, “MySQL Server Logs”.

To achieve better performance, you can specify the following option differently for each server, to spread the load between several physical disks:

- `--tmpdir=dir_name`

Having different temporary directories also makes it easier to determine which MySQL server created any given temporary file.
If you have multiple MySQL installations in different locations, you can specify the base directory for each installation with the `--basedir=dir_name` option. This causes each instance to automatically use a different data directory, log files, and PID file because the default for each of those parameters is relative to the base directory. In that case, the only other options you need to specify are the `--socket` and `--port` options. Suppose that you install different versions of MySQL using `tar` file binary distributions. These install in different locations, so you can start the server for each installation using the command `bin/mysqld_safe` under its corresponding base directory. `mysqld_safe` determines the proper `--basedir` option to pass to `mysqld`, and you need specify only the `--socket` and `--port` options to `mysqld_safe`.

As discussed in the following sections, it is possible to start additional servers by specifying appropriate command options or by setting environment variables. However, if you need to run multiple servers on a more permanent basis, it is more convenient to use option files to specify for each server those option values that must be unique to it. The `--defaults-file` option is useful for this purpose.

### 5.7.1 Setting Up Multiple Data Directories

Each MySQL Instance on a machine should have its own data directory. The location is specified using the `--datadir=dir_name` option.

There are different methods of setting up a data directory for a new instance:

- Create a new data directory.
- Copy an existing data directory.

The following discussion provides more detail about each method.

#### Warning

Normally, you should never have two servers that update data in the same databases. This may lead to unpleasant surprises if your operating system does not support fault-free system locking. If (despite this warning) you run multiple servers using the same data directory and they have logging enabled, you must use the appropriate options to specify log file names that are unique to each server. Otherwise, the servers try to log to the same files.

Even when the preceding precautions are observed, this kind of setup works only with MyISAM and MERGE tables, and not with any of the other storage engines. Also, this warning against sharing a data directory among servers always applies in an NFS environment. Permitting multiple MySQL servers to access a common data directory over NFS is a very bad idea. The primary problem is that NFS is the speed bottleneck. It is not meant for such use. Another risk with NFS is that you must devise a way to ensure that two or more servers do not interfere with each other. Usually NFS file locking is handled by the `lockd` daemon, but at the moment there is no platform that performs locking 100% reliably in every situation.

#### Create a New Data Directory

With this method, the data directory will be in the same state as when you first install MySQL. It will have the default set of MySQL accounts and no user data.

On Unix, initialize the data directory. See Section 2.10, “Postinstallation Setup and Testing”.

On Windows, the data directory is included in the MySQL distribution:
• MySQL Zip archive distributions for Windows contain an unmodified data directory. You can unpack such a distribution into a temporary location, then copy it data directory to where you are setting up the new instance.

• As of MySQL 5.5.5, Windows MSI package installers create and set up the data directory that the installed server will use, but also create a pristine “template” data directory named data under the installation directory. After an installation has been performed using an MSI package, the template data directory can be copied to set up additional MySQL instances.

Copy an Existing Data Directory

With this method, any MySQL accounts or user data present in the data directory are carried over to the new data directory.

1. Stop the existing MySQL instance using the data directory. This must be a clean shutdown so that the instance flushes any pending changes to disk.

2. Copy the data directory to the location where the new data directory should be.

3. Copy the my.cnf or my.ini option file used by the existing instance. This serves as a basis for the new instance.

4. Modify the new option file so that any pathnames referring to the original data directory refer to the new data directory. Also, modify any other options that must be unique per instance, such as the TCP/IP port number and the log files. For a list of parameters that must be unique per instance, see Section 5.7, “Running Multiple MySQL Instances on One Machine”.

5. Start the new instance, telling it to use the new option file.

5.7.2 Running Multiple MySQL Instances on Windows

You can run multiple servers on Windows by starting them manually from the command line, each with appropriate operating parameters, or by installing several servers as Windows services and running them that way. General instructions for running MySQL from the command line or as a service are given in Section 2.3, “Installing MySQL on Microsoft Windows”. The following sections describe how to start each server with different values for those options that must be unique per server, such as the data directory. These options are listed in Section 5.7, “Running Multiple MySQL Instances on One Machine”.

5.7.2.1 Starting Multiple MySQL Instances at the Windows Command Line

The procedure for starting a single MySQL server manually from the command line is described in Section 2.3.6.5, “Starting MySQL from the Windows Command Line”. To start multiple servers this way, you can specify the appropriate options on the command line or in an option file. It is more convenient to place the options in an option file, but it is necessary to make sure that each server gets its own set of options. To do this, create an option file for each server and tell the server the file name with a --defaults-file option when you run it.

Suppose that you want to run one instance of mysqld on port 3307 with a data directory of C:\mydata1, and another instance on port 3308 with a data directory of C:\mydata2. Use this procedure:

1. Make sure that each data directory exists, including its own copy of the mysql database that contains the grant tables.

2. Create two option files. For example, create one file named C:\my-opts1.cnf that looks like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
```
Create a second file named C:\my-opts2.cnf that looks like this:

```
[mysqld]
  datadir = C:/mydata2
  port = 3308
```

3. Use the `--defaults-file` option to start each server with its own option file:

```
C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts1.cnf
C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts2.cnf
```

Each server starts in the foreground (no new prompt appears until the server exits later), so you will need to issue those two commands in separate console windows.

To shut down the servers, connect to each using the appropriate port number:

```
C:\> C:\mysql\bin\mysqladmin --port=3307 --host=127.0.0.1 --user=root --password shutdown
C:\> C:\mysql\bin\mysqladmin --port=3308 --host=127.0.0.1 --user=root --password shutdown
```

Servers configured as just described permit clients to connect over TCP/IP. If your version of Windows supports named pipes and you also want to permit named-pipe connections, specify options that enable the named pipe and specify its name. Each server that supports named-pipe connections must use a unique pipe name. For example, the C:\my-opts1.cnf file might be written like this:

```
[mysqld]
  datadir = C:/mydata1
  port = 3307
  enable-named-pipe
  socket = mypipe1
```

Modify C:\my-opts2.cnf similarly for use by the second server. Then start the servers as described previously.

A similar procedure applies for servers that you want to permit shared-memory connections. Enable such connections by starting the server with the `shared_memory` system variable enabled and specify a unique shared-memory name for each server by setting the `shared_memory_base_name` system variable.

### 5.7.2.2 Starting Multiple MySQL Instances as Windows Services

On Windows, a MySQL server can run as a Windows service. The procedures for installing, controlling, and removing a single MySQL service are described in Section 2.3.6.7, “Starting MySQL as a Windows Service”.

To set up multiple MySQL services, you must make sure that each instance uses a different service name in addition to the other parameters that must be unique per instance.

For the following instructions, suppose that you want to run the `mysqld` server from two different versions of MySQL that are installed at C:\mysql-5.1.55 and C:\mysql-5.5.62, respectively. (This might be the case if you are running 5.1.55 as your production server, but also want to conduct tests using 5.5.62.)

To install MySQL as a Windows service, use the `--install` or `--install-manual` option. For information about these options, see Section 2.3.6.7, “Starting MySQL as a Windows Service”.

Based on the preceding information, you have several ways to set up multiple services. The following instructions describe some examples. Before trying any of them, shut down and remove any existing MySQL services.

- **Approach 1**: Specify the options for all services in one of the standard option files. To do this, use a different service name for each server. Suppose that you want to run the 5.1.55 `mysqld` using the
service name of `mysqld1` and the 5.5.62 `mysqld` using the service name `mysqld2`. In this case, you can use the `[mysqld1]` group for 5.1.55 and the `[mysqld2]` group for 5.5.62. For example, you can set up `C:\my.cnf` like this:

```
# options for mysqld1 service
[mysqld1]
basedir = C:/mysql-5.1.55
port = 3307
enable-named-pipe
socket = mypipe1

# options for mysqld2 service
[mysqld2]
basedir = C:/mysql-5.5.62
port = 3308
enable-named-pipe
socket = mypipe2
```

Install the services as follows, using the full server path names to ensure that Windows registers the correct executable program for each service:

```
C:\> C:\mysql-5.1.55\bin\mysqld --install mysqld1
C:\> C:\mysql-5.5.62\bin\mysqld --install mysqld2
```

To start the services, use the services manager, or `NET START` or `SC START` with the appropriate service names:

```
C:\> SC START mysqld1
C:\> SC START mysqld2
```

To stop the services, use the services manager, or use `NET STOP` or `SC STOP` with the appropriate service names:

```
C:\> SC STOP mysqld1
C:\> SC STOP mysqld2
```

- **Approach 2:** Specify options for each server in separate files and use `--defaults-file` when you install the services to tell each server what file to use. In this case, each file should list options using a `[mysqld]` group.

With this approach, to specify options for the 5.1.55 `mysqld`, create a file `C:\my-opts1.cnf` that looks like this:

```
[mysqld]
basedir = C:/mysql-5.1.55
port = 3307
enable-named-pipe
socket = mypipe1
```

For the 5.5.62 `mysqld`, create a file `C:\my-opts2.cnf` that looks like this:

```
[mysqld]
basedir = C:/mysql-5.5.62
port = 3308
enable-named-pipe
socket = mypipe2
```

Install the services as follows (enter each command on a single line):

```
C:\> C:\mysql-5.1.55\bin\mysqld --install mysqld1
       --defaults-file=C:\my-opts1.cnf
C:\> C:\mysql-5.5.62\bin\mysqld --install mysqld2
       --defaults-file=C:\my-opts2.cnf
```
When you install a MySQL server as a service and use a `--defaults-file` option, the service name must precede the option.

After installing the services, start and stop them the same way as in the preceding example.

To remove multiple services, use `SC DELETE mysqld_service_name` for each one. Alternatively, use `mysqld --remove` for each one, specifying a service name following the `--remove` option. If the service name is the default (MySQL), you can omit it when using `mysqld --remove`.

### 5.7.3 Running Multiple MySQL Instances on Unix

One way is to run multiple MySQL instances on Unix is to compile different servers with different default TCP/IP ports and Unix socket files so that each one listens on different network interfaces. Compiling in different base directories for each installation also results automatically in a separate, compiled-in data directory, log file, and PID file location for each server.

Assume that an existing 5.1 server is configured for the default TCP/IP port number (3306) and Unix socket file (`/tmp/mysql.sock`). To configure a new 5.5.62 server to have different operating parameters, use a CMake command something like this:

```sh
shell> cmake . -DMYSQL_TCP_PORT=port_number \ 
    -DMYSQL_UNIX_ADDR=file_name \ 
    -DCMAKE_INSTALL_PREFIX=/usr/local/mysql-5.5.62
```

Here, `port_number` and `file_name` must be different from the default TCP/IP port number and Unix socket file path name, and the `CMAKE_INSTALL_PREFIX` value should specify an installation directory different from the one under which the existing MySQL installation is located.

If you have a MySQL server listening on a given port number, you can use the following command to find out what operating parameters it is using for several important configurable variables, including the base directory and Unix socket file name:

```sh
shell> mysqladmin --host=host_name --port=port_number variables
```

With the information displayed by that command, you can tell what option values *not* to use when configuring an additional server.

If you specify `localhost` as the host name, `mysqladmin` defaults to using a Unix socket file connection rather than TCP/IP. To explicitly specify the connection protocol, use the `--protocol={TCP|SOCKET|PIPE|MEMORY}` option.

You need not compile a new MySQL server just to start with a different Unix socket file and TCP/IP port number. It is also possible to use the same server binary and start each invocation of it with different parameter values at runtime. One way to do so is by using command-line options:

```sh
shell> mysqld_safe --socket=file_name --port=port_number
```

To start a second server, provide different `--socket` and `--port` option values, and pass a `--datadir=dir_name` option to `mysqld_safe` so that the server uses a different data directory.

Alternatively, put the options for each server in a different option file, then start each server using a `--defaults-file` option that specifies the path to the appropriate option file. For example, if the option files for two server instances are named `/usr/local/mysql/my.cnf` and `/usr/local/mysql/my.cnf2`, start the servers like this: command:

```sh
shell> mysqld_safe --defaults-file=/usr/local/mysql/my.cnf
```
Another way to achieve a similar effect is to use environment variables to set the Unix socket file name and TCP/IP port number:

```
shell> MYSQL_UNIX_PORT=/tmp/mysqld-new.sock
shell> MYSQL_TCP_PORT=3307
shell> export MYSQL_UNIX_PORT MYSQL_TCP_PORT
shell> mysql_install_db --user=mysql
shell> mysqld_safe --datadir=/path/to/datadir &
```

This is a quick way of starting a second server to use for testing. The nice thing about this method is that the environment variable settings apply to any client programs that you invoke from the same shell. Thus, connections for those clients are automatically directed to the second server.

Section 4.9, “Environment Variables”, includes a list of other environment variables you can use to affect MySQL programs.

On Unix, the `mysqld_multi` script provides another way to start multiple servers. See Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”.

### 5.7.4 Using Client Programs in a Multiple-Server Environment

To connect with a client program to a MySQL server that is listening to different network interfaces from those compiled into your client, you can use one of the following methods:

- Start the client with `--host=host_name --port=port_number` to connect using TCP/IP to a remote server, with `--host=127.0.0.1 --port=port_number` to connect using TCP/IP to a local server, or with `--host=localhost --socket=file_name` to connect to a local server using a Unix socket file or a Windows named pipe.

- Start the client with `--protocol=TCP` to connect using TCP/IP, `--protocol=SOCKET` to connect using a Unix socket file, `--protocol=PIPE` to connect using a named pipe, or `--protocol=MEMORY` to connect using shared memory. For TCP/IP connections, you may also need to specify `--host` and `--port` options. For the other types of connections, you may need to specify a `--socket` option to specify a Unix socket file or Windows named-pipe name, or a `--shared-memory-base-name` option to specify the shared-memory name. Shared-memory connections are supported only on Windows.

- On Unix, set the `MYSQL_UNIX_PORT` and `MYSQL_TCP_PORT` environment variables to point to the Unix socket file and TCP/IP port number before you start your clients. If you normally use a specific socket file or port number, you can place commands to set these environment variables in your `.login` file so that they apply each time you log in. See Section 4.9, “Environment Variables”.

- Specify the default Unix socket file and TCP/IP port number in the `[client]` group of an option file. For example, you can use `C:\my.cnf` on Windows, or the `.my.cnf` file in your home directory on Unix. See Section 4.2.2.2, “Using Option Files”.

- In a C program, you can specify the socket file or port number arguments in the `mysql_real_connect()` call. You can also have the program read option files by calling `mysql_options()`. See Section 23.7.6, “C API Function Descriptions”.

- If you are using the Perl `DBD::mysql` module, you can read options from MySQL option files. For example:

```perl
$dsn = "DBI:mysql:test;mysql_read_default_group=client;"
  . "mysql_read_default_file=/usr/local/mysql/data/my.cnf";
$dbh = DBI->connect($dsn, $user, $password);
```
See Section 23.9, “MySQL Perl API”.

Other programming interfaces may provide similar capabilities for reading option files.

5.8 Tracing mysqld Using DTrace

The DTrace probes in the MySQL server are designed to provide information about the execution of queries within MySQL and the different areas of the system being utilized during that process. The organization and triggering of the probes means that the execution of an entire query can be monitored with one level of probes (query-start and query-done) but by monitoring other probes you can get successively more detailed information about the execution of the query in terms of the locks used, sort methods and even row-by-row and storage-engine level execution information.

The DTrace probes are organized so that you can follow the entire query process, from the point of connection from a client, through the query execution, row-level operations, and back out again. You can think of the probes as being fired within a specific sequence during a typical client connect/execute/disconnect sequence, as shown in the following figure.

**Figure 5.1 DTrace Probe Sequence**

```
connection-start
  command-start
    query-start
      query-pure-start
      query-pure-done
      query-cache-miss
      query-cache-hit
      query-exec-start
        query-exec-done
    query-done
  command-done
connection-done
```

Global information is provided in the arguments to the DTrace probes at various levels. Global information, that is, the connection ID and user/host and where relevant the query string, is provided at key levels (connection-start, command-start, query-start, and query-exec-start). As you go deeper into the probes, it is assumed either you are only interested in the individual executions (row-level probes provide information on the database and table name only), or that you will combine the row-level probes with the notional parent probes to provide the information about a specific query. Examples of this will be given as the format and arguments of each probe are provided.

MySQL includes support for DTrace probes on these platforms:

- Solaris 10 Update 5 (Solaris 5/08) on SPARC, x86 and x86_64 platforms
- OS X 10.4 and higher

Enabling the probes should be automatic on these platforms. To explicitly enable or disable the probes during building, use the `-DENABLE_DTRACE=1` or `-DENABLE_DTRACE=0` option to CMake.

If a non-Solaris platform includes DTrace support, building `mysqld` on that platform will include DTrace support.
**Additional Resources**

- For more information on DTrace and writing DTrace scripts, read the [DTrace User Guide](#).
- For an introduction to DTrace, see the MySQL Dev Zone article [Getting started with DTracing MySQL](#).

### 5.8.1 mysqld DTrace Probe Reference

MySQL supports the following static probes, organized into groups of functionality.

Table 5.5 MySQL DTrace Probes

<table>
<thead>
<tr>
<th>Group</th>
<th>Probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection</td>
<td>connection-start, connection-done</td>
</tr>
<tr>
<td>Command</td>
<td>command-start, command-done</td>
</tr>
<tr>
<td>Query</td>
<td>query-start, query-done</td>
</tr>
<tr>
<td>Query Parsing</td>
<td>query-parse-start, query-parse-done</td>
</tr>
<tr>
<td>Query Cache</td>
<td>query-cache-hit, query-cache-miss</td>
</tr>
<tr>
<td>Query Execution</td>
<td>query-exec-start, query-exec-done</td>
</tr>
<tr>
<td>Row Level</td>
<td>insert-row-start, insert-row-done</td>
</tr>
<tr>
<td></td>
<td>update-row-start, update-row-done</td>
</tr>
<tr>
<td></td>
<td>delete-row-start, delete-row-done</td>
</tr>
<tr>
<td>Row Reads</td>
<td>read-row-start, read-row-done</td>
</tr>
<tr>
<td>Index Reads</td>
<td>index-read-row-start, index-read-row-done</td>
</tr>
<tr>
<td>Lock</td>
<td>handler-rdlock-start, handler-rdlock-done</td>
</tr>
<tr>
<td></td>
<td>handler-wrlock-start, handler-wrlock-done</td>
</tr>
<tr>
<td></td>
<td>handler-unlock-start, handler-unlock-done</td>
</tr>
<tr>
<td>Filesort</td>
<td>filesort-start, filesort-done</td>
</tr>
<tr>
<td>Statement</td>
<td>select-start, select-done</td>
</tr>
<tr>
<td></td>
<td>insert-start, insert-done</td>
</tr>
<tr>
<td></td>
<td>insert-select-start, insert-select-done</td>
</tr>
<tr>
<td></td>
<td>update-start, update-done</td>
</tr>
<tr>
<td></td>
<td>multi-update-start, multi-update-done</td>
</tr>
<tr>
<td></td>
<td>delete-start, delete-done</td>
</tr>
<tr>
<td></td>
<td>multi-delete-start, multi-delete-done</td>
</tr>
<tr>
<td>Network</td>
<td>net-read-start, net-read-done, net-write-start, net-write-done</td>
</tr>
<tr>
<td>Keycache</td>
<td>keycache-read-start, keycache-read-block, keycache-read-done, keycache-read-hit, keycache-read-miss, keycache-write-start, keycache-write-block, keycache-write-done</td>
</tr>
</tbody>
</table>

**Note**

When extracting the argument data from the probes, each argument is available as `argN`, starting with `arg0`. To identify each argument within the definitions they are provided with a descriptive name, but you must access the information using the corresponding `argN` parameter.
5.8.1.1 Connection Probes

The `connection-start` and `connection-done` probes enclose a connection from a client, regardless of whether the connection is through a socket or network connection.

- **connection-start**: Triggered after a connection and successful login/authentication have been completed by a client. The arguments contain the connection information:
  - **connectionid**: An unsigned long containing the connection ID. This is the same as the process ID shown as the `Id` value in the output from `SHOW PROCESSLIST`.
  - **user**: The username used when authenticating. The value will be blank for the anonymous user.
  - **host**: The host of the client connection. For a connection made using Unix sockets, the value will be blank.

- **connection-done**: Triggered just as the connection to the client has been closed. The arguments are:
  - **status**: The status of the connection when it was closed. A logout operation will have a value of 0; any other termination of the connection has a nonzero value.
  - **connectionid**: The connection ID of the connection that was closed.

The following D script will quantify and summarize the average duration of individual connections, and provide a count, dumping the information every 60 seconds:

```d
#!/usr/sbin/dtrace -s

mysql*:::connection-start
{
    self->start = timestamp;
}

mysql*:::connection-done
/self->start/
{
    @ = quantize(((timestamp - self->start)/1000000));
    self->start = 0;
}

tick-60s
{
    printa(@);
}
```

When executed on a server with a large number of clients you might see output similar to this:

```
1  57413                        :tick-60s
     value  ------------- Distribution ------------- count
    -1 |                                         0
     0 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ 30011
     1 |                                         59
     2 |                                         20
     4 |                                         29
     8 |                                         18
    16 |                                         27
    32 |                                         30
```

716
5.8.1.2 Command Probes

The command probes are executed before and after a client command is executed, including any SQL statement that might be executed during that period. Commands include operations such as the initialization of the DB, use of the `COM_CHANGE_USER` operation (supported by the MySQL protocol), and manipulation of prepared statements. Many of these commands are used only by the MySQL client API from various connectors such as PHP and Java.

```plaintext
command-start(connectionid, command, user, host)
command-done(status)
```

- **command-start**: Triggered when a command is submitted to the server.
- **connectionid**: The connection ID of the client executing the command.
- **command**: An integer representing the command that was executed. Possible values are shown in the following table.

<table>
<thead>
<tr>
<th>Value</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>COM_SLEEP</td>
<td>Internal thread state</td>
</tr>
<tr>
<td>01</td>
<td>COM.Quit</td>
<td>Close connection</td>
</tr>
<tr>
<td>02</td>
<td>COM_INIT_DB</td>
<td>Select database (USE ...)</td>
</tr>
<tr>
<td>03</td>
<td>COM_QUERY</td>
<td>Execute a query</td>
</tr>
<tr>
<td>04</td>
<td>COM_FIELD_LIST</td>
<td>Get a list of fields</td>
</tr>
<tr>
<td>05</td>
<td>COM_CREATE_DB</td>
<td>Create a database (deprecated)</td>
</tr>
<tr>
<td>06</td>
<td>COM_DROP_DB</td>
<td>Drop a database (deprecated)</td>
</tr>
<tr>
<td>07</td>
<td>COM_REFRESH</td>
<td>Refresh connection</td>
</tr>
<tr>
<td>08</td>
<td>COM_SHUTDOWN</td>
<td>Shutdown server</td>
</tr>
<tr>
<td>09</td>
<td>COM_STATISTICS</td>
<td>Get statistics</td>
</tr>
<tr>
<td>10</td>
<td>COM_PROCESS_INFO</td>
<td>Get processes (<a href="#">SHOW PROCESSLIST</a>)</td>
</tr>
<tr>
<td>11</td>
<td>COM_CONNECT</td>
<td>Initialize connection</td>
</tr>
<tr>
<td>12</td>
<td>COM_PROCESS_KILL</td>
<td>Kill process</td>
</tr>
<tr>
<td>13</td>
<td>COM_DEBUG</td>
<td>Get debug information</td>
</tr>
<tr>
<td>14</td>
<td>COM_PING</td>
<td>Ping</td>
</tr>
<tr>
<td>15</td>
<td>COM_TIME</td>
<td>Internal thread state</td>
</tr>
<tr>
<td>16</td>
<td>COM_DELAYED_INSERT</td>
<td>Internal thread state</td>
</tr>
<tr>
<td>17</td>
<td>COM_CHANGE_USER</td>
<td>Change user</td>
</tr>
<tr>
<td>Value</td>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>18</td>
<td>COM_BINLOG_DUMP</td>
<td>Used by a replication slave or mysqlbinlog to initiate a binary log read</td>
</tr>
<tr>
<td>19</td>
<td>COM_TABLE_DUMP</td>
<td>Used by a replication slave to get the master table information</td>
</tr>
<tr>
<td>20</td>
<td>COM_CONNECT_OUT</td>
<td>Used by a replication slave to log a connection to the server</td>
</tr>
<tr>
<td>21</td>
<td>COM_REGISTER_SLAVE</td>
<td>Used by a replication slave during registration</td>
</tr>
<tr>
<td>22</td>
<td>COM_STMT_PREPARE</td>
<td>Prepare a statement</td>
</tr>
<tr>
<td>23</td>
<td>COM_STMT_EXECUTE</td>
<td>Execute a statement</td>
</tr>
<tr>
<td>24</td>
<td>COM_STMT_SEND_LONG_DATA</td>
<td>Used by a client when requesting extended data</td>
</tr>
<tr>
<td>25</td>
<td>COM_STMT_CLOSE</td>
<td>Close a prepared statement</td>
</tr>
<tr>
<td>26</td>
<td>COM_STMT_RESET</td>
<td>Reset a prepared statement</td>
</tr>
<tr>
<td>27</td>
<td>COM_SET_OPTION</td>
<td>Set a server option</td>
</tr>
<tr>
<td>28</td>
<td>COM_STMT_FETCH</td>
<td>Fetch a prepared statement</td>
</tr>
</tbody>
</table>

- **user**: The user executing the command.
- **host**: The client host.
- **command-done**: Triggered when the command execution completes. The `status` argument contains 0 if the command executed successfully, or 1 if the statement was terminated before normal completion.

The `command-start` and `command-done` probes are best used when combined with the statement probes to get an idea of overall execution time.

### 5.8.1.3 Query Probes

The `query-start` and `query-done` probes are triggered when a specific query is received by the server and when the query has been completed and the information has been successfully sent to the client.

**query-start**(query, connectionid, database, user, host)

**query-done**(status)

- **query-start**: Triggered after the query string has been received from the client. The arguments are:
  - **query**: The full text of the submitted query.
  - **connectionid**: The connection ID of the client that submitted the query. The connection ID equals the connection ID returned when the client first connects and the `Id` value in the output from `SHOW PROCESSLIST`.
  - **database**: The database name on which the query is being executed.
  - **user**: The username used to connect to the server.
  - **host**: The hostname of the client.

- **query-done**: Triggered once the query has been executed and the information has been returned to the client. The probe includes a single argument, `status`, which returns 0 when the query is successfully executed and 1 if there was an error.

You can get a simple report of the execution time for each query using the following D script:

```bash
#!/usr/sbin/dtrace -s
```
#pragma D option quiet

dtrace:::BEGIN
{
    printf("%-20s %-20s %-40s %-9s\n", "Who", "Database", "Query", "Time(ms)");
}

mysql*:::query-start
{
    self->query = copyinstr(arg0);
    self->connid = arg1;
    self->db = copyinstr(arg2);
    self->who = strjoin(copyinstr(arg3), strjoin("@", copyinstr(arg4)));
    self->querystart = timestamp;
}

mysql*:::query-done
{
    printf("%-20s %-20s %-40s %-9d\n", self->who, self->db, self->query,
        (timestamp - self->querystart) / 1000000);
}

When executing the above script you should get a basic idea of the execution time of your queries:

<table>
<thead>
<tr>
<th>Who</th>
<th>Database</th>
<th>Query</th>
<th>Time(ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>root@localhost</td>
<td>test</td>
<td>select * from t1 order by i limit 10</td>
<td>0</td>
</tr>
<tr>
<td>root@localhost</td>
<td>test</td>
<td>set global query_cache_size=0</td>
<td>0</td>
</tr>
<tr>
<td>root@localhost</td>
<td>test</td>
<td>select * from t1 order by i limit 10</td>
<td>776</td>
</tr>
<tr>
<td>root@localhost</td>
<td>test</td>
<td>select * from t1 order by i limit 10</td>
<td>773</td>
</tr>
<tr>
<td>root@localhost</td>
<td>test</td>
<td>select * from t1 order by i desc limit 10</td>
<td>795</td>
</tr>
</tbody>
</table>

5.8.1.4 Query Parsing Probes

The query parsing probes are triggered before the original SQL statement is parsed and when the parsing of the statement and determination of the execution model required to process the statement has been completed:

query-parse-start(query)
query-parse-done(status)

- **query-parse-start**: Triggered just before the statement is parsed by the MySQL query parser. The single argument, `query`, is a string containing the full text of the original query.

- **query-parse-done**: Triggered when the parsing of the original statement has been completed. The `status` is an integer describing the status of the operation. A 0 indicates that the query was successfully parsed. A 1 indicates that the parsing of the query failed.

For example, you could monitor the execution time for parsing a given query using the following D script:

```d
#!/usr/sbin/dtrace -s
#pragma D option quiet

mysql*:::query-parse-start
{
    self->parsestart = timestamp;
    self->parsequery = copyinstr(arg0);
}

mysql*:::query-parse-done
/arg0 == 0/ {
    printf("Parsing %s: %d microseconds\n", self->parsequery, ((timestamp - self->parsestart)/1000));
```
mysqld DTrace Probe Reference

In the above script a predicate is used on `query-parse-done` so that different output is generated based on the status value of the probe.

When running the script and monitoring the execution:

```
shell> ./query-parsing.d
Error parsing select from t1 join (t2) on (t1.i = t2.i) order by t1.s,t1.i limit 10: 36 ms
Parsing select * from t1 join (t2) on (t1.i = t2.i) order by t1.s,t1.i limit 10: 176 ms
```

5.8.1.5 Query Cache Probes

The query cache probes are fired when executing any query. The `query-cache-hit` query is triggered when a query exists in the query cache and can be used to return the query cache information. The arguments contain the original query text and the number of rows returned from the query cache for the query. If the query is not within the query cache, or the query cache is not enabled, then the `query-cache-miss` probe is triggered instead.

```
query-cache-hit(query, rows)
query-cache-miss(query)
```

- **query-cache-hit**: Triggered when the query has been found within the query cache. The first argument, `query`, contains the original text of the query. The second argument, `rows`, is an integer containing the number of rows in the cached query.

- **query-cache-miss**: Triggered when the query is not found within the query cache. The first argument, `query`, contains the original text of the query.

The query cache probes are best combined with a probe on the main query so that you can determine the differences in times between using or not using the query cache for specified queries. For example, in the following D script, the query and query cache information are combined into the information output during monitoring:

```
#!/usr/sbin/dtrace -s
#pragma D option quiet

dtrace:::BEGIN
{
    printf("%20s %20s %-20s %2s %9s\n", "Who", "Database", "Query", "QC", "Time(ms)");
}
mysql*:::query-start
{
    self->query = copyinstr(arg0);
    self->connid = arg1;
    self->db    = copyinstr(arg2);
    self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
    self->querystart = timestamp;
    self->qc = 0;
}
mysql*:::query-cache-hit
{
    self->qc = 1;
}
When executing the script you can see the effects of the query cache. Initially the query cache is disabled. If you set the query cache size and then execute the query multiple times you should see that the query cache is being used to return the query data:

When executing the script you can see the effects of the query cache. Initially the query cache is disabled. If you set the query cache size and then execute the query multiple times you should see that the query cache is being used to return the query data:

<table>
<thead>
<tr>
<th>Shell&gt; ./query-cache.d</th>
</tr>
</thead>
<tbody>
<tr>
<td>root@localhost       test</td>
</tr>
<tr>
<td>root@localhost       test</td>
</tr>
<tr>
<td>root@localhost       test</td>
</tr>
<tr>
<td>root@localhost       test</td>
</tr>
</tbody>
</table>

5.8.1.6 Query Execution Probes

The query execution probe is triggered when the actual execution of the query starts, after the parsing and checking the query cache but before any privilege checks or optimization. By comparing the difference between the start and done probes you can monitor the time actually spent servicing the query (instead of just handling the parsing and other elements of the query).

query-exec-start(query, connectionid, database, user, host, exec_type)
query-exec-done(status)

**Note**

The information provided in the arguments for query-start and query-exec-start are almost identical and designed so that you can choose to monitor either the entire query process (using query-start) or only the execution (using query-exec-start) while exposing the core information about the user, client, and query being executed.

- **query-exec-start**: Triggered when the execution of a individual query is started. The arguments are:
  - **query**: The full text of the submitted query.
  - **connectionid**: The connection ID of the client that submitted the query. The connection ID equals the connection ID returned when the client first connects and the Id value in the output from SHOW PROCESSLIST.
  - **database**: The database name on which the query is being executed.
  - **user**: The username used to connect to the server.
  - **host**: The hostname of the client.
  - **exec_type**: The type of execution. Execution types are determined based on the contents of the query and where it was submitted. The values for each type are shown in the following table.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Executed query from sql_parse, top-level query.</td>
</tr>
<tr>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>Executed prepared statement</td>
</tr>
<tr>
<td>2</td>
<td>Executed cursor statement</td>
</tr>
<tr>
<td>3</td>
<td>Executed query in stored procedure</td>
</tr>
</tbody>
</table>

- **query-exec-done**: Triggered when the execution of the query has completed. The probe includes a single argument, *status*, which returns 0 when the query is successfully executed and 1 if there was an error.

### 5.8.1.7 Row-Level Probes

The *row-{start,done}* probes are triggered each time a row operation is pushed down to a storage engine. For example, if you execute an **INSERT** statement with 100 rows of data, then the **insert-row-start** and **insert-row-done** probes will be triggered 100 times each, for each row insert.

```plaintext
insert-row-start(database, table)
insert-row-done(status)
update-row-start(database, table)
update-row-done(status)
delete-row-start(database, table)
delete-row-done(status)
```

- **insert-row-start**: Triggered before a row is inserted into a table.
- **insert-row-done**: Triggered after a row is inserted into a table.
- **update-row-start**: Triggered before a row is updated in a table.
- **update-row-done**: Triggered before a row is updated in a table.
- **delete-row-start**: Triggered before a row is deleted from a table.
- **delete-row-done**: Triggered before a row is deleted from a table.

The arguments supported by the probes are consistent for the corresponding **start** and **done** probes in each case:

- **database**: The database name.
- **table**: The table name.
- **status**: The status; 0 for success or 1 for failure.

Because the row-level probes are triggered for each individual row access, these probes can be triggered many thousands of times each second, which may have a detrimental effect on both the monitoring script and MySQL. The DTrace environment should limit the triggering on these probes to prevent the performance being adversely affected. Either use the probes sparingly, or use counter or aggregation functions to report on these probes and then provide a summary when the script terminates or as part of a **query-done** or **query-exec-done** probes.

The following example script summarizes the duration of each row operation within a larger query:

```plaintext
#!/usr/sbin/dtrace -s
#pragma D option quiet
```
Running the above script with a query that inserts data into a table, you can monitor the exact time spent performing the raw row insertion:

```
0 @localhost test              13     20767 insert into t1(select * from t2)
4827 -> Row ops
```
5.8.1.8 Read Row Probes

The read row probes are triggered at a storage engine level each time a row read operation occurs. These probes are specified within each storage engine (as opposed to the *row-start probes which are in the storage engine interface). These probes can therefore be used to monitor individual storage engine row-level operations and performance. Because these probes are triggered around the storage engine row read interface, they may be hit a significant number of times during a basic query.

read-row-start(database, table, scan_flag)
read-row-done(status)

- **read-row-start**: Triggered when a row is read by the storage engine from the specified database and table. The scan_flag is set to 1 (true) when the read is part of a table scan (that is, a sequential read), or 0 (false) when the read is of a specific record.

- **read-row-done**: Triggered when a row read operation within a storage engine completes. The status returns 0 on success, or a positive value on failure.

5.8.1.9 Index Probes

The index probes are triggered each time a row is read using one of the indexes for the specified table. The probe is triggered within the corresponding storage engine for the table.

index-read-row-start(database, table)
index-read-row-done(status)

- **index-read-row-start**: Triggered when a row is read by the storage engine from the specified database and table.

- **index-read-row-done**: Triggered when an indexed row read operation within a storage engine completes. The status returns 0 on success, or a positive value on failure.

5.8.1.10 Lock Probes

The lock probes are called whenever an external lock is requested by MySQL for a table using the corresponding lock mechanism on the table as defined by the table's engine type. There are three different types of lock, the read lock, write lock, and unlock operations. Using the probes you can determine the duration of the external locking routine (that is, the time taken by the storage engine to implement the lock, including any time waiting for another lock to become free) and the total duration of the lock/unlock process.

handler-rdlock-start(database, table)
handler-rdlock-done(status)
handler-wrlock-start(database, table)
handler-wrlock-done(status)
handler-unlock-start(database, table)
handler-unlock-done(status)

- **handler-rdlock-start**: Triggered when a read lock is requested on the specified database and table.

- **handler-wrlock-start**: Triggered when a write lock is requested on the specified database and table.

- **handler-unlock-start**: Triggered when an unlock request is made on the specified database and table.
• **handler-rdlock-done**: Triggered when a read lock request completes. The **status** is 0 if the lock operation succeeded, or >0 on failure.

• **handler-wrlock-done**: Triggered when a write lock request completes. The **status** is 0 if the lock operation succeeded, or >0 on failure.

• **handler-unlock-done**: Triggered when an unlock request completes. The **status** is 0 if the unlock operation succeeded, or >0 on failure.

You can use arrays to monitor the locking and unlocking of individual tables and then calculate the duration of the entire table lock using the following script:

```bash
#!/usr/sbin/dtrace -s
#pragma D option quiet

mysql*:::handler-rdlock-start
{
    self->rdlockstart = timestamp;
    this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
    self->lockmap[this->lockref] = self->rdlockstart;
    printf("Start: Lock->Read   %s.%s\n",copyinstr(arg0),copyinstr(arg1));
}

mysql*:::handler-wrlock-start
{
    self->wrlockstart = timestamp;
    this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
    self->lockmap[this->lockref] = self->rdlockstart;
    printf("Start: Lock->Write  %s.%s\n",copyinstr(arg0),copyinstr(arg1));
}

mysql*:::handler-unlock-start
{
    self->unlockstart = timestamp;
    this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
    printf("Start: Lock->Unlock %s.%s (%d ms lock duration)\n", copyinstr(arg0),copyinstr(arg1),
        (timestamp - self->lockmap[this->lockref])/1000000);
}

mysql*:::handler-rdlock-done
{
    printf("End:   Lock->Read   %d ms\n", (timestamp - self->rdlockstart)/1000000);
}

mysql*:::handler-wrlock-done
{
    printf("End:   Lock->Write  %d ms\n", (timestamp - self->wrlockstart)/1000000);
}

mysql*:::handler-unlock-done
{
    printf("End:   Lock->Unlock %d ms\n", (timestamp - self->unlockstart)/1000000);
}
```

When executed, you should get information both about the duration of the locking process itself, and of the locks on a specific table:

```
Start: Lock->Read   test.t2
End:   Lock->Read   0 ms
Start: Lock->Unlock test.t2 (25743 ms lock duration)
```
5.8.1.11 Filesor Probes

The filesort probes are triggered whenever a filesort operation is applied to a table. For more information on filesort and the conditions under which it occurs, see Section 8.2.1.10, “ORDER BY Optimization”.

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>filesort-start(database, table)</td>
<td>Triggered when the filesort operation starts on a table. The two arguments to the probe, database and table, will identify the table being sorted.</td>
</tr>
<tr>
<td>filesort-done(status, rows)</td>
<td>Triggered when the filesort operation completes. Two arguments are supplied, the status (0 for success, 1 for failure), and the number of rows sorted during the filesort process.</td>
</tr>
</tbody>
</table>

An example of this is in the following script, which tracks the duration of the filesort process in addition to the duration of the main query:

```bash
#!/usr/sbin/dtrace -s
#pragma D option quiet

dtrace:::BEGIN
{
    printf("%-2s %-10s %-10s %9s %18s %-s \
", "St", "Who", "DB", "ConnID", "Dur microsec", "Query");
}

mysql*:::query-start
{
    self->query = copyinstr(arg0);
    self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
    self->db    = copyinstr(arg2);
    self->connid = arg1;
    self->querystart = timestamp;
    self->filesort = 0;
    self->fsdb = "";
    self->fstable = "";
}

mysql*:::filesort-start
{
    self->filesort = timestamp;
    self->fsdb = copyinstr(arg0);
    self->fstable = copyinstr(arg1);
}

mysql*:::filesort-done
{
    this->elapsed = (timestamp - self->filesort) /1000;
    printf("%2d %-10s %-10s %9d %18d Filesort on %s\n", 
        arg0, self->who, self->fsdb, 
        self->connid, this->elapsed, self->fstable);
}
```
mysql:::query-done
{
    this->elapsed = (timestamp - self->querystart) /1000;
    printf("%2d %-10s %-10s %9d %18d %s\n",
        arg0, self->who, self->db,
        self->connid, this->elapsed, self->query);
}

Executing a query on a large table with an ORDER BY clause that triggers a filesort, and then creating an index on the table and then repeating the same query, you can see the difference in execution speed:

<table>
<thead>
<tr>
<th>St</th>
<th>Who</th>
<th>DB</th>
<th>ConnID</th>
<th>Dur microsec</th>
<th>Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>@localhost</td>
<td>test</td>
<td>14</td>
<td>11335469</td>
<td>Filesort on t1</td>
</tr>
<tr>
<td>0</td>
<td>@localhost</td>
<td>test</td>
<td>14</td>
<td>11335787</td>
<td>select * from t1 order by i limit 100</td>
</tr>
<tr>
<td>0</td>
<td>@localhost</td>
<td>test</td>
<td>14</td>
<td>466734378</td>
<td>create index t1a on t1 (i)</td>
</tr>
<tr>
<td>0</td>
<td>@localhost</td>
<td>test</td>
<td>14</td>
<td>26472</td>
<td>select * from t1 order by i limit 100</td>
</tr>
</tbody>
</table>

5.8.1.12 Statement Probes

The individual statement probes are provided to give specific information about different statement types. For the start probes the string of the query is provided as a the only argument. Depending on the statement type, the information provided by the corresponding done probe will differ. For all done probes the status of the operation (0 for success, >0 for failure) is provided. For SELECT, INSERT, INSERT ... (SELECT FROM ...), DELETE, and DELETE FROM t1,t2 operations the number of rows affected is returned.

For UPDATE and UPDATE t1,t2 ... statements the number of rows matched and the number of rows actually changed is provided. This is because the number of rows actually matched by the corresponding WHERE clause, and the number of rows changed can differ. MySQL does not update the value of a row if the value already matches the new setting.

• select-start(query)
• select-done(status,rows)
• insert-start(query)
• insert-done(status,rows)
• insert-select-start(query)
• insert-select-done(status,rows)
• update-start(query)
• update-done(status,rowsmatched,rowschanged)
• multi-update-start(query)
• multi-update-done(status,rowsmatched,rowschanged)
• delete-start(query)
• delete-done(status,rows)
• multi-delete-start(query)
• multi-delete-done(status,rows)

- **select-start**: Triggered before a SELECT statement.
- **select-done**: Triggered at the end of a SELECT statement.
- **insert-start**: Triggered before a INSERT statement.
- **insert-done**: Triggered at the end of an INSERT statement.
- **insert-select-start**: Triggered before an INSERT ... SELECT statement.
- **insert-select-done**: Triggered at the end of an INSERT ... SELECT statement.
• **update-start**: Triggered before an **UPDATE** statement.

• **update-done**: Triggered at the end of an **UPDATE** statement.

• **multi-update-start**: Triggered before an **UPDATE** statement involving multiple tables.

• **multi-update-done**: Triggered at the end of an **UPDATE** statement involving multiple tables.

• **delete-start**: Triggered before a **DELETE** statement.

• **delete-done**: Triggered at the end of a **DELETE** statement.

• **multi-delete-start**: Triggered before a **DELETE** statement involving multiple tables.

• **multi-delete-done**: Triggered at the end of a **DELETE** statement involving multiple tables.

The arguments for the statement probes are:

• **query**: The query string.

• **status**: The status of the query. 0 for success, and >0 for failure.

• **rows**: The number of rows affected by the statement. This returns the number rows found for **SELECT**, the number of rows deleted for **DELETE**, and the number of rows successfully inserted for **INSERT**.

• **rowsmatched**: The number of rows matched by the **WHERE** clause of an **UPDATE** operation.

• **rowschanged**: The number of rows actually changed during an **UPDATE** operation.

You use these probes to monitor the execution of these statement types without having to monitor the user or client executing the statements. A simple example of this is to track the execution times:

```bash
#!/usr/sbin/dtrace -s
#pragma D option quiet
dtrace:::BEGIN
{
    printf("%-60s %-8s %-8s %-8s
", "Query", "RowsU", "RowsM", "Dur (ms)");
}
mysql*:::update-start, mysql*:::insert-start,
mysql*:::delete-start, mysql*:::multi-delete-start,
mysql*:::multi-delete-done, mysql*:::select-start,
mysql*:::insert-select-start, mysql*:::multi-update-start
{
    self->query = copyinstr(arg0);
    self->querystart = timestamp;
}
mysql*:::insert-done, mysql*:::select-done,
mysql*:::delete-done, mysql*:::multi-delete-done, mysql*:::insert-select-done
/ self->querystart /
{
    this->elapsed = ((timestamp - self->querystart)/1000000);
    printf("%-60s %-8d %-8d %d
",
        self->query, 0,
        arg1,
        this->elapsed);
    self->querystart = 0;
}```
When executed you can see the basic execution times and rows matches:

<table>
<thead>
<tr>
<th>Query</th>
<th>RowsU</th>
<th>RowsM</th>
<th>Dur (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>select * from t2</td>
<td>0</td>
<td>275</td>
<td>0</td>
</tr>
<tr>
<td>insert into t2 (select * from t2)</td>
<td>0</td>
<td>275</td>
<td>9</td>
</tr>
<tr>
<td>update t2 set i=5 where i &gt; 75</td>
<td>110</td>
<td>110</td>
<td>8</td>
</tr>
<tr>
<td>update t2 set i=5 where i &lt; 25</td>
<td>254</td>
<td>134</td>
<td>12</td>
</tr>
<tr>
<td>delete from t2 where i &lt; 5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Another alternative is to use the aggregation functions in DTrace to aggregate the execution time of individual statements together:

```bash
#!/usr/sbin/dtrace -s
#pragma D option quiet
mysql*:::update-start, mysql*:::insert-start,
mysql*:::delete-start, mysql*:::multi-delete-start,
mysql*:::multi-delete-done, mysql*:::select-start,
mysql*:::insert-select-start, mysql*:::multi-update-start
{
    self->querystart = timestamp;
}
mysql*:::select-done
{
    @statements["select"] = sum(((timestamp - self->querystart)/1000000));
}
mysql*:::insert-done, mysql*:::insert-select-done
{
    @statements["insert"] = sum(((timestamp - self->querystart)/1000000));
}
mysql*:::update-done, mysql*:::multi-update-done
{
    @statements["update"] = sum(((timestamp - self->querystart)/1000000));
}
mysql*:::delete-done, mysql*:::multi-delete-done
{
    @statements["delete"] = sum(((timestamp - self->querystart)/1000000));
}
tick-30s
{
    printa(@statements);
}
```

The script just shown aggregates the times spent doing each operation, which could be used to help benchmark a standard suite of tests.

```
delete 0
```
5.8.1.13 Network Probes

The network probes monitor the transfer of information from the MySQL server and clients of all types over the network. The probes are defined as follows:

- `net-read-start()`: Triggered when a network read operation is started.
- `net-read-done(status, bytes)`: Triggered when the network read operation completes. The `status` is an integer representing the return status for the operation, 0 for success and 1 for failure. The `bytes` argument is an integer specifying the number of bytes read during the process.
- `net-start-bytes`: Triggered when data is written to a network socket. The single argument, `bytes`, specifies the number of bytes written to the network socket.
- `net-write-done`: Triggered when the network write operation has completed. The single argument, `status`, is an integer representing the return status for the operation, 0 for success and 1 for failure.

You can use the network probes to monitor the time spent reading from and writing to network clients during execution. The following D script provides an example of this. Both the cumulative time for the read or write is calculated, and the number of bytes. Note that the dynamic variable size has been increased (using the `dynvarsize` option) to cope with the rapid firing of the individual probes for the network reads/writes.

```d
#!/usr/sbin/dtrace -s
#pragma D option quiet
#pragma D option dynvarsize=4m

dtrace:::BEGIN
{
  printf("%2s %30s %10s %9s %18s %-s \n",
    "St", "Who", "DB", "ConnID", "Dur microsec", "Query");
}

mysql*:::query-start
{
  self->query = copyinstr(arg0);
  self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
  self->db    = copyinstr(arg2);
  self->db    = copyinstr(arg2);
  self->db;
```

<table>
<thead>
<tr>
<th>Operation</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>update</td>
<td>0</td>
</tr>
<tr>
<td>insert</td>
<td>23</td>
</tr>
<tr>
<td>select</td>
<td>2484</td>
</tr>
<tr>
<td>delete</td>
<td>0</td>
</tr>
<tr>
<td>update</td>
<td>26</td>
</tr>
<tr>
<td>insert</td>
<td>56</td>
</tr>
<tr>
<td>select</td>
<td>10744</td>
</tr>
<tr>
<td>delete</td>
<td>0</td>
</tr>
<tr>
<td>update</td>
<td>26</td>
</tr>
<tr>
<td>insert</td>
<td>2287</td>
</tr>
<tr>
<td>select</td>
<td>15985</td>
</tr>
</tbody>
</table>
self->connid = arg1;
self->querystart = timestamp;
self->netwrite = 0;
self->netwritecum = 0;
self->netwritebase = 0;
self->netread = 0;
self->netreadcum = 0;
self->netreadbase = 0;
}

mysql*:::net-write-start
{
    self->netwrite += arg0;
    self->netwritebase = timestamp;
}

mysql*:::net-write-done
{
    self->netwritecum += (timestamp - self->netwritebase);
    self->netwritebase = 0;
}

mysql*:::net-read-start
{
    self->netreadbase = timestamp;
}

mysql*:::net-read-done
{
    self->netread += arg1;
    self->netreadcum += (timestamp - self->netreadbase);
    self->netreadbase = 0;
}

mysql*:::query-done
{
    this->elapsed = (timestamp - self->querystart) /1000000;
    printf("%2d %-30s %-10s %9d %18d %s\n", 
        arg0, self->who, self->db,
        self->connid, this->elapsed, self->query);
    printf("Net read: %d bytes (%d ms) write: %d bytes (%d ms)\n", 
        self->netread, (self->netreadcum/1000000), 
        self->netwrite, (self->netwritecum/1000000));
}

When executing the above script on a machine with a remote client, you can see that approximately a third
of the time spent executing the query is related to writing the query results back to the client.

<table>
<thead>
<tr>
<th>St</th>
<th>Who</th>
<th>DB</th>
<th>ConnID</th>
<th>Dur microsec</th>
<th>Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>root@::ffff:198.51.100.108</td>
<td>test</td>
<td>31</td>
<td>3495</td>
<td>select * from t1 limit 1000000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3495</td>
<td>Net read: 0 bytes (0 ms) write: 10000075 bytes (1220 ms)</td>
</tr>
</tbody>
</table>

### 5.8.1.14 Keycache Probes

The keycache probes are triggered when using the index key cache used with the MyISAM storage engine.
Probes exist to monitor when data is read into the keycache, cached key data is written from the cache into
a cached file, or when accessing the keycache.

Keycache usage indicates when data is read or written from the index files into the cache, and can be
used to monitor how efficient the memory allocated to the keycache is being used. A high number of
keycache reads across a range of queries may indicate that the keycache is too small for size of data
being accessed.

keycache-read-start(filepath, bytes, mem_used, mem_free)
keycache-read-block(bytes)
keycache-read-hit()
keycache-read-miss()
keycache-read-done(mem_used, mem_free)
keycache-write-start(filepath, bytes, mem_used, mem_free)
keycache-write-block(bytes)
keycache-write-done(mem_used, mem_free)

When reading data from the index files into the keycache, the process first initializes the read operation (indicated by keycache-read-start), then loads blocks of data (keycache-read-block), and then the read block is either matches the data being identified (keycache-read-hit) or more data needs to be read (keycache-read-miss). Once the read operation has completed, reading stops with the keycache-read-done.

Data will be read from the index file into the keycache only when the specified key is not already within the keycache.

- **keycache-read-start**: Triggered when the keycache read operation is started. Data is read from the specified filepath, reading the specified number of bytes. The mem_used and mem_avail indicate memory currently used by the keycache and the amount of memory available within the keycache.

- **keycache-read-block**: Triggered when the keycache reads a block of data, of the specified number of bytes, from the index file into the keycache.

- **keycache-read-hit**: Triggered when the block of data read from the index file matches the key data requested.

- **keycache-read-miss**: Triggered when the block of data read from the index file does not match the key data needed.

- **keycache-read-done**: Triggered when the keycache read operation has completed. The mem_used and mem_avail indicate memory currently used by the keycache and the amount of memory available within the keycache.

Keycache writes occur when the index information is updated during an INSERT, UPDATE, or DELETE operation, and the cached key information is flushed back to the index file.

- **keycache-write-start**: Triggered when the keycache write operation is started. Data is written to the specified filepath, reading the specified number of bytes. The mem_used and mem_avail indicate memory currently used by the keycache and the amount of memory available within the keycache.

- **keycache-write-block**: Triggered when the keycache writes a block of data, of the specified number of bytes, to the index file from the keycache.

- **keycache-write-done**: Triggered when the keycache write operation has completed. The mem_used and mem_avail indicate memory currently used by the keycache and the amount of memory available within the keycache.
Chapter 6 Security

Table of Contents

6.1 General Security Issues .......................................................... 734
  6.1.1 Security Guidelines ....................................................... 734
  6.1.2 Keeping Passwords Secure ............................................. 735
  6.1.3 Making MySQL Secure Against Attackers ............................ 743
  6.1.4 Security-Related mysqld Options and Variables .................. 745
  6.1.5 How to Run MySQL as a Normal User ................................ 746
  6.1.6 Security Issues with LOAD DATA LOCAL ............................ 746
  6.1.7 Client Programming Security Guidelines ............................ 748
6.2 Access Control and Account Management .................................. 749
  6.2.1 Account User Names and Passwords ................................. 750
  6.2.2 Privileges Provided by MySQL ...................................... 752
  6.2.3 Grant Tables .................................................................. 758
  6.2.4 Specifying Account Names ............................................. 764
  6.2.5 Access Control, Stage 1: Connection Verification ............... 766
  6.2.6 Access Control, Stage 2: Request Verification .................... 769
  6.2.7 Adding Accounts, Assigning Privileges, and Dropping Accounts .... 772
  6.2.8 When Privilege Changes Take Effect ............................... 775
  6.2.9 Assigning Account Passwords ....................................... 775
  6.2.10 Pluggable Authentication ............................................. 777
  6.2.11 Proxy Users .................................................................. 781
  6.2.12 Setting Account Resource Limits ................................... 787
  6.2.13 Troubleshooting Problems Connecting to MySQL ............. 789
  6.2.14 SQL-Based Account Activity Auditing ............................. 794
6.3 Using Encrypted Connections .................................................. 795
  6.3.1 Configuring MySQL to Use Encrypted Connections ............ 796
  6.3.2 Encrypted Connection TLS Protocols and Ciphers .............. 798
  6.3.3 Creating SSL Certificates and Keys Using openssl .............. 800
  6.3.4 SSL Library-Dependent Capabilities ............................... 806
  6.3.5 Connecting to MySQL Remotely from Windows with SSH ....... 806
6.4 Security Plugins ..................................................................... 807
  6.4.1 Authentication Plugins .................................................. 807
  6.4.2 MySQL Enterprise Audit ................................................ 829

When thinking about security within a MySQL installation, you should consider a wide range of possible topics and how they affect the security of your MySQL server and related applications:

- General factors that affect security. These include choosing good passwords, not granting unnecessary privileges to users, ensuring application security by preventing SQL injections and data corruption, and others. See Section 6.1, “General Security Issues”.

- Security of the installation itself. The data files, log files, and the all the application files of your installation should be protected to ensure that they are not readable or writable by unauthorized parties. For more information, see Section 2.10, “Postinstallation Setup and Testing”.

- Access control and security within the database system itself, including the users and databases granted with access to the databases, views and stored programs in use within the database. For more information, see Section 6.2, “Access Control and Account Management”.

- The features offered by security-related plugins. See Section 6.4, “Security Plugins”.
• Network security of MySQL and your system. The security is related to the grants for individual users, but you may also wish to restrict MySQL so that it is available only locally on the MySQL server host, or to a limited set of other hosts.

• Ensure that you have adequate and appropriate backups of your database files, configuration and log files. Also be sure that you have a recovery solution in place and test that you are able to successfully recover the information from your backups. See Chapter 7, Backup and Recovery.

6.1 General Security Issues

This section describes general security issues to be aware of and what you can do to make your MySQL installation more secure against attack or misuse. For information specifically about the access control system that MySQL uses for setting up user accounts and checking database access, see Section 2.10, “Postinstallation Setup and Testing”.

For answers to some questions that are often asked about MySQL Server security issues, see Section A.9, “MySQL 5.5 FAQ: Security”.

6.1.1 Security Guidelines

Anyone using MySQL on a computer connected to the Internet should read this section to avoid the most common security mistakes.

In discussing security, it is necessary to consider fully protecting the entire server host (not just the MySQL server) against all types of applicable attacks: eavesdropping, altering, playback, and denial of service. We do not cover all aspects of availability and fault tolerance here.

MySQL uses security based on Access Control Lists (ACLs) for all connections, queries, and other operations that users can attempt to perform. There is also support for SSL-encrypted connections between MySQL clients and servers. Many of the concepts discussed here are not specific to MySQL at all; the same general ideas apply to almost all applications.

When running MySQL, follow these guidelines:

• **Do not ever give anyone (except MySQL root accounts) access to the user table in the mysql system database!** This is critical.

• Learn how the MySQL access privilege system works (see Section 6.2, “Access Control and Account Management”). Use the `GRANT` and `REVOKE` statements to control access to MySQL. Do not grant more privileges than necessary. Never grant privileges to all hosts.

Checklist:

• Try `mysql -u root`. If you are able to connect successfully to the server without being asked for a password, anyone can connect to your MySQL server as the MySQL root user with full privileges! Review the MySQL installation instructions, paying particular attention to the information about setting a root password. See Section 2.10.4, “Securing the Initial MySQL Accounts”.

• Use the `SHOW GRANTS` statement to check which accounts have access to what. Then use the `REVOKE` statement to remove those privileges that are not necessary.

• Do not store cleartext passwords in your database. If your computer becomes compromised, the intruder can take the full list of passwords and use them. Instead, use `SHA2()` or some other one-way hashing function and store the hash value.

To prevent password recovery using rainbow tables, do not use these functions on a plain password; instead, choose some string to be used as a salt, and use `hash(hash(password)+salt)` values.
• Do not choose passwords from dictionaries. Special programs exist to break passwords. Even passwords like “xfish98” are very bad. Much better is “duag98” which contains the same word “fish” but typed one key to the left on a standard QWERTY keyboard. Another method is to use a password that is taken from the first characters of each word in a sentence (for example, “Four score and seven years ago” results in a password of “Fsasya”). The password is easy to remember and type, but difficult to guess for someone who does not know the sentence. In this case, you can additionally substitute digits for the number words to obtain the phrase “4 score and 7 years ago”, yielding the password “4sa7ya” which is even more difficult to guess.

• Invest in a firewall. This protects you from at least 50% of all types of exploits in any software. Put MySQL behind the firewall or in a demilitarized zone (DMZ).

Checklist:

• Try to scan your ports from the Internet using a tool such as nmap. MySQL uses port 3306 by default. This port should not be accessible from untrusted hosts. As a simple way to check whether your MySQL port is open, try the following command from some remote machine, where server_host is the host name or IP address of the host on which your MySQL server runs:

```
shell> telnet server_host 3306
```

If `telnet` hangs or the connection is refused, the port is blocked, which is how you want it to be. If you get a connection and some garbage characters, the port is open, and should be closed on your firewall or router, unless you really have a good reason to keep it open.

• Applications that access MySQL should not trust any data entered by users, and should be written using proper defensive programming techniques. See Section 6.1.7, “Client Programming Security Guidelines”.

• Do not transmit plain (unencrypted) data over the Internet. This information is accessible to everyone who has the time and ability to intercept it and use it for their own purposes. Instead, use an encrypted protocol such as SSL or SSH. MySQL supports internal SSL connections. Another technique is to use SSH port-forwarding to create an encrypted (and compressed) tunnel for the communication.

• Learn to use the `tcpdump` and `strings` utilities. In most cases, you can check whether MySQL data streams are unencrypted by issuing a command like the following:

```
shell> tcpdump -l -i eth0 -w - src or dst port 3306 | strings
```

This works under Linux and should work with small modifications under other systems.

Warning

If you do not see cleartext data, this does not always mean that the information actually is encrypted. If you need high security, consult with a security expert.

6.1.2 Keeping Passwords Secure

Passwords occur in several contexts within MySQL. The following sections provide guidelines that enable end users and administrators to keep these passwords secure and avoid exposing them. There is also a discussion of how MySQL uses password hashing internally.

6.1.2.1 End-User Guidelines for Password Security

MySQL users should use the following guidelines to keep passwords secure.

When you run a client program to connect to the MySQL server, it is inadvisable to specify your password in a way that exposes it to discovery by other users. The methods you can use to specify your password
Keeping Passwords Secure

when you run client programs are listed here, along with an assessment of the risks of each method. In short, the safest methods are to have the client program prompt for the password or to specify the password in a properly protected option file.

- Use a `--password=password` or `-p password` option on the command line. For example:

  shell> mysql -u francis -pfrank db_name

**Warning**

This is convenient but insecure. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If your operating environment is set up to display your current command in the title bar of your terminal window, the password remains visible as long as the command is running, even if the command has scrolled out of view in the window content area.

- Use the `--password` or `-p` option on the command line with no password value specified. In this case, the client program solicits the password interactively:

  shell> mysql -u francis -p db_name

  Enter password: ********

  The * characters indicate where you enter your password. The password is not displayed as you enter it.

  It is more secure to enter your password this way than to specify it on the command line because it is not visible to other users. However, this method of entering a password is suitable only for programs that you run interactively. If you want to invoke a client from a script that runs noninteractively, there is no opportunity to enter the password from the keyboard. On some systems, you may even find that the first line of your script is read and interpreted (incorrectly) as your password.

- Store your password in an option file. For example, on Unix, you can list your password in the `[client]` section of the `.my.cnf` file in your home directory:

  [client]
  password=password

  To keep the password safe, the file should not be accessible to anyone but yourself. To ensure this, set the file access mode to 400 or 600. For example:

  shell> chmod 600 .my.cnf

  To name from the command line a specific option file containing the password, use the `--defaults-file=file_name` option, where `file_name` is the full path name to the file. For example:

  shell> mysql --defaults-file=/home/francis/mysql-opts

  *Section 4.2.2.2, “Using Option Files”, discusses option files in more detail.*

- Store your password in the `MYSQL_PWD` environment variable. See *Section 4.9, “Environment Variables”*. This method of specifying your MySQL password must be considered extremely insecure and should not be used. Some versions of `ps` include an option to display the environment of running processes. On some systems, if you set `MYSQL_PWD`, your password is exposed to any other user who runs `ps`.
Keeping Passwords Secure

Even on systems without such a version of `ps`, it is unwise to assume that there are no other methods by which users can examine process environments.

On Unix, the `mysql` client writes a record of executed statements to a history file (see Section 4.5.1.3, “mysql Client Logging”). By default, this file is named `.mysql_history` and is created in your home directory. Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, so if you use these statements, they are logged in the history file. To keep this file safe, use a restrictive access mode, the same way as described earlier for the `.my.cnf` file.

If your command interpreter is configured to maintain a history, any file in which the commands are saved will contain MySQL passwords entered on the command line. For example, `bash` uses `~/.bash_history`. Any such file should have a restrictive access mode.

### 6.1.2.2 Administrator Guidelines for Password Security

Database administrators should use the following guidelines to keep passwords secure.

MySQL stores passwords for user accounts in the `mysql.user` system table. Access to this table should never be granted to any nonadministrative accounts.

A user who has access to modify the plugin directory (the value of the `plugin_dir` system variable) or the `my.cnf` file that specifies the plugin directory location can replace plugins and modify the capabilities provided by plugins, including authentication plugins.

Files such as log files to which passwords might be written should be protected. See Section 6.1.2.3, “Passwords and Logging”.

### 6.1.2.3 Passwords and Logging

Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, `SET PASSWORD`, and statements that invoke the `PASSWORD()` function. If such statements are logged by the MySQL server as written, passwords in them become visible to anyone with access to the logs. This applies to the general query log, the slow query log, and the binary log (see Section 5.4, “MySQL Server Logs”).

Contents of the audit log file produced by the audit log plugin are not encrypted. For security reasons, this file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log. See Section 6.4.2.2, “MySQL Enterprise Audit Security Considerations”.

To guard log files against unwarranted exposure, locate them in a directory that restricts access to the server and the database administrator. If the server logs to tables in the `mysql` database, grant access to those tables only to the database administrator.

Replication slaves store the password for the replication master in the `master.info` file. Restrict this file to be accessible only to the database administrator.

Use a restricted access mode to protect database backups that include log tables or log files containing passwords.

### 6.1.2.4 Password Hashing in MySQL

**Note**

The information in this section applies only for accounts that use the `mysql_native_password` or `mysql_old_password` authentication plugins.
Keeping Passwords Secure

MySQL lists user accounts in the `user` table of the `mysql` database. Each MySQL account can be assigned a password, although the `user` table does not store the cleartext version of the password, but a hash value computed from it.

MySQL uses passwords in two phases of client/server communication:

- When a client attempts to connect to the server, there is an initial authentication step in which the client must present a password that has a hash value matching the hash value stored in the `user` table for the account the client wants to use.

- After the client connects, it can (if it has sufficient privileges) set or change the password hash for accounts listed in the `user` table. The client can do this by using the `PASSWORD()` function to generate a password hash, or by using a password-generating statement (CREATE USER, GRANT, or SET PASSWORD).

In other words, the server checks hash values during authentication when a client first attempts to connect. The server generates hash values if a connected client invokes the `PASSWORD()` function or uses a password-generating statement to set or change a password.

Password hashing methods in MySQL have the history described following. These changes are illustrated by changes in the result from the `PASSWORD()` function that computes password hash values and in the structure of the `user` table where passwords are stored.

**The Original (Pre-4.1) Hashing Method**

The original hashing method produced a 16-byte string. Such hashes look like this:

```
mysql> SELECT PASSWORD('mypass');
+--------------------+
| PASSWORD('mypass') |
| 6f8c114b58f2ce9e   |
+--------------------+
```

To store account passwords, the `Password` column of the `user` table was at this point 16 bytes long.

**The 4.1 Hashing Method**

MySQL 4.1 introduced password hashing that provided better security and reduced the risk of passwords being intercepted. There were several aspects to this change:

- Different format of password values produced by the `PASSWORD()` function
- Widening of the `Password` column
- Control over the default hashing method
- Control over the permitted hashing methods for clients attempting to connect to the server

The changes in MySQL 4.1 took place in two stages:

- MySQL 4.1.0 used a preliminary version of the 4.1 hashing method. This method was short lived and the following discussion says nothing more about it.
- In MySQL 4.1.1, the hashing method was modified to produce a longer 41-byte hash value:

```
mysql> SELECT PASSWORD('mypass');
+-------------------------------------------+
| PASSWORD('mypass')                        |
| 738                                        |
+-------------------------------------------+
```
The longer password hash format has better cryptographic properties, and client authentication based on long hashes is more secure than that based on the older short hashes.

To accommodate longer password hashes, the `Password` column in the `user` table was changed at this point to be 41 bytes, its current length.

A widened `Password` column can store password hashes in both the pre-4.1 and 4.1 formats. The format of any given hash value can be determined two ways:

- The length: 4.1 and pre-4.1 hashes are 41 and 16 bytes, respectively.
- Password hashes in the 4.1 format always begin with a `*` character, whereas passwords in the pre-4.1 format never do.

To permit explicit generation of pre-4.1 password hashes, two additional changes were made:

- The `OLD_PASSWORD()` function was added, which returns hash values in the 16-byte format.
- For compatibility purposes, the `old_passwords` system variable was added, to enable DBAs and applications control over the hashing method. The default `old_passwords` value of 0 causes hashing to use the 4.1 method (41-byte hash values), but setting `old_passwords=1` causes hashing to use the pre-4.1 method. In this case, `PASSWORD()` produces 16-byte values and is equivalent to `OLD_PASSWORD()`

To permit DBAs control over how clients are permitted to connect, the `secure_auth` system variable was added. Starting the server with this variable disabled or enabled permits or prohibits clients to connect using the older pre-4.1 password hashing method. Before MySQL 5.6.5, `secure_auth` is disabled by default. As of 5.6.5, `secure_auth` is enabled by default to promote a more secure default configuration. (DBAs can disable it at their discretion, but this is not recommended.)

In addition, the `mysql` client supports a `--secure-auth` option that is analogous to `secure_auth`, but from the client side. It can be used to prevent connections to less secure accounts that use pre-4.1 password hashing. This option is disabled by default before MySQL 5.6.7, enabled thereafter.

**Compatibility Issues Related to Hashing Methods**

The widening of the `Password` column in MySQL 4.1 from 16 bytes to 41 bytes affects installation or upgrade operations as follows:

- If you perform a new installation of MySQL, the `Password` column is made 41 bytes long automatically.
- Upgrades from MySQL 4.1 or later to current versions of MySQL should not give rise to any issues in regard to the `Password` column because both versions use the same column length and password hashing method.
- For upgrades from a pre-4.1 release to 4.1 or later, you must upgrade the system tables after upgrading. (See Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables").

The 4.1 hashing method is understood only by MySQL 4.1 (and higher) servers and clients, which can result in some compatibility problems. A 4.1 or higher client can connect to a pre-4.1 server, because the client understands both the pre-4.1 and 4.1 password hashing methods. However, a pre-4.1 client that attempts to connect to a 4.1 or higher server may run into difficulties. For example, a 4.0 `mysql` client may fail with the following error message:
Keeping Passwords Secure

```
shell> mysql -h localhost -u root
Client does not support authentication protocol requested by server; consider upgrading MySQL client
```

This phenomenon also occurs for attempts to use the older PHP `mysql` extension after upgrading to MySQL 4.1 or higher. (See Common Problems with MySQL and PHP.)

The following discussion describes the differences between the pre-4.1 and 4.1 hashing methods, and what you should do if you upgrade your server but need to maintain backward compatibility with pre-4.1 clients. (However, permitting connections by old clients is not recommended and should be avoided if possible.) Additional information can be found in Section B.4.2.4, “Client does not support authentication protocol”. This information is of particular importance to PHP programmers migrating MySQL databases from versions older than 4.1 to 4.1 or higher.

The differences between short and long password hashes are relevant both for how the server uses passwords during authentication and for how it generates password hashes for connected clients that perform password-changing operations.

The way in which the server uses password hashes during authentication is affected by the width of the `Password` column:

- If the column is short, only short-hash authentication is used.
- If the column is long, it can hold either short or long hashes, and the server can use either format:
  - Pre-4.1 clients can connect, but because they know only about the pre-4.1 hashing method, they can authenticate only using accounts that have short hashes.
  - 4.1 and later clients can authenticate using accounts that have short or long hashes.

Even for short-hash accounts, the authentication process is actually a bit more secure for 4.1 and later clients than for older clients. In terms of security, the gradient from least to most secure is:

- Pre-4.1 client authenticating with short password hash
- 4.1 or later client authenticating with short password hash
- 4.1 or later client authenticating with long password hash

The way in which the server generates password hashes for connected clients is affected by the width of the `Password` column and by the `old_passwords` system variable. A 4.1 or later server generates long hashes only if certain conditions are met: The `Password` column must be wide enough to hold long values and `old_passwords` must not be set to 1.

Those conditions apply as follows:

- The `Password` column must be wide enough to hold long hashes (41 bytes). If the column has not been updated and still has the pre-4.1 width of 16 bytes, the server notices that long hashes cannot fit into it and generates only short hashes when a client performs password-changing operations using the `PASSWORD()` function or a password-generating statement. This is the behavior that occurs if you have upgraded from a version of MySQL older than 4.1 to 4.1 or later but have not yet run the `mysql_upgrade` program to widen the `Password` column.
- If the `Password` column is wide, it can store either short or long password hashes. In this case, the `PASSWORD()` function and password-generating statements generate long hashes unless the server was started with the `old_passwords` system variable set to 1 to force the server to generate short password hashes instead.
The purpose of the `old_passwords` system variable is to permit backward compatibility with pre-4.1 clients under circumstances where the server would otherwise generate long password hashes. The option does not affect authentication (4.1 and later clients can still use accounts that have long password hashes), but it does prevent creation of a long password hash in the `user` table as the result of a password-changing operation. Were that permitted to occur, the account could no longer be used by pre-4.1 clients. With `old_passwords` disabled, the following undesirable scenario is possible:

- An old pre-4.1 client connects to an account that has a short password hash.
- The client changes its own password. With `old_passwords` disabled, this results in the account having a long password hash.
- The next time the old client attempts to connect to the account, it cannot, because the account has a long password hash that requires the 4.1 hashing method during authentication. (Once an account has a long password hash in the user table, only 4.1 and later clients can authenticate for it because pre-4.1 clients do not understand long hashes.)

This scenario illustrates that, if you must support older pre-4.1 clients, it is problematic to run a 4.1 or higher server without `old_passwords` set to 1. By running the server with `old_passwords=1`, password-changing operations do not generate long password hashes and thus do not cause accounts to become inaccessible to older clients. (Those clients cannot inadvertently lock themselves out by changing their password and ending up with a long password hash.)

The downside of `old_passwords=1` is that any passwords created or changed use short hashes, even for 4.1 or later clients. Thus, you lose the additional security provided by long password hashes. To create an account that has a long hash (for example, for use by 4.1 clients) or to change an existing account to use a long password hash, an administrator can set the session value of `old_passwords` set to 0 while leaving the global value set to 1:

```sql
mysql> SET @@SESSION.old_passwords = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@SESSION.old_passwords, @@GLOBAL.old_passwords;
+-------------------------+------------------------+
<table>
<thead>
<tr>
<th>@@SESSION.old_passwords</th>
<th>@@GLOBAL.old_passwords</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
+-------------------------+------------------------+
1 row in set (0.00 sec)

mysql> CREATE USER 'newuser'@'localhost' IDENTIFIED BY 'newpass';
Query OK, 0 rows affected (0.03 sec)

mysql> SET PASSWORD FOR 'existinguser'@'localhost' = PASSWORD('existingpass');
Query OK, 0 rows affected (0.00 sec)
```

The following scenarios are possible in MySQL 4.1 or later. The factors are whether the `Password` column is short or long, and, if long, whether the server is started with `old_passwords` enabled or disabled.

**Scenario 1:** Short `Password` column in user table:

- Only short hashes can be stored in the `Password` column.
- The server uses only short hashes during client authentication.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.
Keeping Passwords Secure

- The value of `old_passwords` is irrelevant because with a short `Password` column, the server generates only short password hashes anyway.

This scenario occurs when a pre-4.1 MySQL installation has been upgraded to 4.1 or later but `mysql_upgrade` has not been run to upgrade the system tables in the `mysql` database. (This is not a recommended configuration because it does not permit use of more secure 4.1 password hashing.)

**Scenario 2:** Long `Password` column; server started with `old_passwords=1`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate for accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only for accounts that have short hashes.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

In this scenario, newly created accounts have short password hashes because `old_passwords=1` prevents generation of long hashes. Also, if you create an account with a long hash before setting `old_passwords` to 1, changing the account's password while `old_passwords=1` results in the account being given a short password, causing it to lose the security benefits of a longer hash.

To create a new account that has a long password hash, or to change the password of any existing account to use a long hash, first set the session value of `old_passwords` set to 0 while leaving the global value set to 1, as described previously.

In this scenario, the server has an up to date `Password` column, but is running with the default password hashing method set to generate pre-4.1 hash values. This is not a recommended configuration but may be useful during a transitional period in which pre-4.1 clients and passwords are upgraded to 4.1 or later. When that has been done, it is preferable to run the server with `old_passwords=0` and `secure_auth=1`.

**Scenario 3:** Long `Password` column; server started with `old_passwords=0`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate using accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only using accounts that have short hashes.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use long hashes exclusively. A change to an account's password results in that account having a long password hash.

As indicated earlier, a danger in this scenario is that it is possible for accounts that have a short password hash to become inaccessible to pre-4.1 clients. A change to such an account's password made using the `PASSWORD()` function or a password-generating statement results in the account being given a long password hash. From that point on, no pre-4.1 client can connect to the server using that account. The client must upgrade to 4.1 or later.

If this is a problem, you can change a password in a special way. For example, normally you use `SET PASSWORD` as follows to change an account password:

```
SET PASSWORD FOR 'some_user'@'some_host' = PASSWORD('password');
```

To change the password but create a short hash, use the `OLD_PASSWORD()` function instead:
SET PASSWORD FOR 'some_user'@'some_host' = OLD_PASSWORD('password');

OLD_PASSWORD() is useful for situations in which you explicitly want to generate a short hash.

The disadvantages for each of the preceding scenarios may be summarized as follows:

In scenario 1, you cannot take advantage of longer hashes that provide more secure authentication.

In scenario 2, old_passwords=1 prevents accounts with short hashes from becoming inaccessible, but password-changing operations cause accounts with long hashes to revert to short hashes unless you take care to change the session value of old_passwords to 0 first.

In scenario 3, accounts with short hashes become inaccessible to pre-4.1 clients if you change their passwords without explicitly using OLD_PASSWORD().

The best way to avoid compatibility problems related to short password hashes is to not use them:

• Upgrade all client programs to MySQL 4.1 or later.
• Run the server with old_passwords=0.
• Reset the password for any account with a short password hash to use a long password hash.
• For additional security, run the server with secure_auth=1.

6.1.2.5 Implications of Password Hashing Changes in MySQL 4.1 for Application Programs

An upgrade to MySQL version 4.1 or later can cause compatibility issues for applications that use PASSWORD() to generate passwords for their own purposes. Applications really should not do this, because PASSWORD() should be used only to manage passwords for MySQL accounts. But some applications use PASSWORD() for their own purposes anyway.

If you upgrade to 4.1 or later from a pre-4.1 version of MySQL and run the server under conditions where it generates long password hashes, an application using PASSWORD() for its own passwords breaks. The recommended course of action in such cases is to modify the application to use another function, such as SHA2(), SHA1(), or MD5(), to produce hashed values. If that is not possible, you can use the OLD_PASSWORD() function, which is provided for generate short hashes in the old format. However, you should note that OLD_PASSWORD() may one day no longer be supported.

If the server is running with old_passwords=1, it generates short hashes and OLD_PASSWORD() is equivalent to PASSWORD().

PHP programmers migrating their MySQL databases from version 4.0 or lower to version 4.1 or higher should see MySQL and PHP.

6.1.3 Making MySQL Secure Against Attackers

When you connect to a MySQL server, you should use a password. The password is not transmitted as cleartext over the connection. Password handling during the client connection sequence was upgraded in MySQL 4.1.1 to be very secure. If you are still using pre-4.1.1-style passwords, the encryption algorithm is not as strong as the newer algorithm. With some effort, a clever attacker who can sniff the traffic between the client and the server can crack the password. (See Section 6.1.2.4, "Password Hashing in MySQL", for a discussion of the different password handling methods.)

All other information is transferred as text, and can be read by anyone who is able to watch the connection. If the connection between the client and the server goes through an untrusted network, and you are concerned about this, you can use the compressed protocol to make traffic much more difficult to decipher. You can also use MySQL’s internal SSL support to make the connection even more secure.

To make a MySQL system secure, you should strongly consider the following suggestions:

- **Require all MySQL accounts to have a password.** A client program does not necessarily know the identity of the person running it. It is common for client/server applications that the user can specify any other user name to the client program. For example, anyone can use the `mysql` program to connect as any other person simply by invoking it as `mysql -u other_user db_name` if `other_user` has no password. If all accounts have a password, connecting using another user’s account becomes much more difficult.

  For a discussion of methods for setting passwords, see Section 6.2.9, “Assigning Account Passwords”.

- **Make sure that the only Unix user account with read or write privileges in the database directories is the account that is used for running `mysqld`**.

- **Never run the MySQL server as the Unix root user.** This is extremely dangerous, because any user with the FILE privilege is able to cause the server to create files as root (for example, `~root/.bashrc`). To prevent this, `mysqld` refuses to run as root unless that is specified explicitly using the `--user=root` option.

  `mysqld` can (and should) be run as an ordinary, unprivileged user instead. You can create a separate Unix account named `mysql` to make everything even more secure. Use this account only for administering MySQL. To start `mysqld` as a different Unix user, add a `user` option that specifies the user name in the `[mysqld]` group of the `my.cnf` option file where you specify server options. For example:

  ```
  [mysqld]
  user=mysql
  ```

  This causes the server to start as the designated user whether you start it manually or by using `mysqld_safe` or `mysql.server`. For more details, see Section 6.1.5, “How to Run MySQL as a Normal User”.

  Running `mysqld` as a Unix user other than root does not mean that you need to change the root user name in the user table. **User names for MySQL accounts have nothing to do with user names for Unix accounts**.

- **Do not grant the FILE privilege to nonadministrative users.** Any user that has this privilege can write a file anywhere in the file system with the privileges of the `mysqld` daemon. This includes the server’s data directory containing the files that implement the privilege tables. To make FILE-privilege operations a bit safer, files generated with `SELECT ... INTO OUTFILE` do not overwrite existing files and are writable by everyone.

  The FILE privilege may also be used to read any file that is world-readable or accessible to the Unix user that the server runs as. With this privilege, you can read any file into a database table. This could be abused, for example, by using `LOAD DATA` to load `/etc/passwd` into a table, which then can be displayed with `SELECT`.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Section 5.1.7, “Server System Variables”.

- **Do not grant the PROCESS or SUPER privilege to nonadministrative users.** The output of `mysqladmin processlist` and `SHOW PROCESSLIST` shows the text of any statements currently being executed, so
any user who is permitted to see the server process list might be able to see statements issued by other users such as `UPDATE user SET password=PASSWORD('not_secure')`.

`mysqld` reserves an extra connection for users who have the `SUPER` privilege, so that a MySQL root user can log in and check server activity even if all normal connections are in use.

The `SUPER` privilege can be used to terminate client connections, change server operation by changing the value of system variables, and control replication servers.

- Do not permit the use of symlinks to tables. (This capability can be disabled with the `--skip-symbolic-links` option.) This is especially important if you run `mysqld` as `root`, because anyone that has write access to the server’s data directory then could delete any file in the system! See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”.

- Stored programs and views should be written using the security guidelines discussed in Section 20.6, “Stored Object Access Control”.

- If you do not trust your DNS, you should use IP addresses rather than host names in the grant tables. In any case, you should be very careful about creating grant table entries using host name values that contain wildcards.

- If you want to restrict the number of connections permitted to a single account, you can do so by setting the `max_user_connections` variable in `mysqld`. The `GRANT` statement also supports resource control options for limiting the extent of server use permitted to an account. See Section 13.7.1.3, “GRANT Statement”.

- If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `secure_file_priv` to a directory where `SELECT` writes can be made safely.

### 6.1.4 Security-Related mysqld Options and Variables

The following table shows `mysqld` options and system variables that affect security. For descriptions of each of these, see Section 5.1.6, “Server Command Options”, and Section 5.1.7, “Server System Variables”.

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow-suspicious-udfs</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>automatic_sp_privileges</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>chroot</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>des-key-file</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>local_infile</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>old_passwords</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>safe-user-create</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>secure_auth</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>secure_file_priv</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>skip-grant-tables</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>skip_name_resolve</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>skip_networking</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.1.5 How to Run MySQL as a Normal User

On Windows, you can run the server as a Windows service using a normal user account.

On Linux, for installations performed using a MySQL repository, RPM packages, or Debian packages, the MySQL server `mysqld` should be started by the local `mysql` operating system user. Starting by another operating system user is not supported by the init scripts that are included as part of the installation.

On Unix (or Linux for installations performed using `tar` or `tar.gz` packages), the MySQL server `mysqld` can be started and run by any user. However, you should avoid running the server as the Unix `root` user for security reasons. To change `mysqld` to run as a normal unprivileged Unix user `user_name`, you must do the following:

1. Stop the server if it is running (use `mysqladmin shutdown`).

2. Change the database directories and files so that `user_name` has privileges to read and write files in them (you might need to do this as the Unix `root` user):

   ```shell
   sh c> chown -R user_name /path/to/mysql/datadir
   ```

   If you do not do this, the server will not be able to access databases or tables when it runs as `user_name`.

   If directories or files within the MySQL data directory are symbolic links, `chown -R` might not follow symbolic links for you. If it does not, you will also need to follow those links and change the directories and files they point to.

3. Start the server as user `user_name`. Another alternative is to start `mysqld` as the Unix `root` user and use the `--user=user_name` option. `mysqld` starts, then switches to run as the Unix user `user_name` before accepting any connections.

4. To start the server as the given user automatically at system startup time, specify the user name by adding a `user` option to the `[mysqld]` group of the `/etc/my.cnf` option file or the `my.cnf` option file in the server's data directory. For example:

   ```
   [mysqld]
   user=user_name
   ```

   If your Unix machine itself is not secured, you should assign passwords to the MySQL `root` accounts in the grant tables. Otherwise, any user with a login account on that machine can run the `mysql` client with a `--user=root` option and perform any operation. (It is a good idea to assign passwords to MySQL accounts in any case, but especially so when other login accounts exist on the server host.) See Section 2.10.4, “Securing the Initial MySQL Accounts”.

6.1.6 Security Issues with LOAD DATA LOCAL

The `LOAD DATA` statement can load a file located on the server host, or, if the `LOCAL` keyword is specified, on the client host.

There are two potential security issues with the `LOCAL` version of `LOAD DATA`:

- The transfer of the file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server’s choosing rather than the file named by the client in the `LOAD DATA` statement. Such a server could access any file
Security Issues with LOAD DATA LOCAL

on the client host to which the client user has read access. (A patched server could in fact reply with a file-transfer request to any statement, not just LOAD DATA LOCAL, so a more fundamental issue is that clients should not connect to untrusted servers.)

• In a Web environment where the clients are connecting from a Web server, a user could use LOAD DATA LOCAL to read any files that the Web server process has read access to (assuming that a user could run any statement against the SQL server). In this environment, the client with respect to the MySQL server actually is the Web server, not a remote program being run by users who connect to the Web server.

To avoid LOAD DATA issues, clients should avoid using LOCAL. To avoid connecting to untrusted servers, clients can establish a secure connection and verify the server identity by connecting using the --ssl-verify-server-cert option and the appropriate CA certificate.

To enable administrators and applications to manage the local data loading capability, LOCAL configuration works like this:

• On the server side:
  • The local_infile system variable controls server-side LOCAL capability. Depending on the local_infile setting, the server refuses or permits local data loading by clients that have LOCAL enabled on the client side. By default, local_infile is enabled.
  • To explicitly cause the server to refuse or permit LOAD DATA LOCAL statements (regardless of how client programs and libraries are configured at build time or runtime), start mysqld with local_infile disabled or enabled, respectively. local_infile can also be set at runtime.

• On the client side:
  • The ENABLED_LOCAL_INFILE CMake option controls the compiled-in default LOCAL capability for the MySQL client library. Clients that make no explicit arrangements therefore have LOCAL capability disabled or enabled according to the ENABLED_LOCAL_INFILE setting specified at MySQL build time.

By default, the client library in MySQL binary distributions is compiled with ENABLED_LOCAL_INFILE enabled. If you compile MySQL from source, configure it with ENABLED_LOCAL_INFILE disabled or enabled based on whether clients that make no explicit arrangements should have LOCAL capability disabled or enabled, respectively.

• Client programs that use the C API can control load data loading explicitly by invoking mysql_options() to disable or enable the MYSQL_OPT_LOCAL_INFILE option. See Section 23.7.6.49, "mysql_options()".

• For the mysql client, local data loading is disabled by default. To disable or enable it explicitly, use the --local-infile=0 or --local-infile[=1] option.

• For the mysqlimport client, local data loading is disabled by default. To disable or enable it explicitly, use the --local=0 or --local[=1] option.

• If you use LOAD DATA LOCAL in Perl scripts or other programs that read the [client] group from option files, you can add an local-infile option setting to that group. To prevent problems for programs that do not understand this option, specify it using the loose- prefix:

```
[client]
loose-local-infile=0
```

or:
6.1.7 Client Programming Security Guidelines

Applications that access MySQL should not trust any data entered by users, who can try to trick your code by entering special or escaped character sequences in Web forms, URLs, or whatever application you have built. Be sure that your application remains secure if a user enters something like `DROP DATABASE mysql;`. This is an extreme example, but large security leaks and data loss might occur as a result of hackers using similar techniques, if you do not prepare for them.

A common mistake is to protect only string data values. Remember to check numeric data as well. If an application generates a query such as `SELECT * FROM table WHERE ID=234` when a user enters the value `234`, the user can enter the value `234 OR 1=1` to cause the application to generate the query `SELECT * FROM table WHERE ID=234 OR 1=1`. As a result, the server retrieves every row in the table. This exposes every row and causes excessive server load. The simplest way to protect from this type of attack is to use single quotation marks around the numeric constants: `SELECT * FROM table WHERE ID='234'`. If the user enters extra information, it all becomes part of the string. In a numeric context, MySQL automatically converts this string to a number and strips any trailing nonnumeric characters from it.

Sometimes people think that if a database contains only publicly available data, it need not be protected. This is incorrect. Even if it is permissible to display any row in the database, you should still protect against denial of service attacks (for example, those that are based on the technique in the preceding paragraph that causes the server to waste resources). Otherwise, your server becomes unresponsive to legitimate users.

Checklist:

- Enable strict SQL mode to tell the server to be more restrictive of what data values it accepts. See Section 5.1.10, “Server SQL Modes”.
- Try to enter single and double quotation marks (`'` and `"`) in all of your Web forms. If you get any kind of MySQL error, investigate the problem right away.
- Try to modify dynamic URLs by adding `%22 ("), %23 (#), and %27 (’)` to them.
- Try to modify data types in dynamic URLs from numeric to character types using the characters shown in the previous examples. Your application should be safe against these and similar attacks.
- Try to enter characters, spaces, and special symbols rather than numbers in numeric fields. Your application should remove them before passing them to MySQL or else generate an error. Passing unchecked values to MySQL is very dangerous!
- Check the size of data before passing it to MySQL.
- Have your application connect to the database using a user name different from the one you use for administrative purposes. Do not give your applications any access privileges they do not need.
Many application programming interfaces provide a means of escaping special characters in data values. Properly used, this prevents application users from entering values that cause the application to generate statements that have a different effect than you intend:

- MySQL C API: Use the `mysql_real_escape_string()` API call.
- MySQL++: Use the `escape` and `quote` modifiers for query streams.
- PHP: Use either the `mysqli` or `pdo_mysql` extensions, and not the older `ext/mysql` extension. The preferred API's support the improved MySQL authentication protocol and passwords, as well as prepared statements with placeholders. See also Choosing an API.
- If the older `ext/mysql` extension must be used, then for escaping use the `mysql_real_escape_string()` function and not `mysql_escape_string()` or `addslashes()` because only `mysql_real_escape_string()` is character set-aware; the other functions can be “bypassed” when using (invalid) multibyte character sets.
- Perl DBI: Use placeholders or the `quote()` method.
- Ruby DBI: Use placeholders or the `quote()` method.
- Java JDBC: Use a `PreparedStatement` object and placeholders.

Other programming interfaces might have similar capabilities.

### 6.2 Access Control and Account Management

MySQL enables the creation of accounts that permit client users to connect to the server and access data managed by the server. The primary function of the MySQL privilege system is to authenticate a user who connects from a given host and to associate that user with privileges on a database such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. Additional functionality includes the ability to grant privileges for administrative operations.

To control which users can connect, each account can be assigned authentication credentials such as a password. The user interface to MySQL accounts consists of SQL statements such as `CREATE USER`, `GRANT`, and `REVOKE`. See Section 13.7.1, “Account Management Statements”.

The MySQL privilege system ensures that all users may perform only the operations permitted to them. As a user, when you connect to a MySQL server, your identity is determined by the host from which you connect and the user name you specify. When you issue requests after connecting, the system grants privileges according to your identity and what you want to do.

MySQL considers both your host name and user name in identifying you because there is no reason to assume that a given user name belongs to the same person on all hosts. For example, the user `joe` who connects from `office.example.com` need not be the same person as the user `joe` who connects from `home.example.com`. MySQL handles this by enabling you to distinguish users on different hosts that happen to have the same name: You can grant one set of privileges for connections by `joe` from `office.example.com`, and a different set of privileges for connections by `joe` from `home.example.com`. To see what privileges a given account has, use the `SHOW GRANTS` statement. For example:

```
SHOW GRANTS FOR 'joe'@'office.example.com';
SHOW GRANTS FOR 'joe'@'home.example.com';
```

Internally, the server stores privilege information in the grant tables of the `mysql` system database. The MySQL server reads the contents of these tables into memory when it starts and bases access-control decisions on the in-memory copies of the grant tables.
MySQL access control involves two stages when you run a client program that connects to the server:

**Stage 1:** The server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password.

**Stage 2:** Assuming that you can connect, the server checks each statement you issue to determine whether you have sufficient privileges to perform it. For example, if you try to select rows from a table in a database or drop a table from the database, the server verifies that you have the `SELECT` privilege for the table or the `DROP` privilege for the database.

For a more detailed description of what happens during each stage, see Section 6.2.5, “Access Control, Stage 1: Connection Verification”, and Section 6.2.6, “Access Control, Stage 2: Request Verification”. For help in diagnosing privilege-related problems, see Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”.

If your privileges are changed (either by yourself or someone else) while you are connected, those changes do not necessarily take effect immediately for the next statement that you issue. For details about the conditions under which the server reloads the grant tables, see Section 6.2.8, “When Privilege Changes Take Effect”.

There are some things that you cannot do with the MySQL privilege system:

- You cannot explicitly specify that a given user should be denied access. That is, you cannot explicitly match a user and then refuse the connection.
- You cannot specify that a user has privileges to create or drop tables in a database but not to create or drop the database itself.
- A password applies globally to an account. You cannot associate a password with a specific object such as a database, table, or routine.

### 6.2.1 Account User Names and Passwords

MySQL stores accounts in the `user` table of the `mysql` system database. An account is defined in terms of a user name and the client host or hosts from which the user can connect to the server. For information about account representation in the `user` table, see Section 6.2.3, “Grant Tables”.

An account may also have authentication credentials such as a password. The credentials are handled by the account authentication plugin. MySQL supports multiple authentication plugins. Some of them use built-in authentication methods, whereas others enable authentication using external authentication methods. See Section 6.2.10, “Pluggable Authentication”.

There are several distinctions between the way user names and passwords are used by MySQL and your operating system:

- User names, as used by MySQL for authentication purposes, have nothing to do with user names (login names) as used by Windows or Unix. On Unix, most MySQL clients by default try to log in using the current Unix user name as the MySQL user name, but that is for convenience only. The default can be overridden easily, because client programs permit any user name to be specified with a `-u` or `--user` option. This means that anyone can attempt to connect to the server using any user name, so you cannot make a database secure in any way unless all MySQL accounts have passwords. Anyone who specifies a user name for an account that has no password can connect successfully to the server.
- MySQL user names are up to 16 characters long. Operating system user names may have a different maximum length.
Warning

The MySQL user name length limit is hardcoded in MySQL servers and clients, and trying to circumvent it by modifying the definitions of the tables in the `mysql` database does not work.

You should never alter the structure of tables in the `mysql` database in any manner whatsoever except by means of the procedure that is described in Section 2.11, “Upgrading MySQL”. Attempting to redefine MySQL’s system tables in any other fashion results in undefined and unsupported behavior. The server is free to ignore rows that become malformed as a result of such modifications.

- To authenticate client connections for accounts that use built-in authentication methods, the server uses passwords stored in the `user` table. These passwords are distinct from passwords for logging in to your operating system. There is no necessary connection between the “external” password you use to log in to a Windows or Unix machine and the password you use to access the MySQL server on that machine.

  If the server authenticates a client using some other plugin, the authentication method that the plugin implements may or may not use a password stored in the `user` table. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

  Passwords stored in the `user` table are encrypted using plugin-specific algorithms. For information about MySQL native password hashing, see Section 6.1.2.4, “Password Hashing in MySQL”.

- If the user name and password contain only ASCII characters, it is possible to connect to the server regardless of character set settings. To enable connections when the user name or password contain non-ASCII characters, client applications should call the `mysql_options()` C API function with the `MYSQL_SET_CHARSET_NAME` option and appropriate character set name as arguments. This causes authentication to take place using the specified character set. Otherwise, authentication fails unless the server default character set is the same as the encoding in the authentication defaults.

  Standard MySQL client programs support a `--default-character-set` option that causes `mysql_options()` to be called as just described. In addition, character set autodetection is supported as described in Section 10.4, “Connection Character Sets and Collations”. For programs that use a connector that is not based on the C API, the connector may provide an equivalent to `mysql_options()` that can be used instead. Check the connector documentation.

  The preceding notes do not apply for `ucs2`, `utf16`, and `utf32`, which are not permitted as client character sets.

The MySQL installation process populates the grant tables with an initial account or accounts. The names and access privileges for these accounts are described in Section 2.10.4, “Securing the Initial MySQL Accounts”, which also discusses how to assign passwords to them. Thereafter, you normally set up, modify, and remove MySQL accounts using statements such as `CREATE USER`, `DROP USER`, `GRANT`, and `REVOKE`. See Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”, and Section 13.7.1, “Account Management Statements”.

To connect to a MySQL server with a command-line client, specify user name and password options as necessary for the account that you want to use:

shell> `mysql --user=finley --password db_name`

If you prefer short options, the command looks like this:

shell> `mysql -u finley -p db_name`
Privileges Provided by MySQL

If you omit the password value following the `--password` or `-p` option on the command line (as just shown), the client prompts for one. Alternatively, the password can be specified on the command line:

```
shell> mysql --user=finley --password=password db_name
shell> mysql -u finley -p password db_name
```

If you use the `-p` option, there must be no space between `-p` and the following password value.

Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". To avoid giving the password on the command line, use an option file. See Section 4.2.2.2, "Using Option Files".

For additional information about specifying user names, passwords, and other connection parameters, see Section 4.2.4, "Connecting to the MySQL Server Using Command Options".

6.2.2 Privileges Provided by MySQL

The privileges granted to a MySQL account determine which operations the account can perform. MySQL privileges differ in the contexts in which they apply and at different levels of operation:

- Administrative privileges enable users to manage operation of the MySQL server. These privileges are global because they are not specific to a particular database.
- Database privileges apply to a database and to all objects within it. These privileges can be granted for specific databases, or globally so that they apply to all databases.
- Privileges for database objects such as tables, indexes, views, and stored routines can be granted for specific objects within a database, for all objects of a given type within a database (for example, all tables in a database), or globally for all objects of a given type in all databases.

Information about account privileges is stored in the grant tables in the `mysql` system database. For a description of the structure and contents of these tables, see Section 6.2.3, "Grant Tables". The MySQL server reads the contents of the grant tables into memory when it starts, and reloads them under the circumstances indicated in Section 6.2.8, "When Privilege Changes Take Effect". The server bases access-control decisions on the in-memory copies of the grant tables.

**Important**

Some MySQL releases introduce changes to the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to the current structure whenever you upgrade MySQL. See Section 2.11, "Upgrading MySQL".

The following sections summarize the available privileges, provide more detailed descriptions of each privilege, and offer usage guidelines.

- Summary of Available Privileges
- Privilege Descriptions
- Privilege-Granting Guidelines

**Summary of Available Privileges**

The following table shows the privilege names used in `GRANT` and `REVOKE` statements, along with the column name associated with each privilege in the grant tables and the context in which the privilege applies.
### Privileges Provided by MySQL

#### Table 6.2 Permissible Privileges for GRANT and REVOKE

<table>
<thead>
<tr>
<th>Privilege</th>
<th>Grant Table Column</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL [PRIVILEGES]</td>
<td>Synonym for &quot;all privileges&quot;</td>
<td>Server administration</td>
</tr>
<tr>
<td>ALTER</td>
<td>Alter_priv</td>
<td>Tables</td>
</tr>
<tr>
<td>ALTER ROUTINE</td>
<td>Alter_routine_priv</td>
<td>Stored routines</td>
</tr>
<tr>
<td>CREATE</td>
<td>Create_priv</td>
<td>Databases, tables, or indexes</td>
</tr>
<tr>
<td>CREATE ROUTINE</td>
<td>Create_routine_priv</td>
<td>Stored routines</td>
</tr>
<tr>
<td>CREATE TABLESPACE</td>
<td>Create_tablespace_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>CREATE TEMPORARY TABLES</td>
<td>Create_tmp_table_priv</td>
<td>Tables</td>
</tr>
<tr>
<td>CREATE USER</td>
<td>Create_user_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>CREATE VIEW</td>
<td>Create_view_priv</td>
<td>Views</td>
</tr>
<tr>
<td>DELETE</td>
<td>Delete_priv</td>
<td>Tables</td>
</tr>
<tr>
<td>DROP</td>
<td>Drop_priv</td>
<td>Databases, tables, or views</td>
</tr>
<tr>
<td>EVENT</td>
<td>Event_priv</td>
<td>Databases</td>
</tr>
<tr>
<td>EXECUTE</td>
<td>Execute_priv</td>
<td>Stored routines</td>
</tr>
<tr>
<td>FILE</td>
<td>File_priv</td>
<td>File access on server host</td>
</tr>
<tr>
<td>GRANT OPTION</td>
<td>Grant_priv</td>
<td>Databases, tables, or stored routines</td>
</tr>
<tr>
<td>INDEX</td>
<td>Index_priv</td>
<td>Tables</td>
</tr>
<tr>
<td>INSERT</td>
<td>Insert_priv</td>
<td>Tables or columns</td>
</tr>
<tr>
<td>LOCK TABLES</td>
<td>Lock_tables_priv</td>
<td>Databases</td>
</tr>
<tr>
<td>PROCESS</td>
<td>Process_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>PROXY</td>
<td>See proxies_priv table</td>
<td>Server administration</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>References_priv</td>
<td>Databases or tables</td>
</tr>
<tr>
<td>RELOAD</td>
<td>Reload_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>REPLICATION CLIENT</td>
<td>Repl_client_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>REPLICATION_SLAVE</td>
<td>Repl_slave_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>SELECT</td>
<td>Select_priv</td>
<td>Tables or columns</td>
</tr>
<tr>
<td>SHOW DATABASES</td>
<td>Show_db_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>SHOW VIEW</td>
<td>Show_view_priv</td>
<td>Views</td>
</tr>
<tr>
<td>SHUTDOWN</td>
<td>Shutdown_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>SUPER</td>
<td>Super_priv</td>
<td>Server administration</td>
</tr>
<tr>
<td>TRIGGER</td>
<td>Trigger_priv</td>
<td>Tables</td>
</tr>
<tr>
<td>UPDATE</td>
<td>Update_priv</td>
<td>Tables or columns</td>
</tr>
<tr>
<td>USAGE</td>
<td>Synonym for &quot;no privileges&quot;</td>
<td>Server administration</td>
</tr>
</tbody>
</table>

#### Privilege Descriptions

The following list provides general descriptions of each privilege available in MySQL. Particular SQL statements might have more specific privilege requirements than indicated here. If so, the description for the statement in question provides the details.
Privileges Provided by MySQL

- **ALL, ALL PRIVILEGES**
  These privilege specifiers are shorthand for “all privileges available at a given privilege level” (except **GRANT OPTION**). For example, granting `ALL` at the global or table level grants all global privileges or all table-level privileges, respectively.

- **ALTER**
  Enables use of the `ALTER TABLE` statement to change the structure of tables. `ALTER TABLE` also requires the `CREATE` and `INSERT` privileges. Renaming a table requires `ALTER` and `DROP` on the old table, `CREATE`, and `INSERT` on the new table.

- **ALTER ROUTINE**
  Enables use of statements that alter or drop stored routines (stored procedures and functions).

- **CREATE**
  Enables use of statements that create new databases and tables.

- **CREATE ROUTINE**
  Enables use of statements that create stored routines (stored procedures and functions).

- **CREATE TABLESPACE**
  Enables use of statements that create, alter, or drop tablespaces and log file groups.

- **CREATE TEMPORARY TABLES**
  Enables the creation of temporary tables using the `CREATE TEMPORARY TABLE` statement.
  However, other operations on a temporary table, such as `INSERT`, `UPDATE`, or `SELECT`, require additional privileges for those operations for the database containing the temporary table, or for the nontemporary table of the same name. For more information, see Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”.

- **CREATE USER**
  Enables use of the `CREATE USER`, `DROP USER`, `RENAME USER`, and `REVOKE ALL PRIVILEGES` statements.

- **CREATE VIEW**
  Enables use of the `CREATE VIEW` statement.

- **DELETE**
  Enables rows to be deleted from tables in a database.

- **DROP**
  Enables use of statements that drop (remove) existing databases, tables, and views. The `DROP` privilege is required to use the `ALTER TABLE ... DROP PARTITION` statement on a partitioned table. The `DROP` privilege is also required for `TRUNCATE TABLE`.

- **EVENT**
  Enables use of statements that create, alter, drop, or display events for the Event Scheduler.
Privileges Provided by MySQL

- **EXECUTE**
  Enables use of statements that execute stored routines (stored procedures and functions).

- **FILE**
  Affects the following operations and server behaviors:
  
  - Enables reading and writing files on the server host using the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. A user who has the `FILE` privilege can read any file on the server host that is either world-readable or readable by the MySQL server. (This implies the user can read any file in any database directory, because the server can access any of those files.)
  
  - Enables creating new files in any directory where the MySQL server has write access. This includes the server's data directory containing the files that implement the privilege tables.
  
  - As of MySQL 5.5.54, enables use of the `DATA DIRECTORY` or `INDEX DIRECTORY` table option for the `CREATE TABLE` statement.

  As a security measure, the server does not overwrite existing files.

  To limit the location in which files can be read and written, set the `secure_file_priv` system variable to a specific directory. See Section 5.1.7, “Server System Variables”.

- **GRANT OPTION**
  Enables you to grant to or revoke from other users those privileges that you yourself possess.

- **INDEX**
  Enables use of statements that create or drop (remove) indexes. `INDEX` applies to existing tables. If you have the `CREATE` privilege for a table, you can include index definitions in the `CREATE TABLE` statement.

- **INSERT**
  Enables rows to be inserted into tables in a database. `INSERT` is also required for the `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` table-maintenance statements.

- **LOCK TABLES**
  Enables use of explicit `LOCK TABLES` statements to lock tables for which you have the `SELECT` privilege. This includes use of write locks, which prevents other sessions from reading the locked table.

- **PROCESS**
  Enables display of information about the threads executing within the server (that is, information about the statements being executed by sessions). The privilege enables use of `SHOW PROCESSLIST` or `mysqladmin processlist` to see threads belonging to other accounts; you can always see your own threads. The `PROCESS` privilege also enables use of `SHOW ENGINE`.

- **PROXY**
  Enables one user to impersonate or become known as another user. See Section 6.2.11, “Proxy Users”.
Privileges Provided by MySQL

• REFERENCES

This privilege is unused before MySQL 5.5.41. As of 5.5.41, creation of a foreign key constraint requires at least one of the SELECT, INSERT, UPDATE, DELETE, or REFERENCES privileges for the parent table.

• RELOAD

Enables use of the FLUSH statement. It also enables mysqladmin commands that are equivalent to FLUSH operations: flush-hosts, flush-logs, flush-privileges, flush-status, flush-tables, flush-threads, refresh, and reload.

The reload command tells the server to reload the grant tables into memory. flush-privileges is a synonym for reload. The refresh command closes and reopens the log files and flushes all tables. The other flush-xxx commands perform functions similar to refresh, but are more specific and may be preferable in some instances. For example, if you want to flush just the log files, flush-logs is a better choice than refresh.

• REPLICATION CLIENT

Enables use of the SHOW MASTER STATUS and SHOW SLAVE STATUS statements. In MySQL 5.5.25 and later, it also enables use of the SHOW BINARY LOGS statement. Grant this privilege to accounts that are used by slave servers to connect to the current server as their master.

• REPLICATION SLAVE

Enables the account to request updates that have been made to databases on the master server. Grant this privilege to accounts that are used by slave servers to connect to the current server as their master.

• SELECT

Enables rows to be selected from tables in a database. SELECT statements require the SELECT privilege only if they actually access tables. Some SELECT statements do not access tables and can be executed without permission for any database. For example, you can use SELECT as a simple calculator to evaluate expressions that make no reference to tables:

```
SELECT 1+1;
SELECT PI()*2;
```

The SELECT privilege is also needed for other statements that read column values. For example, SELECT is needed for columns referenced on the right hand side of col_name=expr assignment in UPDATE statements or for columns named in the WHERE clause of DELETE or UPDATE statements.

The SELECT privilege is needed for tables or views used with EXPLAIN, including any underlying tables in view definitions.

• SHOW DATABASES

Enables the account to see database names by issuing the SHOW DATABASE statement. Accounts that do not have this privilege see only databases for which they have some privileges, and cannot use the statement at all if the server was started with the --skip-show-database option.

Caution

Because a global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with SHOW DATABASES or by examining the INFORMATION_SCHEMA SCHEMATA table.

• SHOW VIEW
Enables use of the `SHOW CREATE VIEW` statement. This privilege is also needed for views used with `EXPLAIN`.

- **SHUTDOWN**

   Enables use of the `mysqladmin shutdown` command and the `mysql_shutdown()` C API function. There is no corresponding SQL statement.

- **SUPER**

   Affects the following operations and server behaviors:

   - Enables server configuration changes by modifying global system variables. For some system variables, setting the session value also requires the `SUPER` privilege. If a system variable is restricted and requires a special privilege to set the session value, the variable description indicates that restriction. Examples include `binlog_format`, `sql_log_bin`, and `sql_log_off`. See also Section 5.1.8.1, “System Variable Privileges”.

   - Enables changes to the global transaction isolation level (see Section 13.3.6, “SET TRANSACTION Statement”).

   - Enables the account to start and stop replication.

   - Enables use of the `CHANGE MASTER TO` statement.

   - Enables binary log control by means of the `PURGE BINARY LOGS` and `BINLOG` statements.

   - Enables setting the effective authorization ID when executing a view or stored program. A user with this privilege can specify any account in the `DEFINER` attribute of a view or stored program.

   - Enables use of the `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` statements.

   - Enables use of the `mysqladmin debug` command.

   - Enables reading the DES key file by the `DES_ENCRYPT()` function.

   - Enables control over client connections not permitted to non-SUPER accounts:

     - Enables use of the `KILL` statement or `mysqladmin kill` command to kill threads belonging to other accounts. (An account can always kill its own threads.)

     - The server does not execute `init_connect` system variable content when SUPER clients connect.

     - The server accepts one connection from a SUPER client even if the connection limit configured by the `max_connections` system variable is reached.

     - Updates can be performed even when the `read_only` system variable is enabled. This applies to explicit table updates, and to use of account-management statements such as `GRANT` and `REVOKE` that update tables implicitly.

   You may also need the SUPER privilege to create or alter stored functions if binary logging is enabled, as described in Section 20.7, “Stored Program Binary Logging”.

- **TRIGGER**

   Enables trigger operations. You must have this privilege for a table to create, drop, execute, or display triggers for that table.
Grant Tables

When a trigger is activated (by a user who has privileges to execute `INSERT`, `UPDATE`, or `DELETE` statements for the table associated with the trigger), trigger execution requires that the user who defined the trigger still have the `TRIGGER` privilege for the table.

- **UPDATE**

  Enables rows to be updated in tables in a database.

- **USAGE**

  This privilege specifier stands for “no privileges.” It is used at the global level with `GRANT` to modify account attributes such as resource limits or SSL characteristics without naming specific account privileges in the privilege list. `SHOW GRANTS` displays `USAGE` to indicate that an account has no privileges at a privilege level.

Privilege-Granting Guidelines

It is a good idea to grant to an account only those privileges that it needs. You should exercise particular caution in granting the `FILE` and administrative privileges:

- **FILE** can be abused to read into a database table any files that the MySQL server can read on the server host. This includes all world-readable files and files in the server’s data directory. The table can then be accessed using `SELECT` to transfer its contents to the client host.

- **GRANT OPTION** enables users to give their privileges to other users. Two users that have different privileges and with the `GRANT OPTION` privilege are able to combine privileges.

- **ALTER** may be used to subvert the privilege system by renaming tables.

- **SHUTDOWN** can be abused to deny service to other users entirely by terminating the server.

- **PROCESS** can be used to view the plain text of currently executing statements, including statements that set or change passwords.

- **SUPER** can be used to terminate other sessions or change how the server operates.

- Privileges granted for the `mysql` system database itself can be used to change passwords and other access privilege information:

  - Passwords are stored encrypted, so a malicious user cannot simply read them to know the plain text password. However, a user with write access to the `mysql.user` system table `Password` column can change an account’s password, and then connect to the MySQL server using that account.

  - `INSERT` or `UPDATE` granted for the `mysql` system database enable a user to add privileges or modify existing privileges, respectively.

  - `DROP` for the `mysql` system database enables a user to remote privilege tables, or even the database itself.

6.2.3 Grant Tables

The `mysql` system database includes several grant tables that contain information about user accounts and the privileges held by them. This section describes those tables. For information about other tables in the system database, see Section 5.3, “The mysql System Database”.

The discussion here describes the underlying structure of the grant tables and how the server uses their contents when interacting with clients. However, normally you do not modify the grant tables.
directly. Modifications occur indirectly when you use account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to set up accounts and control the privileges available to each one. See Section 13.7.1, “Account Management Statements”. When you use such statements to perform account manipulations, the server modifies the grant tables on your behalf.

**Note**

Direct modification of grant tables using statements such as `INSERT`, `UPDATE`, or `DELETE` is discouraged and done at your own risk. The server is free to ignore rows that become malformed as a result of such modifications.

As of MySQL 5.5.55, for any operation that modifies a grant table, the server checks whether the table has the expected structure and produces an error if not. `mysql_upgrade` must be run to update the tables to the expected structure.

• Grant Table Overview
• The user, db, and host Grant Tables
• The tables_priv and columns_priv Grant Tables
• The procs_priv Grant Table
• The proxies_priv Grant Table
• Grant Table Scope Column Properties
• Grant Table Privilege Column Properties

**Grant Table Overview**

These `mysql` database tables contain grant information:

• **user**: User accounts, global privileges, and other nonprivilege columns.
• **db**: Database-level privileges.
• **host**: Obsolete
• **tables_priv**: Table-level privileges.
• **columns_priv**: Column-level privileges.
• **procs_priv**: Stored procedure and function privileges.
• **proxies_priv**: Proxy-user privileges.

Each grant table contains scope columns and privilege columns:

• Scope columns determine the scope of each row in the tables; that is, the context in which the row applies. For example, a `user` table row with `Host` and `User` values of 'h1.example.net' and 'bob' applies to authenticating connections made to the server from the host `h1.example.net` by a client that specifies a user name of `bob`. Similarly, a `db` table row with `Host`, `User`, and `Db` column values of 'h1.example.net', 'bob' and 'reports' applies when `bob` connects from the host `h1.example.net` to access the reports database. The `tables_priv` and `columns_priv` tables contain scope columns indicating tables or table/column combinations to which each row applies. The `procs_priv` scope columns indicate the stored routine to which each row applies.
Grant Tables

- Privilege columns indicate which privileges a table row grants; that is, which operations it permits to be performed. The server combines the information in the various grant tables to form a complete description of a user’s privileges. Section 6.2.6, “Access Control, Stage 2: Request Verification”, describes the rules for this.

In addition, a grant table may contain columns used for purposes other than scope or privilege assessment.

The server uses the grant tables in the following manner:

- The user table scope columns determine whether to reject or permit incoming connections. For permitted connections, any privileges granted in the user table indicate the user's global privileges. Any privileges granted in this table apply to all databases on the server.

  Caution
  Because a global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with SHOW DATABASES or by examining the INFORMATION_SCHEMA SCHEMATA table.

- The db table scope columns determine which users can access which databases from which hosts. The privilege columns determine the permitted operations. A privilege granted at the database level applies to the database and to all objects in the database, such as tables and stored programs.

- The host table is used in conjunction with the db table when you want a given db table row to apply to several hosts. For example, if you want a user to be able to use a database from several hosts in your network, leave the Host value empty in the user's db table row, then populate the host table with a row for each of those hosts. This mechanism is described more detail in Section 6.2.6, “Access Control, Stage 2: Request Verification”.

  Note
  The host table must be modified directly with statements such as INSERT, UPDATE, and DELETE. It is not affected by statements such as GRANT and REVOKE that modify the grant tables indirectly. Most MySQL installations need not use this table at all.

- The tables_priv and columns_priv tables are similar to the db table, but are more fine-grained: They apply at the table and column levels rather than at the database level. A privilege granted at the table level applies to the table and to all its columns. A privilege granted at the column level applies only to a specific column.

- The procs_priv table applies to stored routines (stored procedures and functions). A privilege granted at the routine level applies only to a single procedure or function.

- The proxies_priv table indicates which users can act as proxies for other users and whether a user can grant the PROXY privilege to other users.

The server reads the contents of the grant tables into memory when it starts. You can tell it to reload the tables by issuing a FLUSH PRIVILEGES statement or executing a mysqladmin flush-privileges or mysqladmin reload command. Changes to the grant tables take effect as indicated in Section 6.2.8, “When Privilege Changes Take Effect”.

When you modify an account, it is a good idea to verify that your changes have the intended effect. To check the privileges for a given account, use the SHOW GRANTS statement. For example, to determine the privileges that are granted to an account with user name and host name values of bob and pc84.example.com, use this statement:
Grant Tables

SHOW GRANTS FOR 'bob'@'pc84.example.com';

The user, db, and host Grant Tables

The server uses the user, db, and host tables in the mysql database at both the first and second stages of access control (see Section 6.2, “Access Control and Account Management”). The columns in the user and db tables are shown here. The host table is similar to the db table but has a specialized use as described in Section 6.2.6, “Access Control, Stage 2: Request Verification”.

Table 6.3 user and db Table Columns

<table>
<thead>
<tr>
<th>Table Name</th>
<th>user</th>
<th>db</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope columns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Host</td>
<td>Host</td>
<td></td>
</tr>
<tr>
<td>User</td>
<td>Db</td>
<td></td>
</tr>
<tr>
<td>Password</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>Privilege columns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select_priv</td>
<td>Select_priv</td>
<td></td>
</tr>
<tr>
<td>Insert_priv</td>
<td>Insert_priv</td>
<td></td>
</tr>
<tr>
<td>Update_priv</td>
<td>Update_priv</td>
<td></td>
</tr>
<tr>
<td>Delete_priv</td>
<td>Delete_priv</td>
<td></td>
</tr>
<tr>
<td>Index_priv</td>
<td>Index_priv</td>
<td></td>
</tr>
<tr>
<td>Alter_priv</td>
<td>Alter_priv</td>
<td></td>
</tr>
<tr>
<td>Create_priv</td>
<td>Create_priv</td>
<td></td>
</tr>
<tr>
<td>Drop_priv</td>
<td>Drop_priv</td>
<td></td>
</tr>
<tr>
<td>Grant_priv</td>
<td>Grant_priv</td>
<td></td>
</tr>
<tr>
<td>Create_view_priv</td>
<td>Create_view_priv</td>
<td></td>
</tr>
<tr>
<td>Show_view_priv</td>
<td>Show_view_priv</td>
<td></td>
</tr>
<tr>
<td>Create_routine_priv</td>
<td>Create_routine_priv</td>
<td></td>
</tr>
<tr>
<td>Alter_routine_priv</td>
<td>Alter_routine_priv</td>
<td></td>
</tr>
<tr>
<td>Execute_priv</td>
<td>Execute_priv</td>
<td></td>
</tr>
<tr>
<td>Trigger_priv</td>
<td>Trigger_priv</td>
<td></td>
</tr>
<tr>
<td>Event_priv</td>
<td>Event_priv</td>
<td></td>
</tr>
<tr>
<td>Create_tmp_table_priv</td>
<td>Create_tmp_table_priv</td>
<td></td>
</tr>
<tr>
<td>Lock_tables_priv</td>
<td>Lock_tables_priv</td>
<td></td>
</tr>
<tr>
<td>References_priv</td>
<td>References_priv</td>
<td></td>
</tr>
<tr>
<td>Reload_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutdown_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>File_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Show_db_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Super_priv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repl_slavePriv</td>
<td>Repl_slavePriv</td>
<td></td>
</tr>
<tr>
<td>Repl_client_priv</td>
<td>Repl_client_priv</td>
<td></td>
</tr>
<tr>
<td>Create_user_priv</td>
<td>Create_user_priv</td>
<td></td>
</tr>
</tbody>
</table>
Grant Tables

<table>
<thead>
<tr>
<th>Table Name</th>
<th>user</th>
<th>db</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Create_tablespace_priv</td>
<td></td>
</tr>
</tbody>
</table>

**Security columns**
- ssl_type
- ssl_cipher
- x509_issuer
- x509_subject
- plugin
- authentication_string

**Resource control columns**
- max_questions
- max_updates
- max_connections
- max_user_connections

The `user` table `plugin`, `Password`, and `authentication_string` columns store authentication plugin and credential information.

If an account row names a plugin in the `plugin` column, the server uses it to authenticate connection attempts for the account. It is up to the plugin whether it uses the `Password` and `authentication_string` column values.

If the `plugin` column for an account row is empty, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

Prior to MySQL 5.5.11, the length of the `plugin` column was 60 characters. This was increased to 64 characters in MySQL 5.5.11 for compatibility with the `mysql.plugin` table's `name` column. (Bug #11766610, Bug #59752)

The `tables_priv` and `columns_priv` Grant Tables

During the second stage of access control, the server performs request verification to ensure that each client has sufficient privileges for each request that it issues. In addition to the `user`, `db`, and `host` grant tables, the server may also consult the `tables_priv` and `columns_priv` tables for requests that involve tables. The latter tables provide finer privilege control at the table and column levels. They have the columns shown in the following table.

### Table 6.4 tables_priv and columns_priv Table Columns

<table>
<thead>
<tr>
<th>Table Name</th>
<th>tables_priv</th>
<th>columns_priv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope columns</td>
<td>Host</td>
<td>Host</td>
</tr>
<tr>
<td></td>
<td>Db</td>
<td>Db</td>
</tr>
<tr>
<td></td>
<td>User</td>
<td>User</td>
</tr>
<tr>
<td></td>
<td>Table_name</td>
<td>Table_name</td>
</tr>
<tr>
<td>Privilege columns</td>
<td>Table_priv</td>
<td>Column_priv</td>
</tr>
<tr>
<td></td>
<td>Column_name</td>
<td></td>
</tr>
<tr>
<td>Other columns</td>
<td>Timestamp</td>
<td>Timestamp</td>
</tr>
</tbody>
</table>
Grant Tables

<table>
<thead>
<tr>
<th>Table Name</th>
<th>tables_priv</th>
<th>columns_priv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grantor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The **Timestamp** and **Grantor** columns are set to the current timestamp and the CURRENT_USER value, respectively, but are otherwise unused.

The **procs_priv** Grant Table

For verification of requests that involve stored routines, the server may consult the **procs_priv** table, which has the columns shown in the following table.

**Table 6.5 procs_priv Table Columns**

<table>
<thead>
<tr>
<th>Table Name</th>
<th>procs_priv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope columns</td>
<td>Host</td>
</tr>
<tr>
<td></td>
<td>Db</td>
</tr>
<tr>
<td></td>
<td>User</td>
</tr>
<tr>
<td></td>
<td>Routine_name</td>
</tr>
<tr>
<td></td>
<td>Routine_type</td>
</tr>
<tr>
<td>Privilege columns</td>
<td>Proc_priv</td>
</tr>
<tr>
<td>Other columns</td>
<td>Timestamp</td>
</tr>
<tr>
<td></td>
<td>Grantor</td>
</tr>
</tbody>
</table>

The **Routine_type** column is an ENUM column with values of 'FUNCTION' or 'PROCEDURE' to indicate the type of routine the row refers to. This column enables privileges to be granted separately for a function and a procedure with the same name.

The **Timestamp** and **Grantor** columns are unused.

The **proxies_priv** Grant Table

The **proxies_priv** table records information about proxy accounts. It has these columns:

- **Host**, **User**: The proxy account; that is, the account that has the PROXY privilege for the proxied account.
- **Proxied_host**, **Proxied_user**: The proxied account.
- **Grantor**, **Timestamp**: Unused.
- **With_grant**: Whether the proxy account can grant the PROXY privilege to other accounts.

For an account to be able to grant the PROXY privilege to other accounts, it must have a row in the **proxies_priv** table with **With_grant** set to 1 and **Proxied_host** and **Proxied_user** set to indicate the account or accounts for which the privilege can be granted. For example, the 'root'@'localhost' account created during MySQL installation has a row in the **proxies_priv** table that enables granting the PROXY privilege for '@', that is, for all users and all hosts. This enables root to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 6.2.11, “Proxy Users”.

**Grant Table Scope Column Properties**

Scope columns in the grant tables contain strings. The default value for each is the empty string. The following table shows the number of characters permitted in each column.
Table 6.6 Grant Table Scope Column Lengths

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Maximum Permitted Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host, Proxied_host</td>
<td>60</td>
</tr>
<tr>
<td>User, Proxied_user</td>
<td>16</td>
</tr>
<tr>
<td>Password</td>
<td>41</td>
</tr>
<tr>
<td>Db</td>
<td>64</td>
</tr>
<tr>
<td>Table_name</td>
<td>64</td>
</tr>
<tr>
<td>Column_name</td>
<td>64</td>
</tr>
<tr>
<td>Routine_name</td>
<td>64</td>
</tr>
</tbody>
</table>

Host and Proxied_host values are converted to lowercase before being stored in the grant tables.

For access-checking purposes, comparisons of User, Proxied_user, Password, Db, and Table_name values are case-sensitive. Comparisons of Host, Proxied_host, Column_name, and Routine_name values are not case-sensitive.

Grant Table Privilege Column Properties

The user, db, and host tables list each privilege in a separate column that is declared as ENUM('N', 'Y') DEFAULT 'N'. In other words, each privilege can be disabled or enabled, with the default being disabled.

The tables_priv, columns_priv, and procs_priv tables declare the privilege columns as SET columns. Values in these columns can contain any combination of the privileges controlled by the table. Only those privileges listed in the column value are enabled.

Table 6.7 Set-Type Privilege Column Values

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Column Name</th>
<th>Possible Set Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>tables_priv</td>
<td>Table_priv</td>
<td>'Select', 'Insert', 'Update', 'Delete', 'Create', 'Drop', 'Grant', 'References', 'Index', 'Alter', 'Create View', 'Show view', 'Trigger'</td>
</tr>
<tr>
<td>tables_priv</td>
<td>Column_priv</td>
<td>'Select', 'Insert', 'Update', 'References'</td>
</tr>
<tr>
<td>columns_priv</td>
<td>Column_priv</td>
<td>'Select', 'Insert', 'Update', 'References'</td>
</tr>
<tr>
<td>procs_priv</td>
<td>Proc_priv</td>
<td>'Execute', 'Alter Routine', 'Grant'</td>
</tr>
</tbody>
</table>

Only the user table specifies administrative privileges, such as RELOAD and SHUTDOWN. Administrative operations are operations on the server itself and are not database-specific, so there is no reason to list these privileges in the other grant tables. Consequently, the server need consult only the user table to determine whether a user can perform an administrative operation.

The FILE privilege also is specified only in the user table. It is not an administrative privilege as such, but a user’s ability to read or write files on the server host is independent of the database being accessed.

6.2.4 Specifying Account Names
Specifying Account Names

MySQL account names consist of a user name and a host name, which enables creation of distinct accounts for users with the same user name who can connect from different hosts. This section describes how to write account names, including special values and wildcard rules.

In SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, account names follow these rules:

- Account name syntax is `'user_name'@'host_name'`.
- An account name consisting only of a user name is equivalent to `'user_name'@'%'`. For example, `me` is equivalent to `'me'@'%'`.
- The user name and host name need not be quoted if they are legal as unquoted identifiers. Quotes are necessary to specify a `user_name` string containing special characters (such as space or `-`), or a `host_name` string containing special characters or wildcard characters (such as `.`, `.` or `%`). For example, in the account name `'test-user'@'%.com'`, both the user name and host name parts require quotes.
- Quote user names and host names as identifiers or as strings, using either backticks (`), single quotation marks ('), or double quotation marks (`"`). For string-quoting and identifier-quoting guidelines, see Section 9.1.1, “String Literals”, and Section 9.2, “Schema Object Names”.
- The user name and host name parts, if quoted, must be quoted separately. That is, write `'me'@'localhost'`, not `'me@localhost'`. The latter is actually equivalent to `'me@localhost'@'%'`.
- A reference to the `CURRENT_USER` or `CURRENT_USER()` function is equivalent to specifying the current client's user name and host name literally.

MySQL stores account names in grant tables in the `mysql` system database using separate columns for the user name and host name parts:

- The `user` table contains one row for each account. The User and Host columns store the user name and host name. This table also indicates which global privileges the account has.
- Other grant tables indicate privileges an account has for databases and objects within databases. These tables have User and Host columns to store the account name. Each row in these tables associates with the account in the `user` table that has the same User and Host values.
- For access-checking purposes, comparisons of User values are case-sensitive. Comparisons of Host values are not case-sensitive.

For additional detail about the properties of user names and host names as stored in the grant tables, such as maximum length, see Grant Table Scope Column Properties.

User names and host names have certain special values or wildcard conventions, as described following.

The user name part of an account name is either a nonblank value that literally matches the user name for incoming connection attempts, or a blank value (empty string) that matches any user name. An account with a blank user name is an anonymous user. To specify an anonymous user in SQL statements, use a quoted empty user name part, such as `'@'localhost'`.

The host name part of an account name can take many forms, and wildcards are permitted:

- A host value can be a host name or an IP address (IPv4 or IPv6). The name `'localhost'` indicates the local host. The IP address `'127.0.0.1'` indicates the IPv4 loopback interface. The IP address `'::1'` indicates the IPv6 loopback interface.
• The % and _ wildcard characters are permitted in host name or IP address values. These have the same meaning as for pattern-matching operations performed with the LIKE operator. For example, a host value of '%' matches any host name, whereas a value of '%.mysql.com' matches any host in the mysql.com domain. '198.51.100.%' matches any host in the 198.51.100 class C network.

Because IP wildcard values are permitted in host values (for example, '198.51.100.%' to match every host on a subnet), someone could try to exploit this capability by naming a host 198.51.100.somewhere.com. To foil such attempts, MySQL does not perform matching on host names that start with digits and a dot. For example, if a host is named 1.2.example.com, its name never matches the host part of account names. An IP wildcard value can match only IP addresses, not host names.

• For a host value specified as an IPv4 address, a netmask can be given to indicate how many address bits to use for the network number. Netmask notation cannot be used for IPv6 addresses. The syntax is host_ip/netmask. For example:

  CREATE USER 'david'@'198.51.100.0/255.255.255.0';

This enables david to connect from any client host having an IP address client_ip for which the following condition is true:

  client_ip & netmask = host_ip

That is, for the CREATE USER statement just shown:

  client_ip & 255.255.255.0 = 198.51.100.0

IP addresses that satisfy this condition range from 198.51.100.0 to 198.51.100.255.

A netmask typically begins with bits set to 1, followed by bits set to 0. Examples:

• 198.0.0.0/255.0.0.0: Any host on the 198 class A network
• 198.51.100.0/255.255.0.0: Any host on the 198.51 class B network
• 198.51.100.0/255.255.255.0: Any host on the 198.51.100 class C network
• 198.51.100.1: Only the host with this specific IP address

The server performs matching of host values in account names against the client host using the value returned by the system DNS resolver for the client host name or IP address. Except in the case that the account host value is specified using netmask notation, the server performs this comparison as a string match, even for an account host value given as an IP address. This means that you should specify account host values in the same format used by DNS. Here are examples of problems to watch out for:

• Suppose that a host on the local network has a fully qualified name of host1.example.com. If DNS returns name lookups for this host as host1.example.com, use that name in account host values. If DNS returns just host1, use host1 instead.

• If DNS returns the IP address for a given host as 198.51.100.2, that will match an account host value of 198.51.100.2 but not 198.051.100.2. Similarly, it will match an account host pattern like 198.51.100.% but not 198.051.100.%.

To avoid problems like these, it is advisable to check the format in which your DNS returns host names and addresses. Use values in the same format in MySQL account names.

6.2.5 Access Control, Stage 1: Connection Verification
Access Control, Stage 1: Connection Verification

When you attempt to connect to a MySQL server, the server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password. If not, the server denies access to you completely. Otherwise, the server accepts the connection, and then enters Stage 2 and waits for requests.

Credential checking is performed using the three user table scope columns (Host, User, and Password). The server accepts the connection only if the Host and User columns in some user table row match the client host name and user name and the client supplies the password specified in that row. The rules for permissible Host and User values are given in Section 6.2.4, “Specifying Account Names”.

Your identity is based on two pieces of information:

- The client host from which you connect
- Your MySQL user name

If the User column value is nonblank, the user name in an incoming connection must match exactly. If the User value is blank, it matches any user name. If the user table row that matches an incoming connection has a blank user name, the user is considered to be an anonymous user with no name, not a user with the name that the client actually specified. This means that a blank user name is used for all further access checking for the duration of the connection (that is, during Stage 2).

The Password column can be blank. This is not a wildcard and does not mean that any password matches. It means that the user must connect without specifying a password. If the server authenticates a client using a plugin, the authentication method that the plugin implements may or may not use the password in the Password column. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

Nonblank Password values in the user table represent encrypted passwords. MySQL does not store passwords as cleartext for anyone to see. Rather, the password supplied by a user who is attempting to connect is encrypted (using the PASSWORD() function). The encrypted password then is used during the connection process when checking whether the password is correct. This is done without the encrypted password ever traveling over the connection. See Section 6.2.1, “Account User Names and Passwords”.

From MySQL’s point of view, the encrypted password is the real password, so you should never give anyone access to it. In particular, do not give nonadministrative users read access to tables in the mysql system database.

The following table shows how various combinations of User and Host values in the user table apply to incoming connections.

<table>
<thead>
<tr>
<th>User Value</th>
<th>Host Value</th>
<th>Permissible Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>'fred'</td>
<td>'h1.example.net'</td>
<td>fred, connecting from h1.example.net</td>
</tr>
<tr>
<td>''</td>
<td>'h1.example.net'</td>
<td>Any user, connecting from h1.example.net</td>
</tr>
<tr>
<td>'fred'</td>
<td>'%'</td>
<td>fred, connecting from any host</td>
</tr>
<tr>
<td>''</td>
<td>'%'</td>
<td>Any user, connecting from any host</td>
</tr>
<tr>
<td>'fred'</td>
<td>'%.example.net'</td>
<td>fred, connecting from any host in the example.net domain</td>
</tr>
<tr>
<td>'fred'</td>
<td>'x.example.%'</td>
<td>fred, connecting from x.example.net, x.example.com, x.example.edu, and so on; this is probably not useful</td>
</tr>
</tbody>
</table>
Access Control, Stage 1: Connection Verification

<table>
<thead>
<tr>
<th>User Value</th>
<th>Host Value</th>
<th>Permissible Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>'fred'</td>
<td>'198.51.100.177'</td>
<td>fred, connecting from the host with IP address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>198.51.100.177</td>
</tr>
<tr>
<td>'fred'</td>
<td>'198.51.100.%'</td>
<td>fred, connecting from any host in the 198.51.100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>class C subnet</td>
</tr>
<tr>
<td>'fred'</td>
<td>'198.51.100.0/255.255.255.0'</td>
<td>Same as previous example</td>
</tr>
</tbody>
</table>

It is possible for the client host name and user name of an incoming connection to match more than one row in the `user` table. The preceding set of examples demonstrates this: Several of the entries shown match a connection from h1.example.net by fred.

When multiple matches are possible, the server must determine which of them to use. It resolves this issue as follows:

- Whenever the server reads the `user` table into memory, it sorts the rows.
- When a client attempts to connect, the server looks through the rows in sorted order.
- The server uses the first row that matches the client host name and user name.

The server uses sorting rules that order rows with the most-specific Host values first. Literal host names and IP addresses are the most specific. (The specificity of a literal IP address is not affected by whether it has a netmask, so 198.51.100.13 and 198.51.100.0/255.255.255.0 are considered equally specific.) The pattern '\%' means “any host” and is least specific. The empty string '' also means “any host” but sorts after '\%'. Rows with the same Host value are ordered with the most-specific User values first (a blank User value means “any user” and is least specific). For rows with equally-specific Host and User values, the order is nondeterministic.

To see how this works, suppose that the `user` table looks like this:

```
+-----------+----------+---
| Host      | User     | ...
+-----------+----------+---
| %         | root     | ...
| %         | jeffrey  | ...
| localhost | root     | ...
| localhost |          | ...
+-----------+----------+---
```

When the server reads the table into memory, it sorts the rows using the rules just described. The result after sorting looks like this:

```
+-----------+----------+---
| Host      | User     | ...
+-----------+----------+---
| localhost | root     | ...
| localhost |          | ...
| %         | jeffrey  | ...
| %         | root     | ...
+-----------+----------+---
```

When a client attempts to connect, the server looks through the sorted rows and uses the first match found. For a connection from localhost by jeffrey, two of the rows from the table match: the one with Host and User values of 'localhost' and '', and the one with values of '\%' and 'jeffrey'. The 'localhost' row appears first in sorted order, so that is the one the server uses.

Here is another example. Suppose that the `user` table looks like this:

```
+-----------+----------+---
| Host      | User     | ...
+-----------+----------+---
| %         | root     | ...
| %         | jeffrey  | ...
+-----------+----------+---
```

768
Access Control, Stage 2: Request Verification

<table>
<thead>
<tr>
<th>Host</th>
<th>User</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>jeffrey</td>
</tr>
<tr>
<td>h1.example.net</td>
<td></td>
</tr>
</tbody>
</table>

The sorted table looks like this:

<table>
<thead>
<tr>
<th>Host</th>
<th>User</th>
</tr>
</thead>
<tbody>
<tr>
<td>h1.example.net</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>jeffrey</td>
</tr>
</tbody>
</table>

A connection by jeffrey from h1.example.net is matched by the first row, whereas a connection by jeffrey from any host is matched by the second.

Note

It is a common misconception to think that, for a given user name, all rows that explicitly name that user are used first when the server attempts to find a match for the connection. This is not true. The preceding example illustrates this, where a connection from h1.example.net by jeffrey is first matched not by the row containing 'jeffrey' as the User column value, but by the row with no user name. As a result, jeffrey is authenticated as an anonymous user, even though he specified a user name when connecting.

If you are able to connect to the server, but your privileges are not what you expect, you probably are being authenticated as some other account. To find out what account the server used to authenticate you, use the CURRENT_USER() function. (See Section 12.15, "Information Functions"). It returns a value in user_name@host_name format that indicates the User and Host values from the matching user table row. Suppose that jeffrey connects and issues the following query:

```sql
mysql> SELECT CURRENT_USER();
```

The result shown here indicates that the matching user table row had a blank User column value. In other words, the server is treating jeffrey as an anonymous user.

Another way to diagnose authentication problems is to print out the user table and sort it by hand to see where the first match is being made.

6.2.6 Access Control, Stage 2: Request Verification

After you establish a connection, the server enters Stage 2 of access control. For each request that you issue through that connection, the server determines what operation you want to perform, then checks whether you have sufficient privileges to do so. This is where the privilege columns in the grant tables come into play. These privileges can come from any of the user, db, host, tables_priv, columns_priv, or procs_priv tables. (You may find it helpful to refer to Section 6.2.3, “Grant Tables”, which lists the columns present in each grant table.)

The user table grants global privileges. The user table row for an account indicates the account privileges that apply on a global basis no matter what the default database is. For example, if the user
table grants you the DELETE privilege, you can delete rows from any table in any database on the server host. It is wise to grant privileges in the user table only to people who need them, such as database administrators. For other users, leave all privileges in the user table set to 'N' and grant privileges at more specific levels only (for particular databases, tables, columns, or routines).

The db and host tables grant database-specific privileges. Values in the scope columns of these tables can take the following forms:

- A blank User value in the db table matches the anonymous user. A nonblank value matches literally; there are no wildcards in user names.

- The wildcard characters % and _ can be used in the Host and Db columns of either table. These have the same meaning as for pattern-matching operations performed with the LIKE operator. If you want to use either character literally when granting privileges, you must escape it with a backslash. For example, to include the underscore character (_) as part of a database name, specify it as \_ in the GRANT statement.

- A '%%' Host value in the db table means “any host.” A blank Host value in the db table means “consult the host table for further information” (a process that is described later in this section).

- A '%' or blank Host value in the host table means “any host.”

- A '%' or blank Db value in either table means “any database.”

The server reads the db and host tables into memory and sorts them at the same time that it reads the user table. The server sorts the db table based on the Host, Db, and User scope columns, and sorts the host table based on the Host and Db scope columns. As with the user table, sorting puts the most-specific values first and least-specific values last, and when the server looks for matching rows, it uses the first match that it finds.

The tables_priv, columns_priv, and procs_priv tables grant table-specific, column-specific, and routine-specific privileges. Values in the scope columns of these tables can take the following forms:

- The wildcard characters % and _ can be used in the Host column. These have the same meaning as for pattern-matching operations performed with the LIKE operator.

- A '%' or blank Host value means “any host.”

- The Db, Table_name, Column_name, and Routine_name columns cannot contain wildcards or be blank.

The server sorts the tables_priv, columns_priv, and procs_priv tables based on the Host, Db, and User columns. This is similar to db table sorting, but simpler because only the Host column can contain wildcards.

The server uses the sorted tables to verify each request that it receives. For requests that require administrative privileges such as SHUTDOWN or RELOAD, the server checks only the user table row because that is the only table that specifies administrative privileges. The server grants access if the row permits the requested operation and denies access otherwise. For example, if you want to execute mysqladmin shutdown but your user table row does not grant the SHUTDOWN privilege to you, the server denies access without even checking the db or host tables. (The latter tables contain no Shutdown_priv column, so there is no need to check them.)

For database-related requests (INSERT, UPDATE, and so on), the server first checks the user's global privileges in the user table row. If the row permits the requested operation, access is granted. If the global
privileges in the user table are insufficient, the server determines the user’s database-specific privileges from the db and host tables:

1. The server looks in the db table for a match on the Host, Db, and User columns. The Host and User columns are matched to the connecting user’s host name and MySQL user name. The Db column is matched to the database that the user wants to access. If there is no row for the Host and User, access is denied.

2. If there is a matching db table row and its Host column is not blank, that row defines the user’s database-specific privileges.

3. If the matching db table row's Host column is blank, it signifies that the host table enumerates which hosts should be permitted access to the database. In this case, a further lookup is done in the host table to find a match on the Host and Db columns. If no host table row matches, access is denied. If there is a match, the user’s database-specific privileges are computed as the intersection (not the union!) of the privileges in the db and host table rows; that is, the privileges that are 'Y' in both rows. (This way you can grant general privileges in the db table row and then selectively restrict them on a host-by-host basis using the host table rows.)

After determining the database-specific privileges granted by the db and host table rows, the server adds them to the global privileges granted by the user table. If the result permits the requested operation, access is granted. Otherwise, the server successively checks the user’s table and column privileges in the tables_priv and columns_priv tables, adds those to the user’s privileges, and permits or denies access based on the result. For stored-routine operations, the server uses the procs_priv table rather than tables_priv and columns_priv.

Expressed in boolean terms, the preceding description of how a user’s privileges are calculated may be summarized like this:

<table>
<thead>
<tr>
<th>global privileges</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR (database privileges AND host privileges)</td>
</tr>
<tr>
<td>OR table privileges</td>
</tr>
<tr>
<td>OR column privileges</td>
</tr>
<tr>
<td>OR routine privileges</td>
</tr>
</tbody>
</table>

It may not be apparent why, if the global privileges are initially found to be insufficient for the requested operation, the server adds those privileges to the database, table, and column privileges later. The reason is that a request might require more than one type of privilege. For example, if you execute an INSERT INTO ... SELECT statement, you need both the INSERT and the SELECT privileges. Your privileges might be such that the user table row grants one privilege global and the db table row grants the other specifically for the relevant database. In this case, you have the necessary privileges to perform the request, but the server cannot tell that from either your global or database privileges alone. It must make an access-control decision based on the combined privileges.

The host table is not affected by the GRANT or REVOKE statements, so it is unused in most MySQL installations. If you modify it directly, you can use it for some specialized purposes, such as to maintain a list of secure servers on the local network that are granted all privileges.

You can also use the host table to indicate hosts that are not secure. Suppose that you have a machine public.example.org that is located in a public area that you do not consider secure. You can enable access to all hosts on your network except that machine by using host table rows like this:

    +-------------------+----+--|
    | Host              | Db | ...|
    +-------------------+----+--|
    | public.example.org| %  | ... (all privileges set to 'N')|
    | %.example.org      | %  | ... (all privileges set to 'Y')|
    +-------------------+----+--
Adding Accounts, Assigning Privileges, and Dropping Accounts

6.2.7 Adding Accounts, Assigning Privileges, and Dropping Accounts

To manage MySQL accounts, use the SQL statements intended for that purpose:

- \texttt{CREATE USER} and \texttt{DROP USER} create and remove accounts.
- \texttt{GRANT} and \texttt{REVOKE} assign privileges to and revoke privileges from accounts.
- \texttt{SHOW GRANTS} displays account privilege assignments.

Account-management statements cause the server to make appropriate modifications to the underlying grant tables, which are discussed in Section 6.2.3, “Grant Tables”.

\section*{Note}

Direct modification of grant tables using statements such as \texttt{INSERT}, \texttt{UPDATE}, or \texttt{DELETE} is discouraged and done at your own risk. The server is free to ignore rows that become malformed as a result of such modifications.

As of MySQL 5.5.55, for any operation that modifies a grant table, the server checks whether the table has the expected structure and produces an error if not. \texttt{mysql_upgrade} must be run to update the tables to the expected structure.

Another option for creating accounts is to use the GUI tool MySQL Workbench. Also, several third-party programs offer capabilities for MySQL account administration. \texttt{phpMyAdmin} is one such program.

This section discusses the following topics:

- Creating Accounts and Granting Privileges
- Checking Account Privileges
- Revoking Account Privileges
- Dropping Accounts

For additional information about the statements discussed here, see Section 13.7.1, “Account Management Statements”.

\section*{Creating Accounts and Granting Privileges}

The following examples show how to use the \texttt{mysql} client program to set up new accounts. These examples assume that the MySQL root account has the \texttt{CREATE USER} privilege and all privileges that it grants to other accounts.

At the command line, connect to the server as the MySQL root user, supplying the appropriate password at the password prompt:

```
shell> mysql -u root -p
Enter password: (enter root password here)
```

After connecting to the server, you can add new accounts. The following example uses \texttt{CREATE USER} and \texttt{GRANT} statements to set up four accounts (where you see \texttt{password}, substitute an appropriate password):

```
CREATE USER 'finley'@'localhost'
    IDENTIFIED BY 'password';
GRANT ALL ON *.*
```
Adding Accounts, Assigning Privileges, and Dropping Accounts

```sql
TO 'finley'@'localhost'
    WITH GRANT OPTION;
CREATE USER 'finley'@'%.example.com'
    IDENTIFIED BY 'password';
GRANT ALL
    ON '*. *
    TO 'finley'@'%.example.com'
    WITH GRANT OPTION;
CREATE USER 'admin'@'localhost'
    IDENTIFIED BY 'password';
GRANT RELOAD,PROCESS
    ON '*. *
    TO 'admin'@'localhost';
CREATE USER 'dummy'@'localhost';
```

The accounts created by those statements have the following properties:

- Two accounts have a user name of `finley`. Both are superuser accounts with full global privileges to do anything. The `'finley'@'localhost'` account can be used only when connecting from the local host. The `'finley'@'%.example.com'` account uses the ` '%' wildcard in the host part, so it can be used to connect from any host in the `example.com` domain.

  The `'finley'@'localhost'` account is necessary if there is an anonymous-user account for `localhost`. Without the `'finley'@'localhost'` account, that anonymous-user account takes precedence when `finley` connects from the local host and `finley` is treated as an anonymous user. The reason for this is that the anonymous-user account has a more specific `Host` column value than the `'finley'@'%'` account and thus comes earlier in the `user` table sort order. (For information about `user` table sorting, see `Section 6.2.5, “Access Control, Stage 1: Connection Verification”`.)

- The `'admin'@'localhost'` account can be used only by `admin` to connect from the local host. It is granted the global `RELOAD` and `PROCESS` administrative privileges. These privileges enable the `admin` user to execute the `mysqladmin reload`, `mysqladmin refresh`, and `mysqladmin flush-xxx` commands, as well as `mysqladmin processlist`. No privileges are granted for accessing any databases. You could add such privileges using `GRANT` statements.

- The `'dummy'@'localhost'` account has no password (which is insecure and not recommended). This account can be used only to connect from the local host. No privileges are granted. It is assumed that you will grant specific privileges to the account using `GRANT` statements.

The previous example grants privileges at the global level. The next example creates three accounts and grants them access at lower levels; that is, to specific databases or objects within databases. Each account has a user name of `custom`, but the host name parts differ:

```sql
CREATE USER 'custom'@'localhost'
    IDENTIFIED BY 'password';
GRANT ALL
    ON bankaccount.*
    TO 'custom'@'localhost';
CREATE USER 'custom'@'host47.example.com'
    IDENTIFIED BY 'password';
GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ON expenses.*
    TO 'custom'@'host47.example.com';
CREATE USER 'custom'@'%.example.com'
    IDENTIFIED BY 'password';
GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ON customer.addresses
```
Adding Accounts, Assigning Privileges, and Dropping Accounts

TO 'custom'@'%.example.com';

The three accounts can be used as follows:

- The 'custom'@'localhost' account has all database-level privileges to access the bankaccount database. The account can be used to connect to the server only from the local host.

- The 'custom'@'host47.example.com' account has specific database-level privileges to access the expenses database. The account can be used to connect to the server only from the host host47.example.com.

- The 'custom'@'%.example.com' account has specific table-level privileges to access the addresses table in the customer database, from any host in the example.com domain. The account can be used to connect to the server from all machines in the domain due to use of the % wildcard character in the host part of the account name.

Checking Account Privileges

To see the privileges for an account, use `SHOW GRANTS`:

```
mysql> SHOW GRANTS FOR 'admin'@'localhost';
+-----------------------------------------------------+
| Grants for admin@localhost                          |
| GRANT RELOAD, PROCESS ON *.* TO 'admin'@'localhost' |
+-----------------------------------------------------+
```

Revoking Account Privileges

To revoke account privileges, use the `REVOKE` statement. Privileges can be revoked at different levels, just as they can be granted at different levels.

Revoke global privileges:

```
REVOKE ALL
ON *.*
FROM 'finley'@'%.example.com';
REVOKE RELOAD
ON *.*
FROM 'admin'@'localhost';
```

Revoke database-level privileges:

```
REVOKE CREATE,DROP
ON expenses.*
FROM 'custom'@'host47.example.com';
```

Revoke table-level privileges:

```
REVOKE INSERT,UPDATE,DELETE
ON customer.addresses
FROM 'custom'@'%.example.com';
```

To check the effect of privilege revocation, use `SHOW GRANTS`:

```
mysql> SHOW GRANTS FOR 'admin'@'localhost';
+---------------------------------------------+
| Grants for admin@localhost                  |
| GRANT PROCESS ON *.* TO 'admin'@'localhost' |
+---------------------------------------------+
```
Dropping Accounts

To remove an account, use the `DROP USER` statement. For example, to drop some of the accounts created previously:

```sql
DROP USER 'finley'@'localhost';
DROP USER 'finley'@'%.example.com';
DROP USER 'admin'@'localhost';
DROP USER 'dummy'@'localhost';
```

---

6.2.8 When Privilege Changes Take Effect

If the `mysqld` server is started without the `--skip-grant-tables` option, it reads all grant table contents into memory during its startup sequence. The in-memory tables become effective for access control at that point.

If you modify the grant tables indirectly using an account-management statement, the server notices these changes and loads the grant tables into memory again immediately. Account-management statements are described in Section 13.7.1, "Account Management Statements". Examples include `GRANT`, `REVOKE`, `SET PASSWORD`, and `RENAME USER`.

If you modify the grant tables directly using statements such as `INSERT`, `UPDATE`, or `DELETE` (which is not recommended), the changes have no effect on privilege checking until you either tell the server to reload the tables or restart it. Thus, if you change the grant tables directly but forget to reload them, the changes have *no effect* until you restart the server. This may leave you wondering why your changes seem to make no difference!

To tell the server to reload the grant tables, perform a flush-privileges operation. This can be done by issuing a `FLUSH PRIVILEGES` statement or by executing a `mysqladmin flush-privileges` or `mysqladmin reload` command.

A grant table reload affects privileges for each existing client session as follows:

- Table and column privilege changes take effect with the client's next request.
- Database privilege changes take effect the next time the client executes a `USE db_name` statement.

**Note**

Client applications may cache the database name; thus, this effect may not be visible to them without actually changing to a different database.

- Global privileges and passwords are unaffected for a connected client. These changes take effect only in sessions for subsequent connections.

If the server is started with the `--skip-grant-tables` option, it does not read the grant tables or implement any access control. Any user can connect and perform any operation, which is insecure. To cause a server thus started to read the tables and enable access checking, flush the privileges.

6.2.9 Assigning Account Passwords

Required credentials for clients that connect to the MySQL server can include a password. This section describes how to assign passwords for MySQL accounts.

MySQL stores credentials in the `user` table in the `mysql` system database. Operations that assign or modify passwords are permitted only to users with the `CREATE USER` privilege, or, alternatively, privileges

---

775
Assigning Account Passwords

for the mysql database (INSERT privilege to create new accounts, UPDATE privilege to modify existing accounts). If the read_only system variable is enabled, use of account-modification statements such as CREATE USER or SET PASSWORD additionally requires the SUPER privilege.

The discussion here summarizes syntax only for the most common password-assignment statements. For complete details on other possibilities, see Section 13.7.1.1, “CREATE USER Statement”, Section 13.7.1.3, “GRANT Statement”, and Section 13.7.1.6, “SET PASSWORD Statement”.

MySQL uses plugins to perform client authentication; see Section 6.2.10, “Pluggable Authentication”. In password-assigning statements, the authentication plugin associated with an account performs any hashing required of a cleartext password specified. This enables MySQL to obfuscate passwords prior to storing them in the mysql.user system table. For most statements described here, MySQL automatically hashes the password specified. An exception is SET PASSWORD ... = PASSWORD('auth_string'), for which you use the PASSWORD() function explicitly to hash the password. There is also syntax for CREATE USER, GRANT, and SET PASSWORD that permits hashed values to be specified literally. For details, see the descriptions of those statements.

To assign a password when you create a new account, use CREATE USER and include an IDENTIFIED BY clause:

```sql
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

CREATE USER also supports syntax for specifying the account authentication plugin. See Section 13.7.1.1, “CREATE USER Statement”.

To assign or change a password for an existing account, use SET PASSWORD with the PASSWORD() function:

```sql
SET PASSWORD FOR 'jeffrey'@'localhost' = PASSWORD('password');
```

If you are not connected as an anonymous user, you can change your own password by omitting the FOR clause:

```sql
SET PASSWORD = PASSWORD('password');
```

The PASSWORD() function hashes the password using the hashing method determined by the value of the old_passwords system variable value. If SET PASSWORD rejects the hashed password value returned by PASSWORD() as not being in the correct format, it may be necessary to change old_passwords to change the hashing method. See Section 13.7.1.6, “SET PASSWORD Statement”.

Use a GRANT USAGE statement at the global level (ON *.* to change an account password without affecting the account’s current privileges:

```sql
GRANT USAGE ON *.* TO 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

To change an account password from the command line, use the mysqladmin command:

```sql
mysqladmin -u user_name -h host_name password "password"
```

The account for which this command sets the password is the one with a row in the mysql.user system table that matches user_name in the User column and the client host from which you connect in the Host column.

**Warning**

Setting a password using mysqladmin should be considered insecure. On some systems, your password becomes visible to system status programs such as ps
that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If you are using MySQL Replication, be aware that, currently, a password used by a replication slave as part of a `CHANGE MASTER TO` statement is effectively limited to 32 characters in length; if the password is longer, any excess characters are truncated. This is not due to any limit imposed by the MySQL Server generally, but rather is an issue specific to MySQL Replication. (For more information, see Bug #43439.)

### 6.2.10 Pluggable Authentication

When a client connects to the MySQL server, the server uses the user name provided by the client and the client host to select the appropriate account row from the `mysql.user` system table. The server then authenticates the client, determining from the account row which authentication plugin applies to the client:

- If the server cannot find the plugin, an error occurs and the connection attempt is rejected. Otherwise, if the account row specifies a plugin, the server invokes it to authenticate the user.

- If the account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

The plugin returns a status to the server indicating whether the user provided the correct password and is permitted to connect.

Pluggable authentication enables these important capabilities:

- **Choice of authentication methods.** Pluggable authentication makes it easy for DBAs to choose and change the authentication method used for individual MySQL accounts.

- **External authentication.** Pluggable authentication makes it possible for clients to connect to the MySQL server with credentials appropriate for authentication methods that store credentials elsewhere than in the `mysql.user` system table. For example, plugins can be created to use external authentication methods such as PAM, Windows login IDs, LDAP, or Kerberos.

- **Proxy users:** If a user is permitted to connect, an authentication plugin can return to the server a user name different from the name of the connecting user, to indicate that the connecting user is a proxy for another user (the proxied user). While the connection lasts, the proxy user is treated, for purposes of access control, as having the privileges of the proxied user. In effect, one user impersonates another. For more information, see Section 6.2.11, “Proxy Users”.

Note

If you start the server with the `--skip-grant-tables` option, authentication plugins are not used even if loaded because the server performs no client authentication and permits any client to connect. Because this is insecure, you might want to use `--skip-grant-tables` in conjunction with enabling the `skip_networking` system variable to prevent remote clients from connecting.
Available Authentication Plugins

MySQL 5.5 provides these authentication plugins:

- Plugins that perform native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication in MySQL. The mysql_native_password plugin implements authentication based on the native password hashing method. The mysql_old_password plugin implements native authentication based on the older (pre-4.1) password hashing method. See Section 6.4.1.1, "Native Pluggable Authentication", and Section 6.4.1.2, "Old Native Pluggable Authentication". Native authentication using mysql_native_password is the default for accounts that have no plugin named explicitly in their account row.

- A client-side plugin that sends the password to the server without hashing or encryption. This plugin is used in conjunction with server-side plugins that require access to the password exactly as provided by the client user. See Section 6.4.1.3, "Client-Side Cleartext Pluggable Authentication".

- A plugin that performs external authentication using PAM (Pluggable Authentication Modules), enabling MySQL Server to use PAM to authenticate MySQL users. This plugin supports proxy users as well. See Section 6.4.1.4, "PAM Pluggable Authentication".

- A plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password. This plugin supports proxy users as well. See Section 6.4.1.5, "Windows Pluggable Authentication".

- A plugin that authenticates clients that connect from the local host through the Unix socket file. See Section 6.4.1.6, "Socket Peer-Credential Pluggable Authentication".

- A test plugin that checks account credentials and logs success or failure to the server error log. This plugin is intended for testing and development purposes, and as an example of how to write an authentication plugin. See Section 6.4.1.7, "Test Pluggable Authentication".

Note

For information about current restrictions on the use of pluggable authentication, including which connectors support which plugins, see Restrictions on Pluggable Authentication.

Third-party connector developers should read that section to determine the extent to which a connector can take advantage of pluggable authentication capabilities and what steps to take to become more compliant.

If you are interested in writing your own authentication plugins, see Section 24.2.4.9, "Writing Authentication Plugins".

Authentication Plugin Usage

This section provides general instructions for installing and using authentication plugins. For instructions specific to a given plugin, see the section that describes that plugin under Section 6.4.1, "Authentication Plugins".

In general, pluggable authentication uses a pair of corresponding plugins on the server and client sides, so you use a given authentication method like this:
Pluggable Authentication

- If necessary, install the plugin library or libraries containing the appropriate plugins. On the server host, install the library containing the server-side plugin, so that the server can use it to authenticate client connections. Similarly, on each client host, install the library containing the client-side plugin for use by client programs. Authentication plugins that are built in need not be installed.

- For each MySQL account that you create, specify the appropriate server-side plugin to use for authentication. If the account is to use the default authentication plugin (`mysql_native_password`), the account-creation statement need not specify the plugin explicitly.

- When a client connects, the server-side plugin tells the client program which client-side plugin to use for authentication.

In the case that an account uses an authentication method that is the default for both the server and the client program, the server need not communicate to the client which client-side plugin to use, and a round trip in client/server negotiation can be avoided. This is true for accounts that use native MySQL authentication.

For standard MySQL clients such as `mysql` and `mysqladmin`, the `--default-auth=plugin_name` option can be specified on the command line as a hint about which client-side plugin the program can expect to use, although the server will override this if the server-side plugin associated with the user account requires a different client-side plugin.

If the client program does not find the client-side plugin library file, specify a `--plugin-dir=dir_name` option to indicate the plugin library directory location.

Restrictions on Pluggable Authentication

The first part of this section describes general restrictions on the applicability of the pluggable authentication framework described at Section 6.2.10, “Pluggable Authentication”. The second part describes how third-party connector developers can determine the extent to which a connector can take advantage of pluggable authentication capabilities and what steps to take to become more compliant.

The term “native authentication” used here refers to authentication against passwords stored in the `Password` column of the `mysql.user` system table. This is the same authentication method provided by MySQL servers older than 5.5.7, before pluggable authentication was implemented. “Windows native authentication” refers to authentication using the credentials of a user who has already logged in to Windows, as implemented by the Windows Native Authentication plugin (“Windows plugin” for short).

- **General Pluggable Authentication Restrictions**

- **Pluggable Authentication and Third-Party Connectors**

General Pluggable Authentication Restrictions

- **Connector/C++**: Clients that use this connector can connect to the server only through accounts that use native authentication.

  Exception: A connector supports pluggable authentication if it was built to link to `libmysqlclient` dynamically (rather than statically) and it loads the current version of `libmysqlclient` if that version is installed, or if the connector is recompiled from source to link against the current `libmysqlclient`.

- **Connector/NET**: Clients that use Connector/NET can connect to the server through accounts that use native authentication or Windows native authentication.

- **Connector/PHP**: Clients that use this connector can connect to the server only through accounts that use native authentication, when compiled using the MySQL native driver for PHP (`mysqlnd`).

779
Pluggable Authentication

- **Windows native authentication**: Connecting through an account that uses the Windows plugin requires Windows Domain setup. Without it, NTLM authentication is used and then only local connections are possible; that is, the client and server must run on the same computer.

- **Proxy users**: Proxy user support is available to the extent that clients can connect through accounts authenticated with plugins that implement proxy user capability (that is, plugins that can return a user name different from that of the connecting user). For example, the PAM and Windows plugins support proxy users. The native authentication plugins do not.

- **Replication**: Before MySQL 5.5.17, replication slaves can connect to the master server only through master accounts that use native authentication. As of 5.5.17 (or 5.5.19 for Windows native authentication), replication slaves can also connect through master accounts that use nonnative authentication if the required client-side plugin is available. If the plugin is built into `libmysqlclient`, it is available by default. Otherwise, the plugin must be installed on the slave side in the directory named by the slave `plugin_dir` system variable.

- **FEDERATED tables**: A FEDERATED table can access the remote table only through accounts on the remote server that use native authentication.

### Pluggable Authentication and Third-Party Connectors

Third-party connector developers can use the following guidelines to determine readiness of a connector to take advantage of pluggable authentication capabilities and what steps to take to become more compliant:

- An existing connector to which no changes have been made uses native authentication and clients that use the connector can connect to the server only through accounts that use native authentication. However, you should test the connector against a recent version of the server to verify that such connections still work without problem.

  Exception: A connector might work with pluggable authentication without any changes if it links to `libmysqlclient` dynamically (rather than statically) and it loads the current version of `libmysqlclient` if that version is installed.

- To take advantage of pluggable authentication capabilities, a connector that is `libmysqlclient`-based should be relinked against the current version of `libmysqlclient`. This enables the connector to support connections though accounts that require client-side plugins now built into `libmysqlclient` (such as the cleartext plugin needed for PAM authentication and the Windows plugin needed for Windows native authentication). Linking with a current `libmysqlclient` also enables the connector to access client-side plugins installed in the default MySQL plugin directory (typically the directory named by the default value of the local server's `plugin_dir` system variable).

  If a connector links to `libmysqlclient` dynamically, it must be ensured that the newer version of `libmysqlclient` is installed on the client host and that the connector loads it at runtime.

- Another way for a connector to support a given authentication method is to implement it directly in the client/server protocol. Connector/NET uses this approach to provide support for Windows native authentication.

- If a connector should be able to load client-side plugins from a directory different from the default plugin directory, it must implement some means for client users to specify the directory. Possibilities for this include a command-line option or environment variable from which the connector can obtain the directory name. Standard MySQL client programs such as `mysql` and `mysqladmin` implement a `--plugin-dir` option. See also Section 23.7.13, “C API Client Plugin Functions”.

- Proxy user support by a connector depends, as described earlier in this section, on whether the authentication methods that it supports permit proxy users.
6.2.11 Proxy Users

The MySQL server authenticates client connections using authentication plugins. The plugin that authenticates a given connection may request that the connecting (external) user be treated as a different user for privilege-checking purposes. This enables the external user to be a proxy for the second user; that is, to assume the privileges of the second user:

• The external user is a “proxy user” (a user who can impersonate or become known as another user).
• The second user is a “proxied user” (a user whose identity and privileges can be assumed by a proxy user).

This section describes how the proxy user capability works. For general information about authentication plugins, see Section 6.2.10, “Pluggable Authentication”. For information about specific plugins, see Section 6.4.1, “Authentication Plugins”. For information about writing authentication plugins that support proxy users, see Implementing Proxy User Support in Authentication Plugins.

• Requirements for Proxy User Support

Requirements for Proxy User Support

For proxying to occur for a given authentication plugin, these conditions must be satisfied:

• The plugin must support proxying.
• The account for the external proxy user must be set up to be authenticated by the plugin. Use the CREATE USER or GRANT statement to associate an account with an authentication plugin.
• The account for the proxied user must exist and be granted the privileges to be assumed by the proxy user. Use the CREATE USER and GRANT statements for this.
• Normally, the proxied user is configured so that it can be used only in proxying scenarios and not for direct logins.
• The proxy user account must have the PROXY privilege for the proxied account. Use the GRANT statement for this.
• For a client connecting to the proxy account to be treated as a proxy user, the authentication plugin must return a user name different from the client user name, to indicate the user name of the proxied account that defines the privileges to be assumed by the proxy user.

The proxy mechanism permits mapping only the external client user name to the proxied user name. There is no provision for mapping host names:

• When a client connects to the server, the server determines the proper account based on the user name passed by the client program and the host from which the client connects.
• If that account is a proxy account, the server attempts to determine the appropriate proxied account by finding a match for a proxied account using the user name returned by the authentication plugin and the host name of the proxy account. The host name in the proxied account is ignored.

**Simple Proxy User Example**

Consider the following account definitions:

```sql
-- create proxy account
CREATE USER 'employee_ext'@'localhost'
  IDENTIFIED WITH my_auth_plugin
  AS 'my_auth_string';

-- create proxied account and grant its privileges
CREATE USER 'employee'@'localhost'
  IDENTIFIED BY 'employee_password';
GRANT ALL
  ON employees.*
  TO 'employee'@'localhost';

-- grant to proxy account the PROXY privilege for proxied account
GRANT PROXY
  ON 'employee'@'localhost'
  TO 'employee_ext'@'localhost';
```

When a client connects as `employee_ext` from the local host, MySQL uses the plugin named `my_auth_plugin` to perform authentication. Suppose that `my_auth_plugin` returns a user name of `employee` to the server, based on the content of `'my_auth_string'` and perhaps by consulting some external authentication system. The name `employee` differs from `employee_ext`, so returning `employee` serves as a request to the server to treat the `employee_ext` external user, for purposes of privilege checking, as the `employee` local user.

In this case, `employee_ext` is the proxy user and `employee` is the proxied user.

The server verifies that proxy authentication for `employee` is possible for the `employee_ext` user by checking whether `employee_ext` (the proxy user) has the `PROXY` privilege for `employee` (the proxied user). If this privilege has not been granted, an error occurs. Otherwise, `employee_ext` assumes the privileges of `employee`. The server checks statements executed during the client session by `employee_ext` against the privileges granted to `employee`. In this case, `employee_ext` can access tables in the `employees` database.

To ensure that the proxied account, `employee`, cannot be used directly, do not tell anyone else its password. If you do not let anyone know the password for the account, clients cannot use it to connect directly to the MySQL server.

When proxying occurs, the `USER()` and `CURRENT_USER()` functions can be used to see the difference between the connecting user (the proxy user) and the account whose privileges apply during the current session (the proxied user). For the example just described, those functions return these values:

```sql
mysql> SELECT USER(), CURRENT_USER();
+------------------------+--------------------+
<table>
<thead>
<tr>
<th>USER()</th>
<th>CURRENT_USER()</th>
</tr>
</thead>
<tbody>
<tr>
<td>employee_ext@localhost</td>
<td>employee@localhost</td>
</tr>
</tbody>
</table>
+------------------------+--------------------+
```

In the `CREATE USER` statement that creates the proxy user account, the `IDENTIFIED WITH` clause that names the proxy-supporting authentication plugin is optionally followed by an `AS 'auth_string'` clause specifying a string that the server passes to the plugin when the user connects. If present, the string
Proxy Users

provides information that helps the plugin determine how to map the proxy (external) client user name to a proxied user name. It is up to each plugin whether it requires the AS clause. If so, the format of the authentication string depends on how the plugin intends to use it. Consult the documentation for a given plugin for information about the authentication string values it accepts.

Preventing Direct Login to Proxied Accounts

Proxied accounts generally are intended to be used only by means of proxy accounts. That is, clients connect using a proxy account, then are mapped onto and assume the privileges of the appropriate proxied user.

To ensure that a proxied account cannot be used directly, create the account with a password but do not tell anyone else the password. If you do not let anyone know the password for the account, clients cannot use it to connect directly to the MySQL server.

Granting and Revoking the PROXY Privilege

The PROXY privilege is needed to enable an external user to connect as and have the privileges of another user. To grant this privilege, use the GRANT statement. For example:

```
GRANT PROXY ON 'proxied_user' TO 'proxy_user';
```

The statement creates a row in the mysql.proxies_priv grant table.

At connect time, proxy_user must represent a valid externally authenticated MySQL user, and proxied_user must represent a valid locally authenticated user. Otherwise, the connection attempt fails.

The corresponding REVOKE syntax is:

```
REVOKE PROXY ON 'proxied_user' FROM 'proxy_user';
```

MySQL GRANT and REVOKE syntax extensions work as usual. Examples:

```
-- grant PROXY to multiple accounts
GRANT PROXY ON 'a' TO 'b', 'c', 'd';

-- revoke PROXY from multiple accounts
REVOKE PROXY ON 'a' FROM 'b', 'c', 'd';

-- grant PROXY to an account and enable the account to grant
-- PROXY to the proxied account
GRANT PROXY ON 'a' TO 'd' WITH GRANT OPTION;

-- grant PROXY to default proxy account
GRANT PROXY ON 'a' TO '@';
```

The PROXY privilege can be granted in these cases:

- By a user that has GRANT PROXY ... WITH GRANT OPTION for proxied_user.
- By proxied_user for itself: The value of USER() must exactly match CURRENT_USER() and proxied_user, for both the user name and host name parts of the account name.

The initial root account created during MySQL installation has the PROXY ... WITH GRANT OPTION privilege for '@', that is, for all users and all hosts. This enables root to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. For example, root can do this:

```
CREATE USER 'admin'@'localhost'
```
Those statements create an admin user that can manage all GRANT PROXY mappings. For example, admin can do this:

GRANT PROXY ON sally TO joe;

**Default Proxy Users**

To specify that some or all users should connect using a given authentication plugin, create a “blank” MySQL account with an empty user name and host name (’@’), associate it with that plugin, and let the plugin return the real authenticated user name (if different from the blank user). Suppose that there exists a plugin named ldap_auth that implements LDAP authentication and maps connecting users onto either a developer or manager account. To set up proxying of users onto these accounts, use the following statements:

```
-- create default proxy account
CREATE USER ''@''
    IDENTIFIED WITH ldap_auth
    AS 'O=Oracle, OU=MySQL';
-- create proxied accounts
CREATE USER 'developer'@'localhost'
    IDENTIFIED BY 'developer_password';
CREATE USER 'manager'@'localhost'
    IDENTIFIED BY 'manager_password';
-- grant to default proxy account the
-- PROXY privilege for proxied accounts
GRANT PROXY
    ON 'manager'@'localhost'
    TO ''@'';
GRANT PROXY
    ON 'developer'@'localhost'
    TO ''@'';
```

As with proxied accounts created in previous examples, the password should be kept secret so that clients cannot use the accounts to log in directly to the MySQL server.

Now assume that a client connects as follows:

```
shell> mysql --user=myuser --password ...
Enter password: myuser_password
```

The server will not find myuser defined as a MySQL user. But because there is a blank user account (’@’) that matches the client user name and host name, the server authenticates the client against that account: The server invokes the ldap_auth authentication plugin and passes myuser and myuser_password to it as the user name and password.

If the ldap_auth plugin finds in the LDAP directory that myuser_password is not the correct password for myuser, authentication fails and the server rejects the connection.

If the password is correct and ldap_auth finds that myuser is a developer, it returns the user name developer to the MySQL server, rather than myuser. Returning a user name different from the client user name of myuser signals to the server that it should treat myuser as a proxy. The server verifies that '@' can authenticate as developer (because '@' has the PROXY privilege to do so) and accepts
Proxy Users

the connection. The session proceeds with `myuser` having the privileges of the `developer` proxied user. (These privileges should be set up by the DBA using `GRANT` statements, not shown.) The `USER()` and `CURRENT_USER()` functions return these values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+---------------------+
| USER()           | CURRENT_USER()      |
+------------------+---------------------+
| myuser@localhost | developer@localhost |
+------------------+---------------------+
```

If the plugin instead finds in the LDAP directory that `myuser` is a manager, it returns `manager` as the user name and the session proceeds with `myuser` having the privileges of the `manager` proxied user.

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+-------------------+
| USER()           | CURRENT_USER()    |
+------------------+-------------------+
| myuser@localhost | manager@localhost |
+------------------+-------------------+
```

For simplicity, external authentication cannot be multilevel: Neither the credentials for `developer` nor those for `manager` are taken into account in the preceding example. However, they are still used if a client tries to connect and authenticate directly as the `developer` or `manager` account, which is why those proxied accounts should be protected against direct login (see Preventing Direct Login to Proxied Accounts).

**Default Proxy User and Anonymous User Conflicts**

If you intend to create a default proxy user, check for other existing “match any user” accounts that take precedence over the default proxy user because they can prevent that user from working as intended.

In the preceding discussion, the default proxy user account has `'` in the host part, which matches any host. If you set up a default proxy user, take care to also check whether nonproxy accounts exist with the same user part and `'%` in the host part, because `'%` also matches any host, but has precedence over `'` by the rules that the server uses to sort account rows internally (see Section 6.2.5, “Access Control, Stage 1: Connection Verification”).

Suppose that a MySQL installation includes these two accounts:

```
-- create default proxy account
CREATE USER ''@''
  IDENTIFIED WITH some_plugin
  AS 'some_auth_string';
-- create anonymous account
CREATE USER ''@'%''
  IDENTIFIED BY 'anon_user_password';
```

The first account (`''@''`) is intended as the default proxy user, used to authenticate connections for users who do not otherwise match a more-specific account. The second account (`''@'%'`) is an anonymous-user account, which might have been created, for example, to enable users without their own account to connect anonymously.

Both accounts have the same user part (`''`), which matches any user. And each account has a host part that matches any host. Nevertheless, there is a priority in account matching for connection attempts because the matching rules sort a host of `'%` ahead of `'`. For accounts that do not match any more-specific account, the server attempts to authenticate them against `''@'%'` (the anonymous user) rather than `''@''` (the default proxy user). As a result, the default proxy account is never used.
To avoid this problem, use one of the following strategies:

- Remove the anonymous account so that it does not conflict with the default proxy user.
- Use a more-specific default proxy user that matches ahead of the anonymous user. For example, to permit only `localhost` proxy connections, use `'@'localhost':`

```sql
CREATE USER ''@'localhost'
    IDENTIFIED WITH some_plugin
    AS 'some_auth_string';
```

In addition, modify any `GRANT PROXY` statements to name `'@'localhost'` rather than `'@'` as the proxy user.

Be aware that this strategy prevents anonymous-user connections from `localhost`.

- Use a named default account rather than an anonymous default account. For an example of this technique, consult the instructions for using the `authentication_windows` plugin. See Section 6.4.1.5, “Windows Pluggable Authentication”.

- Create multiple proxy users, one for local connections and one for “everything else” (remote connections). This can be useful particularly when local users should have different privileges from remote users.

Create the proxy users:

```sql
-- create proxy user for local connections
CREATE USER ''@'localhost'
    IDENTIFIED WITH some_plugin
    AS 'some_auth_string';

-- create proxy user for remote connections
CREATE USER ''@'%
    IDENTIFIED WITH some_plugin
    AS 'some_auth_string';
```

Create the proxied users:

```sql
-- create proxied user for local connections
CREATE USER 'developer'@'localhost'
    IDENTIFIED BY 'some_password';

-- create proxied user for remote connections
CREATE USER 'developer'@'%
    IDENTIFIED BY 'some_password';
```

Grant to each proxy account the `PROXY` privilege for the corresponding proxied account:

```sql
GRANT PROXY
    ON 'developer'@'localhost'
    TO ''@'localhost';
GRANT PROXY
    ON 'developer'@'%
    TO ''@'%;
```

Finally, grant appropriate privileges to the local and remote proxied users (not shown).

Assume that the `some_plugin/'some_auth_string'` combination causes `some_plugin` to map the client user name to `developer`. Local connections match the `'@'localhost'` proxy user, which maps to the `'developer'@'localhost'` proxied user. Remote connections match the `'@'%'` proxy user, which maps to the `'developer'@'%'` proxied user.

### Proxy User System Variables
Two system variables help trace the proxy login process:

- **proxy_user**: This value is NULL if proxying is not used. Otherwise, it indicates the proxy user account. For example, if a client authenticates through the '@' proxy account, this variable is set as follows:

  ```
  mysql> SELECT @@proxy_user;
  +--------------+
  | @@proxy_user |
  +--------------+
  | '@'          |
  +--------------+
  ```

- **external_user**: Sometimes the authentication plugin may use an external user to authenticate to the MySQL server. For example, when using Windows native authentication, a plugin that authenticates using the windows API does not need the login ID passed to it. However, it still uses a Windows user ID to authenticate. The plugin may return this external user ID (or the first 512 UTF-8 bytes of it) to the server using the external_user read-only session variable. If the plugin does not set this variable, its value is NULL.

### 6.2.12 Setting Account Resource Limits

One means of restricting client use of MySQL server resources is to set the global `max_user_connections` system variable to a nonzero value. This limits the number of simultaneous connections that can be made by any given account, but places no limits on what a client can do once connected. In addition, setting `max_user_connections` does not enable management of individual accounts. Both types of control are of interest to MySQL administrators.

To address such concerns, MySQL permits limits for individual accounts on use of these server resources:

- The number of queries an account can issue per hour
- The number of updates an account can issue per hour
- The number of times an account can connect to the server per hour
- The number of simultaneous connections to the server by an account

Any statement that a client can issue counts against the query limit, unless its results are served from the query cache. Only statements that modify databases or tables count against the update limit.

An “account” in this context corresponds to a row in the `mysql.user` system table. That is, a connection is assessed against the User and Host values in the user table row that applies to the connection. For example, an account 'usera'@'%.example.com' corresponds to a row in the user table that has User and Host values of usera and %.example.com, to permit usera to connect from any host in the example.com domain. In this case, the server applies resource limits in this row collectively to all connections by usera from any host in the example.com domain because all such connections use the same account.

Before MySQL 5.0, an “account” was assessed against the actual host from which a user connects. This older method of accounting may be selected by starting the server with the `--old-style-user-limits` option. In this case, if usera connects simultaneously from host1.example.com and host2.example.com, the server applies the account resource limits separately to each connection. If usera connects again from host1.example.com, the server applies the limits for that connection together with the existing connection from that host.

To establish resource limits for an account, use the GRANT statement (see Section 13.7.1.3, “GRANT Statement”). Provide a WITH clause that names each resource to be limited. The default value for each
limit is zero (no limit). For example, to create a new account that can access the customer database, but only in a limited fashion, issue these statements:

```sql
mysql> CREATE USER 'francis'@'localhost' IDENTIFIED BY 'frank';
mysql> GRANT ALL ON customer.* TO 'francis'@'localhost'
    -> WITH MAX_QUERIES_PER_HOUR 20
    -> MAX_UPDATES_PER_HOUR 10
    -> MAX_CONNECTIONS_PER_HOUR 5
    -> MAX_USER_CONNECTIONS 2;
```

The limit types need not all be named in the WITH clause, but those named can be present in any order. The value for each per-hour limit should be an integer representing a count per hour. For MAX_USER_CONNECTIONS, the limit is an integer representing the maximum number of simultaneous connections by the account. If this limit is set to zero, the global max_user_connections system variable value determines the number of simultaneous connections. If max_user_connections is also zero, there is no limit for the account.

To modify limits for an existing account, use a GRANT USAGE statement at the global level (ON *.*). The following statement changes the query limit for francis to 100:

```sql
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    -> WITH MAX_QUERIES_PER_HOUR 100;
```

The statement modifies only the limit value specified and leaves the account otherwise unchanged.

To remove a limit, set its value to zero. For example, to remove the limit on how many times per hour francis can connect, use this statement:

```sql
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    -> WITH MAX_CONNECTIONS_PER_HOUR 0;
```

As mentioned previously, the simultaneous-connection limit for an account is determined from the MAX_USER_CONNECTIONS limit and the max_user_connections system variable. Suppose that the global max_user_connections value is 10 and three accounts have individual resource limits specified as follows:

```sql
GRANT ... TO 'user1'@'localhost' WITH MAX_USER_CONNECTIONS 0;
GRANT ... TO 'user2'@'localhost' WITH MAX_USER_CONNECTIONS 5;
GRANT ... TO 'user3'@'localhost' WITH MAX_USER_CONNECTIONS 20;
```

user1 has a connection limit of 10 (the global max_user_connections value) because it has a MAX_USER_CONNECTIONS limit of zero. user2 and user3 have connection limits of 5 and 20, respectively, because they have nonzero MAX_USER_CONNECTIONS limits.

The server stores resource limits for an account in the user table row corresponding to the account. The max_questions, max_updates, and max_connections columns store the per-hour limits, and the max_user_connections column stores the MAX_USER_CONNECTIONS limit. (See Section 6.2.3, "Grant Tables".)

Resource-use counting takes place when any account has a nonzero limit placed on its use of any of the resources.

As the server runs, it counts the number of times each account uses resources. If an account reaches its limit on number of connections within the last hour, the server rejects further connections for the account until that hour is up. Similarly, if the account reaches its limit on the number of queries or updates, the server rejects further queries or updates until the hour is up. In all such cases, the server issues appropriate error messages.
Troubleshooting Problems Connecting to MySQL

Resource counting occurs per account, not per client. For example, if your account has a query limit of 50, you cannot increase your limit to 100 by making two simultaneous client connections to the server. Queries issued on both connections are counted together.

The current per-hour resource-use counts can be reset globally for all accounts, or individually for a given account:

- To reset the current counts to zero for all accounts, issue a `FLUSH USER_RESOURCES` statement. The counts also can be reset by reloading the grant tables (for example, with a `FLUSH PRIVILEGES` statement or a `mysqladmin` `reload` command).
- The counts for an individual account can be reset to zero by setting any of its limits again. Specify a limit value equal to the value currently assigned to the account.

Per-hour counter resets do not affect the `MAX_USER_CONNECTIONS` limit.

All counts begin at zero when the server starts. Counts do not carry over through server restarts.

For the `MAX_USER_CONNECTIONS` limit, an edge case can occur if the account currently has open the maximum number of connections permitted to it: A disconnect followed quickly by a connect can result in an error (`ER_TOO_MANY_USER_CONNECTIONS` or `ER_USER_LIMIT_REACHED`) if the server has not fully processed the disconnect by the time the connect occurs. When the server finishes disconnect processing, another connection will once more be permitted.

### 6.2.13 Troubleshooting Problems Connecting to MySQL

If you encounter problems when you try to connect to the MySQL server, the following items describe some courses of action you can take to correct the problem.

- Make sure that the server is running. If it is not, clients cannot connect to it. For example, if an attempt to connect to the server fails with a message such as one of those following, one cause might be that the server is not running:

  ```shell
  mysql
  ERROR 2003: Can't connect to MySQL server on 'host_name' (111)
  ```

  ```shell
  mysql
  ERROR 2002: Can't connect to local MySQL server through socket '/tmp/mysql.sock' (111)
  ```

- It might be that the server is running, but you are trying to connect using a TCP/IP port, named pipe, or Unix socket file different from the one on which the server is listening. To correct this when you invoke a client program, specify a `--port` option to indicate the proper port number, or a `--socket` option to indicate the proper named pipe or Unix socket file. To find out where the socket file is, you can use this command:

  ```shell
  netstat -ln | grep mysql
  ```

- Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with the `skip_networking` system variable enabled, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

- Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or Windows Firewall may need to be configured not to block the MySQL port.
Troubleshooting Problems Connecting to MySQL

- The grant tables must be properly set up so that the server can use them for access control. For some distribution types (such as binary distributions on Windows, or RPM distributions on Linux), the installation process initializes the MySQL data directory, including the `mysql` system database containing the grant tables. For distributions that do not do this, you must initialize the data directory manually. For details, see Section 2.10, “Postinstallation Setup and Testing”.

To determine whether you need to initialize the grant tables, look for a `mysql` directory under the data directory. (The data directory normally is named `data` or `var` and is located under your MySQL installation directory.) Make sure that you have a file named `user.MYD` in the `mysql` database directory. If not, initialize the data directory. After doing so and starting the server, test the initial privileges by executing this command:

```shell
shell> mysql -u root
```

The server should let you connect without error.

- After a fresh installation, you should connect to the server and set up your users and their access permissions:

```shell
shell> mysql -u root mysql
```

The server should let you connect because the MySQL `root` user has no password initially. That is also a security risk, so setting the password for the `root` accounts is something you should do while you’re setting up your other MySQL accounts. For instructions on setting the initial passwords, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

- If you have updated an existing MySQL installation to a newer version, did you perform the MySQL upgrade procedure? If not, do so. The structure of the grant tables changes occasionally when new capabilities are added, so after an upgrade you should always make sure that your tables have the current structure. For instructions, see Section 2.11, “Upgrading MySQL”.

- If a client program receives the following error message when it tries to connect, it means that the server expects passwords in a newer format than the client is capable of generating:

```shell
shell> mysql
```

`Client does not support authentication protocol requested by server; consider upgrading MySQL client`

For information on how to deal with this, see Section 6.1.2.4, “Password Hashing in MySQL”, and Section B.4.2.4, “Client does not support authentication protocol”.

- Remember that client programs use connection parameters specified in option files or environment variables. If a client program seems to be sending incorrect default connection parameters when you have not specified them on the command line, check any applicable option files and your environment. For example, if you get `Access denied` when you run a client without any options, make sure that you have not specified an old password in any of your option files!

You can suppress the use of option files by a client program by invoking it with the `--no-defaults` option. For example:

```shell
shell> mysqladmin --no-defaults -u root version
```

The option files that clients use are listed in Section 4.2.2.2, “Using Option Files”. Environment variables are listed in Section 4.9, “Environment Variables”.

- If you get the following error, it means that you are using an incorrect `root` password:

```shell
shell> mysqladmin -u root --password xxxxx version
```

`Access denied for user ‘root’@’localhost’ (using password: YES)`
Troubleshooting Problems Connecting to MySQL

If the preceding error occurs even when you have not specified a password, it means that you have an incorrect password listed in some option file. Try the --no-defaults option as described in the previous item.

For information on changing passwords, see Section 6.2.9, “Assigning Account Passwords”.

If you have lost or forgotten the root password, see Section B.4.3.2, “How to Reset the Root Password”.

• If you change a password by using SET PASSWORD, INSERT, or UPDATE, you must encrypt the password using the PASSWORD() function. If you do not use PASSWORD() for these statements, the password will not work. For example, the following statement assigns a password, but fails to encrypt it, so the user is not able to connect afterward:

```sql
SET PASSWORD FOR 'abe'@'host_name' = 'eagle';
```

Instead, set the password like this:

```sql
SET PASSWORD FOR 'abe'@'host_name' = PASSWORD('eagle');
```

The PASSWORD() function is unnecessary when you specify a password using the CREATE USER or GRANT statements or the mysqladmin password command. Each of those automatically uses PASSWORD() to encrypt the password. See Section 6.2.9, “Assigning Account Passwords”, and Section 13.7.1.1, “CREATE USER Statement”.

• localhost is a synonym for your local host name, and is also the default host to which clients try to connect if you specify no host explicitly.

You can use a --host=127.0.0.1 option to name the server host explicitly. This will make a TCP/IP connection to the local mysqld server. You can also use TCP/IP by specifying a --host option that uses the actual host name of the local host. In this case, the host name must be specified in a user table row on the server host, even though you are running the client program on the same host as the server.

• The Access denied error message tells you who you are trying to log in as, the client host from which you are trying to connect, and whether you were using a password. Normally, you should have one row in the user table that exactly matches the host name and user name that were given in the error message. For example, if you get an error message that contains using password: NO, it means that you tried to log in without a password.

• If you get an Access denied error when trying to connect to the database with mysql -u user_name, you may have a problem with the user table. Check this by executing mysql -u root mysql and issuing this SQL statement:

```sql
SELECT * FROM user;
```

The result should include a row with the Host and User columns matching your client's host name and your MySQL user name.

• If the following error occurs when you try to connect from a host other than the one on which the MySQL server is running, it means that there is no row in the user table with a Host value that matches the client host:

```
Host ... is not allowed to connect to this MySQL server
```

You can fix this by setting up an account for the combination of client host name and user name that you are using when trying to connect.
Troubleshooting Problems Connecting to MySQL

If you do not know the IP address or host name of the machine from which you are connecting, you should put a row with '%\n as the `Host` column value in the `user` table. After trying to connect from the client machine, use a `SELECT USER()` query to see how you really did connect. Then change the '%\n in the `user` table row to the actual host name that shows up in the log. Otherwise, your system is left insecure because it permits connections from any host for the given user name.

On Linux, another reason that this error might occur is that you are using a binary MySQL version that is compiled with a different version of the `glibc` library than the one you are using. In this case, you should either upgrade your operating system or `glibc`, or download a source distribution of MySQL version and compile it yourself. A source RPM is normally trivial to compile and install, so this is not a big problem.

- If you specify a host name when trying to connect, but get an error message where the host name is not shown or is an IP address, it means that the MySQL server got an error when trying to resolve the IP address of the client host to a name:

  ```
  shell> mysqladmin -u root -pxxxx -h some_hostname ver
  Access denied for user 'root'@'' (using password: YES)
  ```

  If you try to connect as `root` and get the following error, it means that you do not have a row in the `user` table with a `User` column value of `root` and that `mysqld` cannot resolve the host name for your client:

  ```
  Access denied for user ''@'unknown'
  ```

  These errors indicate a DNS problem. To fix it, execute `mysqladmin flush-hosts` to reset the internal DNS host cache. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

Some permanent solutions are:

- Determine what is wrong with your DNS server and fix it.
- Specify IP addresses rather than host names in the MySQL grant tables.
- Put an entry for the client machine name in `/etc/hosts` on Unix or `/windows/hosts` on Windows.
- Start `mysqld` with the `skip_name_resolve` system variable enabled.
- Start `mysqld` with the `--skip-host-cache` option.
- On Unix, if you are running the server and the client on the same machine, connect to `localhost`. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file, unless there are connection parameters specified to ensure that the client makes a TCP/IP connection. For more information, see Section 4.2.4, “Connecting to the MySQL Server Using Command Options”.
- On Windows, if you are running the server and the client on the same machine and the server supports named pipe connections, connect to the host name . (period). Connections to . use a named pipe rather than TCP/IP.
- If `mysql -u root` works but `mysql -h your_hostname -u root` results in `Access denied` (where `your_hostname` is the actual host name of the local host), you may not have the correct name for your host in the `user` table. A common problem here is that the `Host` value in the `user` table row specifies an unqualified host name, but your system's name resolution routines return a fully qualified domain name (or vice versa). For example, if you have a row with host 'pluto' in the `user` table, but your DNS tells MySQL that your host name is 'pluto.example.com', the row does
Troubleshooting Problems Connecting to MySQL

not work. Try adding a row to the user table that contains the IP address of your host as the Host column value. (Alternatively, you could add a row to the user table with a Host value that contains a wildcard (for example, 'pluto.%'). However, use of Host values ending with % is insecure and is not recommended!)

• If mysql -u user_name works but mysql -u user_name some_db does not, you have not granted access to the given user for the database named some_db.

• If mysql -u user_name works when executed on the server host, but mysql -h host_name -u user_name does not work when executed on a remote client host, you have not enabled access to the server for the given user name from the remote host.

• If you cannot figure out why you get Access denied, remove from the user table all rows that have Host values containing wildcards (rows that contain '% or '_' characters). A very common error is to insert a new row with Host='%' and User='some_user', thinking that this enables you to specify localhost to connect from the same machine. The reason that this does not work is that the default privileges include a row with Host='localhost' and User='. Because that row has a Host value 'localhost' that is more specific than '%%', it is used in preference to the new row when connecting from localhost! The correct procedure is to insert a second row with Host='localhost' and User='some_user', or to delete the row with Host='localhost' and User='. After deleting the row, remember to issue a FLUSH_PRIVILEGES statement to reload the grant tables. See also Section 6.2.5, “Access Control, Stage 1: Connection Verification”.

• If you are able to connect to the MySQL server, but get an Access denied message whenever you issue a SELECT ... INTO OUTFILE or LOAD DATA statement, your row in the user table does not have the FILE privilege enabled.

• If you change the grant tables directly (for example, by using INSERT, UPDATE, or DELETE statements) and your changes seem to be ignored, remember that you must execute a FLUSH_PRIVILEGES statement or a mysqladmin flush-privileges command to cause the server to reload the privilege tables. Otherwise, your changes have no effect until the next time the server is restarted. Remember that after you change the root password with an UPDATE statement, you will not need to specify the new password until after you flush the privileges, because the server will not know you've changed the password yet!

• If your privileges seem to have changed in the middle of a session, it may be that a MySQL administrator has changed them. Reloading the grant tables affects new client connections, but it also affects existing connections as indicated in Section 6.2.8, "When Privilege Changes Take Effect".

• If you have access problems with a Perl, PHP, Python, or ODBC program, try to connect to the server with mysql -u user_name db_name or mysql -u user_name -ppassword db_name. If you are able to connect using the mysql client, the problem lies with your program, not with the access privileges. (There is no space between -p and the password; you can also use the --password=password syntax to specify the password. If you use the -p or --password option with no password value, MySQL prompts you for the password.)

• For testing purposes, start the mysqld server with the --skip-grant-tables option. Then you can change the MySQL grant tables and use the mysqlaccess script to check whether your modifications have the desired effect. When you are satisfied with your changes, execute mysqladmin flush-privileges to tell the mysqld server to reload the privileges. This enables you to begin using the new grant table contents without stopping and restarting the server.
If you get the following error, you may have a problem with the `db` or `host` table:

```
Access to database denied
```

If the row selected from the `db` table has an empty value in the `Host` column, make sure that there are one or more corresponding rows in the `host` table specifying which hosts the `db` table row applies to. This problem occurs infrequently because the `host` table is rarely used.

If everything else fails, start the `mysqld` server with a debugging option (for example, `--debug=d,general,query`). This prints host and user information about attempted connections, as well as information about each command issued. See Section 24.5.3, “The DBUG Package”.

If you have any other problems with the MySQL grant tables and ask on the MySQL Community Slack, always provide a dump of the MySQL grant tables. You can dump the tables with the `mysqldump` command. To file a bug report, see the instructions at Section 1.6, “How to Report Bugs or Problems”. In some cases, you may need to restart `mysqld` with `--skip-grant-tables` to run `mysqldump`.

### 6.2.14 SQL-Based Account Activity Auditing

Applications can use the following guidelines to perform SQL-based auditing that ties database activity to MySQL accounts.

MySQL accounts correspond to rows in the `mysql.user` system table. When a client connects successfully, the server authenticates the client to a particular row in this table. The `User` and `Host` column values in this row uniquely identify the account and correspond to the `'user_name'@'host_name'` format in which account names are written in SQL statements.

The account used to authenticate a client determines which privileges the client has. Normally, the `CURRENT_USER()` function can be invoked to determine which account this is for the client user. Its value is constructed from the `User` and `Host` columns of the `user` table row for the account.

However, there are circumstances under which the `CURRENT_USER()` value corresponds not to the client user but to a different account. This occurs in contexts when privilege checking is not based on the client’s account:

- Stored routines (procedures and functions) defined with the `SQL SECURITY DEFINER` characteristic
- Views defined with the `SQL SECURITY DEFINER` characteristic
- Triggers and events

In those contexts, privilege checking is done against the `DEFINER` account and `CURRENT_USER()` refers to that account, not to the account for the client who invoked the stored routine or view or who caused the trigger to activate. To determine the invoking user, you can call the `USER()` function, which returns a value indicating the actual user name provided by the client and the host from which the client connected. However, this value does not necessarily correspond directly to an account in the `user` table, because the `USER()` value never contains wildcards, whereas account values (as returned by `CURRENT_USER()`) may contain user name and host name wildcards.

For example, a blank user name matches any user, so an account of `'@localhost'` enables clients to connect as an anonymous user from the local host with any user name. In this case, if a client connects as `user1` from the local host, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+-----------------+----------------+
| USER()          | CURRENT_USER() |
|-----------------+----------------|
```

794
Using Encrypted Connections

The host name part of an account can contain wildcards, too. If the host name contains a '%', or '_', pattern character or uses netmask notation, the account can be used for clients connecting from multiple hosts and the `CURRENT_USER()` value will not indicate which one. For example, the account 'user2'@'%.example.com' can be used by user2 to connect from any host in the example.com domain. If user2 connects from remote.example.com, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+--------------------------+---------------------+
| USER()                   | CURRENT_USER()      |
+--------------------------+---------------------+
| user2@remote.example.com | user2@%.example.com |
+--------------------------+---------------------+
```

If an application must invoke `USER()` for user auditing (for example, if it does auditing from within triggers) but must also be able to associate the `USER()` value with an account in the `user` table, it is necessary to avoid accounts that contain wildcards in the `User` or `Host` column. Specifically, do not permit `User` to be empty (which creates an anonymous-user account), and do not permit pattern characters or netmask notation in `Host` values. All accounts must have a nonempty `User` value and literal `Host` value.

With respect to the previous examples, the ''@'localhost' and 'user2'@'%.example.com' accounts should be changed not to use wildcards:

```
RENAME USER ''@'localhost' TO 'user1'@'localhost';
RENAME USER 'user2'@'%.example.com' TO 'user2'@'remote.example.com';
```

If user2 must be able to connect from several hosts in the example.com domain, there should be a separate account for each host.

To extract the user name or host name part from a `CURRENT_USER()` or `USER()` value, use the `SUBSTRING_INDEX()` function:

```
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',1);
+---------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',1) |
+---------------------------------------+
| user1                                 |
```

```
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',-1);
+----------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',-1) |
+----------------------------------------+
| localhost                              |
```

6.3 Using Encrypted Connections

With an unencrypted connection between the MySQL client and the server, someone with access to the network could watch all your traffic and inspect the data being sent or received between client and server.

When you must move information over a network in a secure fashion, an unencrypted connection is unacceptable. To make any kind of data unreadable, use encryption. Encryption algorithms must include security elements to resist many kinds of known attacks such as changing the order of encrypted messages or replaying data twice.

MySQL supports encrypted connections between clients and the server using the TLS (Transport Layer Security) protocol. TLS is sometimes referred to as SSL (Secure Sockets Layer) but MySQL does not
Configuring MySQL to Use Encrypted Connections

actually use the SSL protocol for encrypted connections because its encryption is weak (see Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”).

TLS uses encryption algorithms to ensure that data received over a public network can be trusted. It has mechanisms to detect data change, loss, or replay. TLS also incorporates algorithms that provide identity verification using the X.509 standard.

X.509 makes it possible to identify someone on the Internet. In basic terms, there should be some entity called a “Certificate Authority” (or CA) that assigns electronic certificates to anyone who needs them. Certificates rely on asymmetric encryption algorithms that have two encryption keys (a public key and a secret key). A certificate owner can present the certificate to another party as proof of identity. A certificate consists of its owner’s public key. Any data encrypted using this public key can be decrypted only using the corresponding secret key, which is held by the owner of the certificate.

MySQL can be compiled for encrypted-connection support using OpenSSL or yaSSL. For a comparison of the two packages, see Section 6.3.4, “SSL Library-Dependent Capabilities.” For information about the encryption protocols and ciphers each package supports, see Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers.”

MySQL programs attempt to connect using encryption if the proper options are given and the server supports encrypted connections. For information about options that affect use of encrypted connections, see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections” and Command Options for Encrypted Connections.

MySQL performs encryption on a per-connection basis, and use of encryption for a given user can be optional or mandatory. This enables you to choose an encrypted or unencrypted connection according to the requirements of individual applications. For information on how to require users to use encrypted connections, see the discussion of the REQUIRE clause of the GRANT statement in Section 13.7.1.3, “GRANT Statement.”

Encrypted connections are not used by default. For applications that require the security provided by encrypted connections, the extra computation to encrypt the data is worthwhile.

Encrypted connections can be used between master and slave replication servers. See Section 17.3.7, “Setting Up Replication to Use Encrypted Connections.”

For information about using encrypted connections from the MySQL C API, see Section 23.7.14, “C API Encrypted Connection Support.”

It is also possible to connect using encryption from within an SSH connection to the MySQL server host. For an example, see Section 6.3.5, “Connecting to MySQL Remotely from Windows with SSH.”

6.3.1 Configuring MySQL to Use Encrypted Connections

To enable encrypted connections, your MySQL distribution must be built with SSL support, as described in Section 2.9.6, “Configuring SSL Library Support.” In addition, several options are available to indicate whether to use encrypted connections, and to specify the appropriate certificate and key files. This section provides general guidance about configuring the server and clients for encrypted connections:

- **Server-Side Startup Configuration for Encrypted Connections**
- **Client-Side Configuration for Encrypted Connections**

For a complete list of options related to establishment of encrypted connections, see Command Options for Encrypted Connections. To create any Command Options for Encrypted Connections. Instructions for creating any required certificate and key files are available in Section 6.3.3, “Creating SSL Certificates and Keys Using openssl.”
Encrypted connections also can be used in these contexts:

- Between master and slave replication servers. See Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”.

- By client programs that are based on the MySQL C API. See Section 23.7.14, “C API Encrypted Connection Support”.

**Note**

If the server is compiled against OpenSSL, clients from MySQL 5.5 versions older than 5.5.37 are not able to connect to the server using encrypted connections if the client library is compiled using yaSSL. Either use a client and server compiled using the same SSL package, or upgrade to clients compiled against a client library version from MySQL 5.5.37 or higher.

**Server-Side Startup Configuration for Encrypted Connections**

These options on the server side specify the certificate and key files the server uses when permitting clients to establish encrypted connections:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)

- `--ssl-cert`: The path name of the server public key certificate file. This certificate can be sent to the client and authenticated against the CA certificate that it has.

- `--ssl-key`: The path name of the server private key file.

For example, to enable the server for encrypted connections, start it with these lines in the `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=ca.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Each certificate and key option names a file in PEM format. If you have a MySQL source distribution, you can test your setup using the demonstration certificate and key files in its `mysql-test/std_data` directory.

The values of the `--ssl-xxx` options set the values of the corresponding system variables (`ssl_ca`, `ssl_cert`, `ssl_key`, and so forth).

**Client-Side Configuration for Encrypted Connections**

These options on the client side identify the certificate and key files clients use when establishing encrypted connections to the server. They are similar to the options used on the server side, but `--ssl-cert` and `--ssl-key` identify the client public and private key:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)

- `--ssl-cert`: The path name of the client public key certificate file.

- `--ssl-key`: The path name of the client private key file.

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and
Encrypted Connection TLS Protocols and Ciphers

client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended:

- To specify the CA certificate, use \texttt{--ssl-ca} (or \texttt{--ssl-capath}).
- To enable host name identity verification as well, specify \texttt{--ssl-verify-server-cert}.
- To require an encrypted connection, specify \texttt{--ssl-mode=REQUIRED}.

Depending on the encryption requirements of the MySQL account used by a client, the client may be required to specify certain options to connect using encryption to the MySQL server.

Suppose that you want to connect using an account that has no special encryption requirements or that was created using a \texttt{GRANT} statement that included the \texttt{REQUIRE SSL} clause. As a recommended set of encrypted-connection options, start the server with at least \texttt{--ssl-cert} and \texttt{--ssl-key}, and invoke the client with \texttt{--ssl-ca} (or \texttt{--ssl-capath}). A client can connect using encryption like this:

```
mysql --ssl-ca=ca.pem
```

To require that a client certificate also be specified, create the account using a \texttt{REQUIRE X509} clause. Then the client must also specify the proper client key and certificate files or the server will reject the connection:

```
mysql --ssl-ca=ca.pem \n   --ssl-cert=client-cert.pem \n   --ssl-key=client-key.pem
```

For additional information about the \texttt{REQUIRE} clause, see Section 13.7.1.3, “GRANT Statement”.

To prevent use of encryption and override other \texttt{--ssl-xxx} options, invoke the client program with \texttt{--ssl=0} or a synonym (\texttt{--skip-ssl}, \texttt{--disable-ssl}):

```
mysql --ssl=0
```

To determine whether the current connection with the server uses encryption, check the session value of the \texttt{Ssl_cipher} status variable. If the value is empty, the connection is not encrypted. Otherwise, the connection is encrypted and the value indicates the encryption cipher. For example:

```
mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+-----------------------------+--------------------+
| Variable_name | Value              |
+-----------------------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+-----------------------------+--------------------+
```

For the \texttt{mysql} client, an alternative is to use the \texttt{STATUS} or \texttt{\s} command and check the \texttt{SSL} line:

```
mysql> \s
...  
SSL: Not in use
...
```

Or:

```
mysql> \s
...
SSL: Cipher in use is DHE-RSA-AES256-SHA
...
```

### 6.3.2 Encrypted Connection TLS Protocols and Ciphers

MySQL supports TLS encryption, and enables configuring which ciphers to permit for encrypted connections. It is also possible to determine which TLS protocol and cipher the current session uses.
Encrypted Connection TLS Protocols and Ciphers

- Supported Connection TLS Protocols
- Connection Cipher Configuration
- Monitoring Current Session TLS Protocol and Cipher

Supported Connection TLS Protocols

MySQL supports encrypted connections using the TLSv1 protocol. As of MySQL 5.5.42, SSL 2.0 and SSL 3.0 are explicitly disabled because they provide weak encryption.

Connection Cipher Configuration

A default set of ciphers applies to encrypted connections, which can be overridden by explicitly configuring the permitted ciphers. During connection establishment, both sides of a connection must permit some cipher in common or the connection fails. Of the permitted ciphers common to both sides, the SSL library chooses the one supported by the provided certificate that has the highest priority.

To specify a cipher or ciphers for encrypted connections, use the `--ssl-cipher` option, which is available for the server and for client programs.

For master/slave replication, the `MASTER_SSL_CIPHER` option for the `CHANGE MASTER TO` statement specifies which ciphers a slave server permits for connections to the master.

To determine which ciphers a given server supports, check the session value of the `Ssl_cipher_list` status variable:

```sql
SHOW SESSION STATUS LIKE 'Ssl_cipher_list';
```

The `Ssl_cipher_list` status variable lists the possible SSL ciphers (empty for non-SSL connections). The set of available ciphers depends on your MySQL version and whether MySQL was compiled using OpenSSL or yaSSL, and (for OpenSSL) the library version used to compile MySQL.

MySQL passes a default cipher list to the SSL library.

MySQL passes this default cipher list to OpenSSL:

```
AES256-GCM-SHA384
AES256-SHA
AES256-SHA256
CAMELLIA256-SHA
DES-CBC3-SHA
DHE-DSS-AES256-GCM-SHA384
DHE-DSS-AES256-SHA
DHE-DSS-AES256-SHA256
DHE-DSS-CAMELLIA256-SHA
DHE-RSA-AES256-GCM-SHA384
DHE-RSA-AES256-SHA
DHE-RSA-AES256-SHA256
DHE-RSA-CAMELLIA256-SHA
ECDH-ECDSA-AES128-GCM-SHA256
ECDH-ECDSA-AES128-SHA
ECDH-ECDSA-AES128-SHA256
ECDH-ECDSA-AES256-GCM-SHA384
ECDH-ECDSA-AES256-SHA
ECDH-ECDSA-AES256-SHA256
ECDH-ECDSA-DES-CBC3-SHA
ECDH-ECDSA-DES-DES3-SHA
ECDH-RSA-AES128-GCM-SHA384
ECDH-RSA-AES128-SHA
ECDH-RSA-AES128-SHA256
ECDH-RSA-DES-CBC3-SHA
ECDHE-ECDSA-AES128-GCM-SHA256
ECDHE-ECDSA-AES128-SHA
ECDHE-ECDSA-AES128-SHA256
ECDHE-ECDSA-AES256-GCM-SHA384
```
Creating SSL Certificates and Keys Using openssl

<table>
<thead>
<tr>
<th>Cipher Suite</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECDHE-ECDSA-AES256-SHA</td>
</tr>
<tr>
<td>ECDHE-ECDSA-AES256-SHA384</td>
</tr>
<tr>
<td>ECDHE-ECDSA-DES-CBC3-SHA</td>
</tr>
<tr>
<td>ECDHE-RSA-AES128-GCM-SHA256</td>
</tr>
<tr>
<td>ECDHE-RSA-AES128-SHA</td>
</tr>
<tr>
<td>ECDHE-RSA-AES128-SHA256</td>
</tr>
<tr>
<td>ECDHE-RSA-AES256-GCM-SHA384</td>
</tr>
<tr>
<td>ECDHE-RSA-AES256-SHA</td>
</tr>
<tr>
<td>ECDHE-RSA-AES256-SHA384</td>
</tr>
<tr>
<td>EDH-DSS-DES-CBC3-SHA</td>
</tr>
<tr>
<td>EDH-RSA-DES-CBC3-SHA</td>
</tr>
<tr>
<td>PSK-3DES-EDE-CBC-SHA</td>
</tr>
<tr>
<td>PSK-AES256-CBC-SHA</td>
</tr>
<tr>
<td>SRP-DSS-3DES-EDE-CBC-SHA</td>
</tr>
<tr>
<td>SRP-DSS-AES-128-CBC-SHA</td>
</tr>
<tr>
<td>SRP-DSS-AES-256-CBC-SHA</td>
</tr>
<tr>
<td>SRP-RSA-DES-3DES-EDE-CBC-SHA</td>
</tr>
<tr>
<td>SRP-RSA-AES-128-CBC-S</td>
</tr>
<tr>
<td>SRP-RSA-AES-256-CBC-SH</td>
</tr>
</tbody>
</table>

MySQL passes this default cipher list to yaSSL:

<table>
<thead>
<tr>
<th>Cipher Suite</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES128-RMD</td>
</tr>
<tr>
<td>AES128-SHA</td>
</tr>
<tr>
<td>AES256-RMD</td>
</tr>
<tr>
<td>AES256-SHA</td>
</tr>
<tr>
<td>DES-CBC-SHA</td>
</tr>
<tr>
<td>DES-CBC3-RMD</td>
</tr>
<tr>
<td>DES-CBC3-SHA</td>
</tr>
<tr>
<td>DHE-RSA-AES128-RMD</td>
</tr>
<tr>
<td>DHE-RSA-AES128-SHA</td>
</tr>
<tr>
<td>DHE-RSA-AES256-RMD</td>
</tr>
<tr>
<td>DHE-RSA-AES256-SHA</td>
</tr>
<tr>
<td>DHE-RSA-DES-CBC3-RMD</td>
</tr>
<tr>
<td>DHE-RSA-DES-CBC3-SHA</td>
</tr>
<tr>
<td>RC4-MD5</td>
</tr>
<tr>
<td>RC4-SHA</td>
</tr>
</tbody>
</table>

Monitoring Current Session TLS Protocol and Cipher

To determine which encryption TLS protocol and cipher the current session uses, check the session values of the `Ssl_version` and `Ssl_cipher` status variables:

```sql
mysql> SHOW SESSION STATUS LIKE 'Ssl_version';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Ssl_version   | TLSv1 |
+---------------+-------+

mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+---------------+--------------------+
| Variable_name | Value              |
+---------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+--------------------+
```

If the connection is not encrypted, both variables have an empty value.

6.3.3 Creating SSL Certificates and Keys Using openssl

This section describes how to use the `openssl` command to set up SSL certificate and key files for use by MySQL servers and clients. The first example shows a simplified procedure such as you might use...
from the command line. The second shows a script that contains more detail. The first two examples are intended for use on Unix and both use the `openssl` command that is part of OpenSSL. The third example describes how to set up SSL files on Windows.

**Important**

Whatever method you use to generate the certificate and key files, the Common Name value used for the server and client certificates/keys must each differ from the Common Name value used for the CA certificate. Otherwise, the certificate and key files will not work for servers compiled using OpenSSL. A typical error in this case is:

```
ERROR 2026 (HY000): SSL connection error:
error:00000001:lib(0):func(0):reason(1)
```

- **Example 1**: Creating SSL Files from the Command Line on Unix
- **Example 2**: Creating SSL Files Using a Script on Unix
- **Example 3**: Creating SSL Files on Windows

### Example 1: Creating SSL Files from the Command Line on Unix

The following example shows a set of commands to create MySQL server and client certificate and key files. You will need to respond to several prompts by the `openssl` commands. To generate test files, you can press Enter to all prompts. To generate files for production use, you should provide nonempty responses.

```bash
# Create clean environment
rm -rf newcerts
mkdir newcerts && cd newcerts

# Create CA certificate
openssl genrsa 2048 > ca-key.pem
openssl req -new -x509 -nodes -days 3600 -key ca-key.pem -out ca.pem

# Create server certificate, remove passphrase, and sign it
# server-cert.pem = public key, server-key.pem = private key
openssl req -newkey rsa:2048 -days 3600 -nodes -keyout server-key.pem -out server-req.pem
openssl rsa -in server-key.pem -out server-key.pem
openssl x509 -req -in server-req.pem -days 3600 -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out server-cert.pem

# Create client certificate, remove passphrase, and sign it
# client-cert.pem = public key, client-key.pem = private key
openssl req -newkey rsa:2048 -days 3600 -nodes -keyout client-key.pem -out client-req.pem
openssl rsa -in client-key.pem -out client-key.pem
openssl x509 -req -in client-req.pem -days 3600 -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out client-cert.pem
```

After generating the certificates, verify them:

```
openssl verify -CAfile ca.pem server-cert.pem client-cert.pem
```

You should see a response like this:

```
server-cert.pem: OK
client-cert.pem: OK
```

Now you have a set of files that can be used as follows:
• **ca.pem**: Use this as the argument to `--ssl-ca` on the server and client sides. (The CA certificate, if used, must be the same on both sides.)

• **server-cert.pem, server-key.pem**: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the server side.

• **client-cert.pem, client-key.pem**: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the client side.

For additional usage instructions, see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

### Example 2: Creating SSL Files Using a Script on Unix

Here is an example script that shows how to set up SSL certificate and key files for MySQL. After executing the script, use the files for SSL connections as described in Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

```bash
DIR=`pwd`/openssl
PRIV=$DIR/private
mkdir $DIR $PRIV $DIR/newcerts

cp /usr/share/ssl/openssl.cnf $DIR
replace ./demoCA $DIR -- $DIR/openssl.cnf

# Create necessary files: $database, $serial and $new_certs_dir
# directory (optional)
touch $DIR/index.txt
echo "01" > $DIR/serial

# Generation of Certificate Authority(CA)
openssl req -new -x509 -keyout $PRIV/cakey.pem -out $DIR/ca.pem
-timeout 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# .................+++++
# ........+++      
# writing new private key to '/home/finley/openssl/private/cakey.pem'
# Enter PEM pass phrase: enter PEM pass phrase:
# -----  
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----  
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL admin
# Email Address []:

# Create server request and key
```

802
Creating SSL Certificates and Keys Using openssl

openssl req -new -keyout $DIR/server-key.pem -out $DIR/server-req.pem -days 3600 -config $DIR/openssl.cnf

Sample output:
Using configuration from /home/finley/openssl/openssl.cnf
Generating a 1024 bit RSA private key
..+++++
........+++++
writing new private key to '/home/finley/openssl/server-key.pem'

Enter PEM pass phrase:
Verifying password - Enter PEM pass phrase:
-----
You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN.

There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:FI
State or Province Name (Full name) [Some-State]:.
Locality Name (eg, city) []:
Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
Organizational Unit Name (eg, section) []:
Common Name (eg, YOUR name) []:MySQL server
Email Address []:

Please enter the following 'extra' attributes to be sent with your certificate request
A challenge password []:
An optional company name []:

Remove the passphrase from the key

openssl rsa -in $DIR/server-key.pem -out $DIR/server-key.pem

Sign server cert

openssl ca -cert $DIR/ca.pem -policy policyAnything \
-out $DIR/server-cert.pem -config $DIR/openssl.cnf \
-infiles $DIR/server-req.pem

Sample output:
Using configuration from /home/finley/openssl/openssl.cnf
Enter PEM pass phrase:
Check that the request matches the signature
Signature ok
The Subjects Distinguished Name is as follows
countryName:PRINTABLE:'FI'
organizationName:PRINTABLE:'MySQL AB'
commonName:PRINTABLE:'MySQL admin'
Certificate is to be certified until Sep 13 14:22:46 2003 GMT
(365 days)
Sign the certificate? [y/n]:y

1 out of 1 certificate requests certified, commit? [y/n]:y
Write out database with 1 new entries
Data Base Updated

Create client request and key

openssl req -new -keyout $DIR/client-key.pem -out \

Creating SSL Certificates and Keys Using openssl

```bash
$DIR/client-req.pem -days 3600 -config $DIR/openssl.cnf
```

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# .....................................++++++
# .............................................++++++
# writing new private key to '/home/finley/openssl/client-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL user
# Email Address []:
# Please enter the following 'extra' attributes
to be sent with your certificate request
# A challenge password []:
# An optional company name []:
# Remove the passphrase from the key

```bash
openssl rsa -in $DIR/client-key.pem -out $DIR/client-key.pem
```

# Sign client cert

```bash
openssl ca -cert $DIR/ca.pem -policy policy_anything \
-out $DIR/client-cert.pem -config $DIR/openssl.cnf \
-infiles $DIR/client-req.pem
```

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName :PRINTABLE:'FI'
# organizationName :PRINTABLE:'MySQL AB'
# commonName :PRINTABLE:'MySQL user'
# Certificate is to be certified until Sep 13 16:45:17 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
# 
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

# Create a my.cnf file that you can use to test the certificates
```
Example 3: Creating SSL Files on Windows

Download OpenSSL for Windows if it is not installed on your system. An overview of available packages can be seen here:

\[\text{http://www.alproweb.com/products/Win32OpenSSL.html}\]

Choose the Win32 OpenSSL Light or Win64 OpenSSL Light package, depending on your architecture (32-bit or 64-bit). The default installation location will be \(C:\text{OpenSSL-Win32}\) or \(C:\text{OpenSSL-Win64}\), depending on which package you downloaded. The following instructions assume a default location of \(C:\text{OpenSSL-Win32}\). Modify this as necessary if you are using the 64-bit package.

If a message occurs during setup indicating '...critical component is missing: Microsoft Visual C++ 2008 Redistributables', cancel the setup and download one of the following packages as well, again depending on your architecture (32-bit or 64-bit):

- Visual C++ 2008 Redistributables (x86), available at:

- Visual C++ 2008 Redistributables (x64), available at:

After installing the additional package, restart the OpenSSL setup procedure.

During installation, leave the default \(C:\text{OpenSSL-Win32}\) as the install path, and also leave the default option 'Copy OpenSSL DLL files to the Windows system directory' selected.

When the installation has finished, add \(C:\text{OpenSSL-Win32}\bin\) to the Windows System Path variable of your server:

1. On the Windows desktop, right-click the My Computer icon, and select Properties.
2. Select the Advanced tab from the System Properties menu that appears, and click the Environment Variables button.
3. Under System Variables, select Path, then click the Edit button. The Edit System Variable dialogue should appear.
4. Add \(;'C:\text{OpenSSL-Win32}\bin'\) to the end (notice the semicolon).
5. Press OK 3 times.
6. Check that OpenSSL was correctly integrated into the Path variable by opening a new command console (Start>Run>cmd.exe) and verifying that OpenSSL is available (depending on your version of Windows, the following path-setting instructions might differ slightly):

Microsoft Windows [Version ...]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.
After OpenSSL has been installed, use instructions similar to those from Example 1 (shown earlier in this section), with the following changes:

- Change the following Unix commands:

  ```
  # Create clean environment
  rm -rf newcerts
  mkdir newcerts && cd newcerts
  ```

  On Windows, use these commands instead:

  ```
  # Create clean environment
  md c:\newcerts
  cd c:\newcerts
  ```

- When a `'` character is shown at the end of a command line, this `'` character must be removed and the command lines entered all on a single line.

After generating the certificate and key files, to use them for SSL connections, see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

### 6.3.4 SSL Library-Dependent Capabilities

MySQL can be compiled using OpenSSL or yaSSL, both of which enable encrypted connections based on the OpenSSL API:

- MySQL Enterprise Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL (see Section 2.9.6, “Configuring SSL Library Support”).

OpenSSL and yaSSL offer the same basic functionality, but additional features are available in MySQL distributions compiled using OpenSSL:

- OpenSSL supports a more flexible syntax for specifying ciphers for the `--ssl-cipher` option, and supports a wider range of encryption ciphers from which to choose. See Command Options for Encrypted Connections, and Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”.
- OpenSSL supports the `--ssl-capath` option. MySQL distributions compiled using yaSSL do not because yaSSL does not look in any directory and do not follow a chained certificate tree. yaSSL requires that all components of the CA certificate tree be contained within a single CA certificate tree and that each certificate in the file has a unique SubjectName value. To work around this limitation, concatenate the individual certificate files comprising the certificate tree into a new file and specify that file as the value of the `--ssl-ca` option.

### 6.3.5 Connecting to MySQL Remotely from Windows with SSH

This section describes how to get an encrypted connection to a remote MySQL server with SSH. The information was provided by David Carlson <dcarlson@mplcomm.com>.
1. Install an SSH client on your Windows machine. For a comparison of SSH clients, see http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.

2. Start your Windows SSH client. Set Host_Name = yourmysqlserver_URL_or_IP. Set userid=your_userid to log in to your server. This userid value might not be the same as the user name of your MySQL account.

3. Set up port forwarding. Either do a remote forward (Set local_port: 3306, remote_host: yourmysqlservername_or_ip, remote_port: 3306) or a local forward (Set port: 3306, host: localhost, remote port: 3306).

4. Save everything, otherwise you will have to redo it the next time.

5. Log in to your server with the SSH session you just created.

6. On your Windows machine, start some ODBC application (such as Access).

7. Create a new file in Windows and link to MySQL using the ODBC driver the same way you normally do, except type in localhost for the MySQL host server, not yourmysqlservername.

At this point, you should have an ODBC connection to MySQL, encrypted using SSH.

6.4 Security Plugins

MySQL includes several plugins that implement security features:

- Plugins for authenticating attempts by clients to connect to MySQL Server. Plugins are available for several authentication protocols. For general discussion of the authentication process, see Section 6.2.10, “Pluggable Authentication”. For characteristics of specific authentication plugins, see Section 6.4.1, “Authentication Plugins”.

- (MySQL Enterprise Edition only) MySQL Enterprise Audit, implemented using a server plugin, uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines. See Section 6.4.2, “MySQL Enterprise Audit”.

6.4.1 Authentication Plugins

The following sections describe pluggable authentication methods available in MySQL and the plugins that implement these methods. For general discussion of the authentication process, see Section 6.2.10, “Pluggable Authentication”.

6.4.1.1 Native Pluggable Authentication

MySQL includes two plugins that implement native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication. This section describes mysql_native_password, which implements authentication against the mysql.user system table using the native password hashing method. For information about mysql_old_password, which implements authentication using the older (pre-4.1) native password hashing method, see Section 6.4.1.2, “Old Native Pluggable Authentication”. For information about these password hashing methods, see Section 6.1.2.4, “Password Hashing in MySQL”.

The mysql_native_password native authentication plugin is backward compatible. Older clients that do not support authentication plugins do use the native authentication protocol, so they can connect to servers that support pluggable authentication.
The following table shows the plugin names on the server and client sides.

**Table 6.8 Plugin and Library Names for Native Password Authentication**

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>mysql_native_password</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td>mysql_native_password</td>
</tr>
<tr>
<td>Library file</td>
<td>None (plugins are built in)</td>
</tr>
</tbody>
</table>

The following sections provide installation and usage information specific to native pluggable authentication:

- **Installing Native Pluggable Authentication**
  - The `mysql_native_password` plugin exists in server and client forms:
    - The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
    - The client-side plugin is built into the `libmysqlclient` client library and is available to any program linked against `libmysqlclient`.

- **Using Native Pluggable Authentication**
  - MySQL client programs use `mysql_native_password` by default. The `--default-auth` option can be used as a hint about which client-side plugin the program can expect to use:
    ```
    shell> mysql --default-auth=mysql_native_password ...
    ```
  - If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

**6.4.1.2 Old Native Pluggable Authentication**

MySQL includes two plugins that implement native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication. This section describes `mysql_old_password`, which implements authentication against the `mysql.user` system table using the older (pre-4.1) native password hashing method. For information about `mysql_native_password`, which implements authentication using the native password hashing method, see Section 6.4.1.1, “Native Pluggable Authentication”. For information about these password hashing methods, see Section 6.1.2.4, “Password Hashing in MySQL”.

**Note**

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.
The `mysql_old_password` native authentication plugin is backward compatible. Older clients that do not support authentication plugins do use the native authentication protocol, so they can connect to servers that support pluggable authentication.

The following table shows the plugin names on the server and client sides.

**Table 6.9 Plugin and Library Names for Old Native Password Authentication**

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td><code>mysql_old_password</code></td>
</tr>
<tr>
<td>Client-side plugin</td>
<td><code>mysql_old_password</code></td>
</tr>
<tr>
<td>Library file</td>
<td>None (plugins are built in)</td>
</tr>
</tbody>
</table>

The following sections provide installation and usage information specific to old native pluggable authentication:

- **Installing Old Native Pluggable Authentication**
- **Using Old Native Pluggable Authentication**

For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”.

**Installing Old Native Pluggable Authentication**

The `mysql_old_password` plugin exists in server and client forms:

- The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
- The client-side plugin is built into the `libmysqlclient` client library and is available to any program linked against `libmysqlclient`.

**Using Old Native Pluggable Authentication**

MySQL client programs can use the `--default-auth` option to specify the `mysql_old_password` plugin as a hint about which client-side plugin the program can expect to use:

```
shell> mysql --default-auth=mysql_old_password ...
```

If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

**6.4.1.3 Client-Side Cleartext Pluggable Authentication**

As of MySQL 5.5.10, a client-side authentication plugin is available that enables clients to send passwords to the server as cleartext, without hashing or encryption. This plugin is built into the MySQL client library.

The following table shows the plugin name.

**Table 6.10 Plugin and Library Names for Cleartext Authentication**

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>None, see discussion</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td><code>mysql_clear_password</code></td>
</tr>
<tr>
<td>Library file</td>
<td>None (plugin is built in)</td>
</tr>
</tbody>
</table>
Many client-side authentication plugins perform hashing or encryption of a password before the client sends it to the server. This enables clients to avoid sending passwords as cleartext.

Hashing or encryption cannot be done for authentication schemes that require the server to receive the password as entered on the client side. In such cases, the client-side `mysql_clear_password` plugin is used to send the password to the server as cleartext. There is no corresponding server-side plugin. Rather, the client-side plugin can be used by any server-side plugin that needs a cleartext password.

Hashing or encryption cannot be done for authentication schemes that require the server to receive the password as entered on the client side. In such cases, the client-side `mysql_clear_password` plugin is used, which enables the client to send the password to the server as cleartext. There is no corresponding server-side plugin. Rather, `mysql_clear_password` can be used on the client side in concert with any server-side plugin that needs a cleartext password. (The PAM authentication plugin is one such; see Section 6.4.1.4, “PAM Pluggable Authentication”.)

The following discussion provides usage information specific to cleartext pluggable authentication. For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”.

### Note

Sending passwords as cleartext may be a security problem in some configurations. To avoid problems if there is any possibility that the password would be intercepted, clients should connect to MySQL Server using a method that protects the password. Possibilities include SSL (see Section 6.3, “Using Encrypted Connections”), IPsec, or a private network.

As of MySQL 5.5.27, to make inadvertent use of the `mysql_clear_password` plugin less likely, MySQL clients must explicitly enable it. This can be done in several ways:

- Set the `LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN` environment variable to a value that begins with `1`, `Y`, or `y`. This enables the plugin for all client connections.

- The `mysql`, `mysqladmin`, and `mysqlslap` client programs (also `mysqlcheck`, `mysqldump`, and `mysqlshow` for MySQL 5.5.47 and later) support an `--enable-cleartext-plugin` option that enables the plugin on a per-invocation basis.

- The `mysql_options()` C API function supports a `MYSQL_ENABLE_CLEARTEXT_PLUGIN` option that enables the plugin on a per-connection basis. Also, any program that uses `libmysqlclient` and reads option files can enable the plugin by including an `enable-cleartext-plugin` option in an option group read by the client library.

### 6.4.1.4 PAM Pluggable Authentication

### Note

PAM pluggable authentication is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see https://www.mysql.com/products/.

As of MySQL 5.5.16, MySQL Enterprise Edition supports an authentication method that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as traditional Unix passwords or an LDAP directory.

PAM pluggable authentication provides these capabilities:
Authentication Plugins

- External authentication: PAM authentication enables MySQL Server to accept connections from users defined outside the MySQL grant tables and that authenticate using methods supported by PAM.

- Proxy user support: PAM authentication can return to MySQL a user name different from the external user name passed by the client program, based on the PAM groups the external user is a member of and the authentication string provided. This means that the plugin can return the MySQL user that defines the privileges the external PAM-authenticated user should have. For example, an operating system user named joe can connect and have the privileges of a MySQL user named developer.

PAM pluggable authentication has been tested on Linux and macOS.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file must be located in the directory named by the plugin_dir system variable. For installation information, see Installing PAM Pluggable Authentication.

Table 6.11 Plugin and Library Names for PAM Authentication

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>authentication_pam</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td>mysql_clear_password</td>
</tr>
<tr>
<td>Library file</td>
<td>authentication_pam.so</td>
</tr>
</tbody>
</table>

As of MySQL 5.5.10, the client-side mysql_clear_password cleartext plugin that communicates with the server-side PAM plugin is built into the libmysqlclient client library and is included in all distributions, including community distributions. Inclusion of the client-side cleartext plugin in all MySQL distributions enables clients from any distribution to connect to a server that has the server-side PAM plugin loaded.

The following sections provide installation and usage information specific to PAM pluggable authentication:

- How PAM Authentication of MySQL Users Works
- Installing PAM Pluggable Authentication
- Uninstalling PAM Pluggable Authentication
- Using PAM Pluggable Authentication
- PAM Unix Password Authentication without Proxy Users
- PAM LDAP Authentication without Proxy Users
- PAM Unix Password Authentication with Proxy Users and Group Mapping
- PAM Authentication Access to Unix Password Store
- PAM Authentication Debugging

For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”. For information about the mysql_clear_password plugin, see Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”. For proxy user information, see Section 6.2.11, “Proxy Users”.

How PAM Authentication of MySQL Users Works

This section provides a general overview of how MySQL and PAM work together to authenticate MySQL users. For examples showing how to set up MySQL accounts to use specific PAM services, see Using PAM Pluggable Authentication.

1. The client program and the server communicate, with the client sending to the server the client user name (the operating system user name by default) and password:
Authentication Plugins

- The client user name is the external user name.

- For accounts that use the PAM server-side authentication plugin, the corresponding client-side plugin is `mysql_clear_password`. This client-side plugin performs no password hashing, with the result that the client sends the password to the server as cleartext.

2. The server finds a matching MySQL account based on the external user name and the host from which the client connects. The PAM plugin uses the information passed to it by MySQL Server (such as user name, host name, password, and authentication string). When you define a MySQL account that authenticates using PAM, the authentication string contains:

   - A PAM service name, which is a name that the system administrator can use to refer to an authentication method for a particular application. There can be multiple applications associated with a single database server instance, so the choice of service name is left to the SQL application developer.

   - Optionally, if proxying is to be used, a mapping from PAM groups to MySQL user names.

3. The plugin uses the PAM service named in the authentication string to check the user credentials and returns 'Authentication succeeded, Username is user_name' or 'Authentication failed'. The password must be appropriate for the password store used by the PAM service. Examples:

   - For traditional Unix passwords, the service looks up passwords stored in the `/etc/shadow` file.

   - For LDAP, the service looks up passwords stored in an LDAP directory.

   If the credentials check fails, the server refuses the connection.

4. Otherwise, the authentication string indicates whether proxying occurs. If the string contains no PAM group mapping, proxying does not occur. In this case, the MySQL user name is the same as the external user name.

5. Otherwise, proxying is indicated based on the PAM group mapping, with the MySQL user name determined based on the first matching group in the mapping list. The meaning of “PAM group” depends on the PAM service. Examples:

   - For traditional Unix passwords, groups are Unix groups defined in the `/etc/group` file, possibly supplemented with additional PAM information in a file such as `/etc/security/group.conf`.

   - For LDAP, groups are LDAP groups defined in an LDAP directory.

   If the proxy user (the external user) has the `PROXY` privilege for the proxied MySQL user name, proxying occurs, with the proxy user assuming the privileges of the proxied user.

**Installing PAM Pluggable Authentication**

This section describes how to install the PAM authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, configure the plugin directory location by setting the value of `plugin_dir` at server startup.

The plugin library file base name is `authentication_pam`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).
Authentication Plugins

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in the server `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=authentication_pam.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to load the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN authentication_pam SONAME 'authentication_pam.so';
```

`INSTALL PLUGIN` loads the plugin immediately, and also registers it in the `mysql.plugins` system table to cause the server to load it for each subsequent normal startup without the need for `--plugin-load`.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
FROM INFORMATION_SCHEMA.PLUGINS
WHERE PLUGIN_NAME LIKE '%pam%';
+--------------------+---------------+
| PLUGIN_NAME        | PLUGIN_STATUS |
+--------------------+---------------+
| authentication_pam | ACTIVE        |
+--------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the PAM plugin, see Using PAM Pluggable Authentication.

Uninstalling PAM Pluggable Authentication

The method used to uninstall the PAM authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.

- If you installed the plugin at runtime using an `INSTALL PLUGIN` statement, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```
UNINSTALL PLUGIN authentication_pam;
```

Using PAM Pluggable Authentication

This section describes in general terms how to use the PAM authentication plugin to connect from MySQL client programs to the server. The following sections provide instructions for using PAM authentication in specific ways. It is assumed that the server is running with the server-side PAM plugin enabled, as described in Installing PAM Pluggable Authentication, and that client programs are recent enough to include the client-side plugin.

To refer to the PAM authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_pam`. For example:

```
CREATE USER user
IDENTIFIED WITH authentication_pam
AS 'auth_string';
```

The authentication string specifies the following types of information:
Authentication Plugins

- The PAM service name (see How PAM Authentication of MySQL Users Works). Examples in the following discussion use a service name of `mysql-unix` for authentication using traditional Unix passwords, and `mysql-ldap` for authentication using LDAP.

- For proxy support, PAM provides a way for a PAM module to return to the server a MySQL user name other than the external user name passed by the client program when it connects to the server. Use the authentication string to control the mapping from external user names to MySQL user names. If you want to take advantage of proxy user capabilities, the authentication string must include this kind of mapping.

For example, if an account uses the `mysql-unix` PAM service name and should map operating system users in the `root` and `users` PAM groups to the `developer` and `data_entry` MySQL users, respectively, use a statement like this:

```sql
CREATE USER user
IDENTIFIED WITH authentication_pam
AS 'mysql-unix, root=developer, users=data_entry';
```

Authentication string syntax for the PAM authentication plugin follows these rules:

- The string consists of a PAM service name, optionally followed by a PAM group mapping list consisting of one or more keyword/value pairs each specifying a PAM group name and a MySQL user name:

```
pam_service_name[,pam_group_name=mysql_user_name]...
```

The plugin parses the authentication string for each connection attempt that uses the account. To minimize overhead, keep the string as short as possible.

- Each `pam_group_name=mysql_user_name` pair must be preceded by a comma.

- Leading and trailing spaces not inside double quotation marks are ignored.

- Unquoted `pam_service_name`, `pam_group_name`, and `mysql_user_name` values can contain anything except equal sign, comma, or space.

- If a `pam_service_name`, `pam_group_name`, or `mysql_user_name` value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the value contains space characters. All characters are legal except double quotation mark and backslash (`\`). To include either character, escape it with a backslash.

If the plugin successfully authenticates the external user name (the name passed by the client), it looks for a PAM group mapping list in the authentication string and, if present, uses it to return a different MySQL user name to the MySQL server based on which PAM groups the external user is a member of:

- If the authentication string contains no PAM group mapping list, the plugin returns the external name.

- If the authentication string does contain a PAM group mapping list, the plugin examines each `pam_group_name=mysql_user_name` pair in the list from left to right and tries to find a match for the `pam_group_name` value in a non-MySQL directory of the groups assigned to the authenticated user and returns `mysql_user_name` for the first match it finds. If the plugin finds no match for any PAM group, it returns the external name. If the plugin is not capable of looking up a group in a directory, it ignores the PAM group mapping list and returns the external name.

The following sections describe how to set up several authentication scenarios that use the PAM authentication plugin:

- No proxy users. This uses PAM only to check login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use PAM authentication. (For a MySQL account of `user_name@host_name` to match the external user, `user_name` must be the external user name and `host_name` must match the host from which the
client connects.) Authentication can be performed by various PAM-supported methods. Later discussion shows how to authenticate client credentials using traditional Unix passwords, and passwords in LDAP.

PAM authentication, when not done through proxy users or PAM groups, requires the MySQL user name to be same as the operating system user name. MySQL user names are limited to 16 characters (see Section 6.2.3, “Grant Tables”), which limits PAM nonproxy authentication to Unix accounts with names of at most 16 characters.

• Proxy users only, with PAM group mapping. For this scenario, create one or more MySQL accounts that define different sets of privileges. (Ideally, nobody should connect using those accounts directly.) Then define a default user authenticating through PAM that uses some mapping scheme (usually based on the external PAM groups the users are members of) to map all the external user names to the few MySQL accounts holding the privilege sets. Any client who connects and specifies an external user name as the client user name is mapped to one of the MySQL accounts and uses its privileges. The discussion shows how to set this up using traditional Unix passwords, but other PAM methods such as LDAP could be used instead.

Variations on these scenarios are possible:

• You can permit some users to log in directly (without proxying) but require others to connect through proxy accounts.

• You can use one PAM authentication method for some users, and another method for other users, by using differing PAM service names among your PAM-authenticated accounts. For example, you can use the mysql-unix PAM service for some users, and mysql-ldap for others.

The examples make the following assumptions. You might need to make some adjustments if your system is set up differently.

• The login name and password are antonio and antonio_password, respectively. Change these to correspond to the user you want to authenticate.

• The PAM configuration directory is /etc/pam.d.

• The PAM service name corresponds to the authentication method (mysql-unix or mysql-ldap in this discussion). To use a given PAM service, you must set up a PAM file with the same name in the PAM configuration directory (creating the file if it does not exist). In addition, you must use the PAM service name in the authentication string of CREATE USER or GRANT statements for any account that authenticates using that service.

The PAM authentication plugin checks at initialization time whether the AUTHENTICATION_PAM_LOG environment value is set in the server's startup environment. If so, the plugin enables logging of diagnostic messages to the standard output. Depending on how your server is started, the message might appear on the console or in the error log. These messages can be helpful for debugging PAM-related issues that occur when the plugin performs authentication. For more information, see PAM Authentication Debugging.

PAM Unix Password Authentication without Proxy Users

This authentication scenario uses PAM to check external users defined in terms of operating system user names and Unix passwords, without proxying. Every such external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use PAM authentication through traditional Unix password store.

Note

Traditional Unix passwords are checked using the /etc/shadow file. For information regarding possible issues related to this file, see PAM Authentication Access to Unix Password Store.
1. Verify that Unix authentication permits logins to the operating system with the user name `antonio` and password `antonio_password`.

2. Set up PAM to authenticate MySQL connections using traditional Unix passwords by creating a `mysql-unix` PAM service file named `/etc/pam.d/mysql-unix`. The file contents are system dependent, so check existing login-related files in the `/etc/pam.d` directory to see what they look like. On Linux, the `mysql-unix` file might look like this:

```bash
# %PAM-1.0
auth        include         password-auth
account     include         password-auth
```

For macOS, use `login` rather than `password-auth`.

The PAM file format might differ on some systems. For example, on Ubuntu and other Debian-based systems, use these file contents instead:

```bash
@include common-auth
@include common-account
@include common-session-noninteractive
```

3. Create a MySQL account with the same user name as the operating system user name and define it to authenticate using the PAM plugin and the `mysql-unix` PAM service:

```sql
CREATE USER 'antonio'@'localhost'
IDENTIFIED WITH authentication_pam
AS 'mysql-unix';
GRANT ALL PRIVILEGES
ON mydb.*
TO 'antonio'@'localhost';
```

Here, the authentication string contains only the PAM service name, `mysql-unix`, which authenticates Unix passwords.

4. Use the `mysql` command-line client to connect to the MySQL server as `antonio`. For example:

```bash
shell> mysql --user=antonio --password --enable-cleartext-plugin
Enter password: antonio_password
```

The server should permit the connection and the following query returns output as shown:

```sql
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+-------------------+--------------+
| USER()            | CURRENT_USER()    | @@proxy_user |
+-------------------+-------------------+--------------+
| antonio@localhost | antonio@localhost | NULL         |
+-------------------+-------------------+--------------+
```

This demonstrates that the `antonio` operating system user is authenticated to have the privileges granted to the `antonio` MySQL user, and that no proxying has occurred.

---

**Note**

The client-side `mysql_clear_password` authentication plugin leaves the password untouched, so client programs send it to the MySQL server as cleartext. This enables the password to be passed as is to PAM. A cleartext password is necessary to use the server-side PAM library, but may be a security problem in some configurations. These measures minimize the risk:

- To make inadvertent use of the `mysql_clear_password` plugin less likely, MySQL clients must explicitly enable it (for example, with the `--enable-`
Authentication Plugins

- cleartext-plugin option). See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.

- To avoid password exposure with the mysql_clear_password plugin enabled, MySQL clients should connect to the MySQL server using an encrypted connection. See Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

PAM LDAP Authentication without Proxy Users

This authentication scenario uses PAM to check external users defined in terms of operating system user names and LDAP passwords, without proxying. Every such external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use PAM authentication through LDAP.

To use PAM LDAP pluggable authentication for MySQL, these prerequisites must be satisfied:

- An LDAP server must be available for the PAM LDAP service to communicate with.
- LDAP users to be authenticated by MySQL must be present in the directory managed by the LDAP server.

Configure MySQL for PAM LDAP authentication as follows:

1. Verify that Unix authentication permits logins to the operating system with the user name antonio and password antonio_password.
2. Set up PAM to authenticate MySQL connections using LDAP by creating a mysql-ldap PAM service file named /etc/pam.d/mysql-ldap. The file contents are system dependent, so check existing login-related files in the /etc/pam.d directory to see what they look like. On Linux, the mysql-ldap file might look like this:

   # PAM-1.0
   auth required pam_ldap.so
   account required pam_ldap.so

   If PAM object files have a suffix different from .so on your system, substitute the correct suffix.

   The PAM file format might differ on some systems.
3. Create a MySQL account with the same user name as the operating system user name and define it to authenticate using the PAM plugin and the mysql-ldap PAM service:

   CREATE USER 'antonio'@'localhost'
   IDENTIFIED WITH authentication_pam
   AS 'mysql-ldap';
   GRANT ALL PRIVILEGES
   ON mydb.*
   TO 'antonio'@'localhost';

   Here, the authentication string contains only the PAM service name, mysql-ldap, which authenticates using LDAP.
4. Connecting to the server is the same as described in PAM Unix Password Authentication without Proxy Users.

PAM Unix Password Authentication with Proxy Users and Group Mapping

The authentication scheme described here uses proxying and PAM group mapping to map connecting MySQL users who authenticate using PAM onto other MySQL accounts that define different sets of privileges. Users do not connect directly through the accounts that define the privileges. Instead, they
Authentication Plugins

connect through a default proxy account authenticated using PAM, such that all the external users are mapped to the MySQL accounts that hold the privileges. Any user who connects using the proxy account is mapped to one of those MySQL accounts, the privileges for which determine the database operations permitted to the external user.

The procedure shown here uses Unix password authentication. To use LDAP instead, see the early steps of PAM LDAP Authentication without Proxy Users.

Note

Traditional Unix passwords are checked using the /etc/shadow file. For information regarding possible issues related to this file, see PAM Authentication Access to Unix Password Store.

1. Verify that Unix authentication permits logins to the operating system with the user name antonio and password antonio_password.

2. Verify that antonio is a member of the root or users PAM group.

3. Set up PAM to authenticate the mysql-unix PAM service through operating system users by creating a file named /etc/pam.d/mysql-unix. The file contents are system dependent, so check existing login-related files in the /etc/pam.d directory to see what they look like. On Linux, the mysql-unix file might look like this:

```
#%PAM-1.0
auth        include         password-auth
account     include         password-auth
```

For macOS, use login rather than password-auth.

The PAM file format might differ on some systems. For example, on Ubuntu and other Debian-based systems, use these file contents instead:

```
@include common-auth
@include common-account
@include common-session-noninteractive
```

4. Create a default proxy user ("@") that maps external PAM users to the proxied accounts:

```
CREATE USER ''@'' IDENTIFIED WITH authentication_pam AS 'mysql-unix, root=developer, users=data_entry';
```

Here, the authentication string contains the PAM service name, mysql-unix, which authenticates Unix passwords. The authentication string also maps external users in the root and users PAM groups to the developer and data_entry MySQL user names, respectively.

The PAM group mapping list following the PAM service name is required when you set up proxy users. Otherwise, the plugin cannot tell how to perform mapping from external user names to the proper proxied MySQL user names.

Note

If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this issue, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

5. Create the proxied accounts and grant to them the privileges required for MySQL access:

```
CREATE USER 'developer'@'localhost'
```
IDENTIFIED BY 'very secret password';
CREATE USER 'data_entry'@'localhost'
    IDENTIFIED BY 'very secret password';

GRANT ALL PRIVILEGES
    ON mydevdb.*
    TO 'developer'@'localhost';
GRANT ALL PRIVILEGES
    ON mydb.*
    TO 'data_entry'@'localhost';

If you do not let anyone know the passwords for these accounts, clients cannot use them to connect directly to the MySQL server. Instead, it is expected that users who authenticate using PAM will use the developer or data_entry account by proxy based on their PAM group.

6. Grant to the proxy account the PROXY privilege for each proxied account:

    GRANT PROXY
    ON 'developer'@'localhost'
    TO '''@'';
    GRANT PROXY
    ON 'data_entry'@'localhost'
    TO '''@'';

7. Use the mysql command-line client to connect to the MySQL server as antonio.

    mysql --user=antonio --password --enable-cleartext-plugin
    Enter password: antonio_password

    The server authenticates the connection using the default ''@'' proxy account. The resulting privileges for antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups antonio depend on which PAM groups

    This demonstrates that the antonio operating system user is authenticated to have the privileges granted to the developer MySQL user, and that proxying occurs through the default proxy account.

    If antonio is not a member of the root PAM group but is a member of the users PAM group, a similar process occurs, but the plugin maps user PAM group membership to the data_entry MySQL user name and returns that name to the server:

    mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
    +-------------------+---------------------+--------------+
    | USER()            | CURRENT_USER()      | @@proxy_user |
    +-------------------+---------------------+--------------+
    | antonio@localhost | data_entry@localhost | ''@''        |
    +-------------------+---------------------+--------------+

    This demonstrates that the antonio operating system user is authenticated to have the privileges of the data_entry MySQL user, and that proxying occurs through the default proxy account.
Note

The client-side mysql_clear_password authentication plugin leaves the password untouched, so client programs send it to the MySQL server as cleartext. This enables the password to be passed as is to PAM. A cleartext password is necessary to use the server-side PAM library, but may be a security problem in some configurations. These measures minimize the risk:

- To make inadvertent use of the mysql_clear_password plugin less likely, MySQL clients must explicitly enable it (for example, with the --enable-cleartext-plugin option). See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.

- To avoid password exposure with the mysql_clear_password plugin enabled, MySQL clients should connect to the MySQL server using an encrypted connection. See Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

### PAM Authentication Access to Unix Password Store

On some systems, Unix authentication uses a password store such as /etc/shadow, a file that typically has restricted access permissions. This can cause MySQL PAM-based authentication to fail. Unfortunately, the PAM implementation does not permit distinguishing “password could not be checked” (due, for example, to inability to read /etc/shadow) from “password does not match.” If you are using Unix password store for PAM authentication, you may be able to enable access to it from MySQL using one of the following methods:

- Assuming that the MySQL server is run from the mysql operating system account, put that account in the shadow group that has /etc/shadow access:

  1. Create a shadow group in /etc/group.
  2. Add the mysql operating system user to the shadow group in /etc/group.
  3. Assign /etc/group to the shadow group and enable the group read permission:

```
chgrp shadow /etc/shadow
chmod g+r /etc/shadow
```
  4. Restart the MySQL server.

- If you are using the pam_unix module and the unix_chkpwd utility, enable password store access as follows:

```
chmod u-s /usr/sbin/unix_chkpwd
setcap cap_dac_read_search+ep /usr/sbin/unix_chkpwd
```

Adjust the path to unix_chkpwd as necessary for your platform.

### PAM Authentication Debugging

The PAM authentication plugin checks at initialization time whether the AUTHENTICATION_PAM_LOG environment value is set (the value does not matter). If so, the plugin enables logging of diagnostic messages to the standard output. These messages may be helpful for debugging PAM-related issues that occur when the plugin performs authentication.

Some messages include reference to PAM plugin source files and line numbers, which enables plugin actions to be tied more closely to the location in the code where they occur.
Another technique for debugging connection failures and determining what is happening during connection attempts is to configure PAM authentication to permit all connections, then check the system log files. This technique should be used only on a temporary basis, and not on a production server.

Configure a PAM service file named `/etc/pam.d/mysql-any-password` with these contents (the format may differ on some systems):

```bash
# PAM-1.0
auth    required    pam_permit.so
account required    pam_permit.so
```

Create an account that uses the PAM plugin and names the `mysql-any-password` PAM service:

```sql
CREATE USER 'testuser'@'localhost'
    IDENTIFIED WITH authentication_pam
    AS 'mysql-any-password';
```

The `mysql-any-password` service file causes any authentication attempt to return true, even for incorrect passwords. If an authentication attempt fails, that tells you the configuration problem is on the MySQL side. Otherwise, the problem is on the operating system/PAM side. To see what might be happening, check system log files such as `/var/log/secure`, `/var/log/audit.log`, `/var/log/syslog`, or `/var/log/messages`.

After determining what the problem is, remove the `mysql-any-password` PAM service file to disable any-password access.

### 6.4.1.5 Windows Pluggable Authentication

**Note**

Windows pluggable authentication is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see [https://www.mysql.com/products/](https://www.mysql.com/products/).

As of MySQL 5.5.16, MySQL Enterprise Edition for Windows supports an authentication method that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password.

The client and server exchange data packets in the authentication handshake. As a result of this exchange, the server creates a security context object that represents the identity of the client in the Windows OS. This identity includes the name of the client account. Windows pluggable authentication uses the identity of the client to check whether it is a given account or a member of a group. By default, negotiation uses Kerberos to authenticate, then NTLM if Kerberos is unavailable.

Windows pluggable authentication provides these capabilities:

- **External authentication**: Windows authentication enables MySQL Server to accept connections from users defined outside the MySQL grant tables who have logged in to Windows.

- **Proxy user support**: Windows authentication can return to MySQL a user name different from the external user name passed by the client program. This means that the plugin can return the MySQL user that defines the privileges the external Windows-authenticated user should have. For example, a Windows user named `joe` can connect and have the privileges of a MySQL user named `developer`.

The following table shows the plugin and library file names. The file must be located in the directory named by the `plugin_dir` system variable.
### Table 6.12 Plugin and Library Names for Windows Authentication

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>authentication_windows</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td>authentication_windows_client</td>
</tr>
<tr>
<td>Library file</td>
<td>authentication_windows.dll</td>
</tr>
</tbody>
</table>

The library file includes only the server-side plugin. As of MySQL 5.5.13, the client-side plugin is built into the `libmysqlclient` client library.

The server-side Windows authentication plugin is included only in MySQL Enterprise Edition. It is not included in MySQL community distributions. The client-side plugin is included in all distributions, including community distributions. This permits clients from any 5.5.13 or higher distribution to connect to a server that has the server-side plugin loaded.

The Windows authentication plugin is supported on any version of Windows supported by MySQL 5.5 (see [https://www.mysql.com/support/supportedplatforms/database.html](https://www.mysql.com/support/supportedplatforms/database.html)). It requires MySQL Server 5.5.16 or higher.

The following sections provide installation and usage information specific to Windows pluggable authentication:

- Installing Windows Pluggable Authentication
- Uninstalling Windows Pluggable Authentication
- Using Windows Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”. For proxy user information, see Section 6.2.11, “Proxy Users”.

### Installing Windows Pluggable Authentication

This section describes how to install the Windows authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, configure the plugin directory location by setting the value of `plugin_dir` at server startup.

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in the server `my.cnf` file:

```
[mysqld]
plugin-load=authentication_windows.dll
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to load the plugin at runtime, use this statement:

```
INSTALL PLUGIN authentication_windows SONAME 'authentication_windows.dll';
```

`INSTALL PLUGIN` loads the plugin immediately, and also registers it in the `mysql.plugins` system table to cause the server to load it for each subsequent normal startup without the need for `--plugin-load`.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:
Authentication Plugins

<table>
<thead>
<tr>
<th>PLUGIN_NAME</th>
<th>PLUGIN_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>authentication_windows</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the Windows authentication plugin, see Using Windows Pluggable Authentication. Additional plugin control is provided by the authentication_windows_use_principal_name and authentication_windows_log_level system variables. See Section 5.1.7, “Server System Variables”.

Uninstalling Windows Pluggable Authentication

The method used to uninstall the Windows authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using an `INSTALL PLUGIN` statement, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```
UNINSTALL PLUGIN authentication_windows;
```

In addition, remove any startup options that set Windows plugin-related system variables.

Using Windows Pluggable Authentication

The Windows authentication plugin supports the use of MySQL accounts such that users who have logged in to Windows can connect to the MySQL server without having to specify an additional password. It is assumed that the server is running with the server-side plugin enabled, as described in Installing Windows Pluggable Authentication, and that client programs are recent enough to include the client-side plugin built into `libmysqlclient` (MySQL 5.5.13 or higher). Once the DBA has enabled the server-side plugin and set up accounts to use it, clients can connect using those accounts with no other setup required on their part.

To refer to the Windows authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_windows`. Suppose that the Windows users Rafal and Tasha should be permitted to connect to MySQL, as well as any users in the `Administrators` or `Power Users` group. To set this up, create a MySQL account named `sql_admin` that uses the Windows plugin for authentication:

```
CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
    AS 'Rafal, Tasha, Administrators, "Power Users"';
```

The plugin name is `authentication_windows`. The string following the `AS` keyword is the authentication string. It specifies that the Windows users named Rafal or Tasha are permitted to authenticate to the server as the MySQL user `sql_admin`, as are any Windows users in the `Administrators` or `Power Users` group. The latter group name contains a space, so it must be quoted with double quote characters.

After you create the `sql_admin` account, a user who has logged in to Windows can attempt to connect to the server using that account:

```
C:\> mysql --user=sql_admin
```
No password is required here. The `authentication_windows` plugin uses the Windows security API to check which Windows user is connecting. If that user is named Rafal or Tasha, or is a member of the Administrators or Power Users group, the server grants access and the client is authenticated as sql_admin and has whatever privileges are granted to the sql_admin account. Otherwise, the server denies access.

Authentication string syntax for the Windows authentication plugin follows these rules:

- The string consists of one or more user mappings separated by commas.
- Each user mapping associates a Windows user or group name with a MySQL user name:

  ```
  win_user_or_group_name=mysql_user_name
  win_user_or_group_name
  ```

  For the latter syntax, with no `mysql_user_name` value given, the implicit value is the MySQL user created by the `CREATE USER` statement. Thus, these statements are equivalent:

  ```
  CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal, Tasha, Administrators, "Power Users"';
  
  CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal=sql_admin, Tasha=sql_admin, Administrators=sql_admin, "Power Users"=sql_admin';
  ```

- Each backslash character (\) in a value must be doubled because backslash is the escape character in MySQL strings.
- Leading and trailing spaces not inside double quotation marks are ignored.
- Unquoted `win_user_or_group_name` and `mysql_user_name` values can contain anything except equal sign, comma, or space.
- If a `win_user_or_group_name` and or `mysql_user_name` value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the name contains space characters. All characters within double quotes are legal except double quotation mark and backslash. To include either character, escape it with a backslash.

  `win_user_or_group_name` values use conventional syntax for Windows principals, either local or in a domain. Examples (note the doubling of backslashes):

  ```
  domain\user
  .\user
  domain\group
  .\group
  BUILTIN\WellKnownGroup
  ```

When invoked by the server to authenticate a client, the plugin scans the authentication string left to right for a user or group match to the Windows user. If there is a match, the plugin returns the corresponding `mysql_user_name` to the MySQL server. If there is no match, authentication fails.

A user name match takes preference over a group name match. Suppose that the Windows user named `win_user` is a member of `win_group` and the authentication string looks like this:

`'win_group = sql_user1, win_user = sql_user2'`

When `win_user` connects to the MySQL server, there is a match both to `win_group` and to `win_user`. The plugin authenticates the user as `sql_user2` because the more-specific user match takes precedence over the group match, even though the group is listed first in the authentication string.
Windows authentication always works for connections from the same computer on which the server is running. For cross-computer connections, both computers must be registered with Windows Active Directory. If they are in the same Windows domain, it is unnecessary to specify a domain name. It is also possible to permit connections from a different domain, as in this example:

```sql
CREATE USER sql_accounting
  IDENTIFIED WITH authentication_windows
  AS 'SomeDomain\Accounting';
```

Here `SomeDomain` is the name of the other domain. The backslash character is doubled because it is the MySQL escape character within strings.

MySQL supports the concept of proxy users whereby a client can connect and authenticate to the MySQL server using one account but while connected has the privileges of another account (see Section 6.2.11, “Proxy Users”). Suppose that you want Windows users to connect using a single user name but be mapped based on their Windows user and group names onto specific MySQL accounts as follows:

- The `local_user` and `MyDomain\domain_user` local and domain Windows users should map to the `local_wlad` MySQL account.
- Users in the `MyDomain\Developers` domain group should map to the `local_dev` MySQL account.
- Local machine administrators should map to the `local_admin` MySQL account.

To set this up, create a proxy account for Windows users to connect to, and configure this account so that users and groups map to the appropriate MySQL accounts (`local_wlad`, `local_dev`, `local_admin`). In addition, grant the MySQL accounts the privileges appropriate to the operations they need to perform. The following instructions use `win_proxy` as the proxy account, and `local_wlad`, `local_dev`, and `local_admin` as the proxied accounts.

1. **Create the proxy MySQL account:**

   ```sql
   CREATE USER win_proxy
   IDENTIFIED WITH authentication_windows
   AS 'local_user = local_wlad,
   MyDomain\domain_user = local_wlad,
   MyDomain\Developers = local_dev,
   BUILTIN\Administrators = local_admin';
   ``

2. **For proxying to work, the proxied accounts must exist, so create them:**

   ```sql
   CREATE USER local_wlad IDENTIFIED BY 'secret_wlad_pass';
   CREATE USER local_dev IDENTIFIED BY 'secret_dev_pass';
   CREATE USER local_admin IDENTIFIED BY 'secret_admin_pass';
   ``

   If you do not let anyone know the passwords for these accounts, clients cannot use them to connect directly to the MySQL server. Instead, it is expected that users who authenticate using Windows will use the `win_proxy` proxy account.

   You should also execute `GRANT` statements (not shown) that grant each proxied account the privileges required for MySQL access.

3. **Grant to the proxy account the PROXY privilege for each proxied account:**

   ```sql
   GRANT PROXY ON local_wlad TO win_proxy;
   GRANT PROXY ON local_dev TO win_proxy;
   GRANT PROXY ON local_admin TO win_proxy;
   ``

   Now the Windows users `local_user` and `MyDomain\domain_user` can connect to the MySQL server as `win_proxy` and when authenticated have the privileges of the account given in the authentication
Authentication Plugins

string (in this case, local_wlad). A user in the MyDomain\Developers group who connects as win_proxy has the privileges of the local_dev account. A user in the BUILTIN\Administrators group has the privileges of the local_admin account.

To configure authentication so that all Windows users who do not have their own MySQL account go through a proxy account, substitute the default proxy account ("@") for win_proxy in the preceding instructions. For information about default proxy accounts, see Section 6.2.11, “Proxy Users”.

Note
If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this issue, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

To use the Windows authentication plugin with Connector/NET connection strings in Connector/NET 6.4.4 and higher, see Using the Windows Native Authentication Plugin.

6.4.1.6 Socket Peer-Credential Pluggable Authentication

As of MySQL 5.5.10, a server-side auth_socket authentication plugin is available that authenticates clients that connect from the local host through the Unix socket file. The plugin uses the SO_PEERCRED socket option to obtain information about the user running the client program. Thus, the plugin can be used only on systems that support the SO_PEERCRED option, such as Linux.

The source code for this plugin can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

The following table shows the plugin and library file names. The file must be located in the directory named by the plugin_dir system variable.

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>auth_socket</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td>None, see discussion</td>
</tr>
<tr>
<td>Library file</td>
<td>auth_socket.so</td>
</tr>
</tbody>
</table>

The following sections provide installation and usage information specific to socket pluggable authentication:

• Installing Socket Pluggable Authentication

• Uninstalling Socket Pluggable Authentication

• Using Socket Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”.

Installing Socket Pluggable Authentication

This section describes how to install the socket authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the plugin_dir system variable). If necessary, configure the plugin directory location by setting the value of plugin_dir at server startup.
Authentication Plugins

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in the server `my.cnf` file:

```ini
[mysqld]
plugin-load=auth_socket.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to load the plugin at runtime, use this statement:

```sql
INSTALL PLUGIN auth_socket SONAME 'auth_socket.so';
```

`INSTALL PLUGIN` loads the plugin immediately, and also registers it in the `mysql.plugins` system table to cause the server to load it for each subsequent normal startup without the need for `--plugin-load`.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```sql
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
    FROM INFORMATION_SCHEMA.PLUGINS
    WHERE PLUGIN_NAME LIKE '%socket%';
```

<table>
<thead>
<tr>
<th>PLUGIN_NAME</th>
<th>PLUGIN_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>auth_socket</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the socket plugin, see Using Socket Pluggable Authentication.

Uninstalling Socket Pluggable Authentication

The method used to uninstall the socket authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using an `INSTALL PLUGIN` statement, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

  ```sql
  UNINSTALL PLUGIN auth_socket;
  ```

Using Socket Pluggable Authentication

The socket plugin checks whether the socket user name (the operating system user name) matches the MySQL user name specified by the client program to the server, and permits the connection only if the names match.

Suppose that a MySQL account is created for an operating system user named `valerie` who is to be authenticated by the `auth_socket` plugin for connections from the local host through the socket file:

```sql
CREATE USER 'valerie'@'localhost' IDENTIFIED WITH auth_socket;
```

If a user on the local host with a login name of `stefanie` invokes `mysql` with the option `--user=valerie` to connect through the socket file, the server uses `auth_socket` to authenticate the client. The plugin determines that the `--user` option value (`valerie`) differs from the client user's name (`stephanie`) and refuses the connection. If a user named `valerie` tries the same thing, the plugin finds that the user name and the MySQL user name are both `valerie` and permits the connection. However,
the plugin refuses the connection even for valerie if the connection is made using a different protocol, such as TCP/IP.

### 6.4.1.7 Test Pluggable Authentication

MySQL includes a test plugin that checks account credentials and logs success or failure to the server error log. This is a loadable plugin (not built in) and must be installed prior to use.

The test plugin source code is separate from the server source, unlike the built-in native plugin, so it can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

**Note**

This plugin is intended for testing and development purposes, and is not for use in production environments or on servers that are exposed to public networks.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file must be located in the directory named by the plugin_dir system variable.

**Table 6.14 Plugin and Library Names for Test Authentication**

<table>
<thead>
<tr>
<th>Plugin or File</th>
<th>Plugin or File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server-side plugin</td>
<td>test_plugin_server</td>
</tr>
<tr>
<td>Client-side plugin</td>
<td>auth_test_plugin</td>
</tr>
<tr>
<td>Library file</td>
<td>auth_test_plugin.so</td>
</tr>
</tbody>
</table>

The following sections provide installation and usage information specific to test pluggable authentication:

- Installing Test Pluggable Authentication
- Uninstalling Test Pluggable Authentication
- Using Test Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.2.10, “Pluggable Authentication”.

### Installing Test Pluggable Authentication

This section describes how to install the test authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the plugin_dir system variable). If necessary, configure the plugin directory location by setting the value of plugin_dir at server startup.

To load the plugin at server startup, use the --plugin-load option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in the server my.cnf file (adjust the .so suffix for your platform as necessary):

```
[mysqld]
plugin-load=auth_test_plugin.so
```

After modifying my.cnf, restart the server to cause the new settings to take effect.

Alternatively, to load the plugin at runtime, use this statement (adjust the .so suffix for your platform as necessary):

```
INSTALL PLUGIN test_plugin_server SONAME 'auth_test_plugin.so';
```
**INSTALL PLUGIN** loads the plugin immediately, and also registers it in the `mysql.plugins` system table to cause the server to load it for each subsequent normal startup without the need for `--plugin-load`.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```sql
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
    FROM INFORMATION_SCHEMA.PLUGINS
    WHERE PLUGIN_NAME LIKE '%test_plugin%';
```

<table>
<thead>
<tr>
<th>PLUGIN_NAME</th>
<th>PLUGIN_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>test_plugin_server</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the test plugin, see Using Test Pluggable Authentication.

### Uninstalling Test Pluggable Authentication

The method used to uninstall the test authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using an `INSTALL PLUGIN` statement, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```sql
UNINSTALL PLUGIN test_plugin_server;
```

### Using Test Pluggable Authentication

To use the test authentication plugin, create an account and name that plugin in the `IDENTIFIED WITH` clause:

```sql
CREATE USER 'testuser'@'localhost' IDENTIFIED WITH test_plugin_server;
SET PASSWORD FOR 'testuser'@'localhost' = PASSWORD('testpassword');
```

Then provide the `--user` and `--password` options for that account when you connect to the server. For example:

```
shell> mysql --user=testuser --password
Enter password: testpassword
```

The plugin fetches the password as received from the client and compares it with the value stored in the `authentication_string` column of the account row in the `mysql.user` system table. If the two values match, the plugin returns the `authentication_string` value as the new effective user ID.

You can look in the server error log for a message indicating whether authentication succeeded (notice that the password is reported as the “user”):

```plaintext
[Note] Plugin test_plugin_server reported: 'successfully authenticated user testpassword'
```

### 6.4.2 MySQL Enterprise Audit

**Note**

MySQL Enterprise Audit is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see https://www.mysql.com/products/.
As of MySQL 5.5.28, MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin named audit_log. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of the box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

After you install the plugin (see Section 6.4.2.1, "Installing MySQL Enterprise Audit"), it writes an audit log file. By default, the file is named audit.log in the server data directory. To change the name of the file, set the audit_log_file system variable at server startup.

Audit log file contents are not encrypted. See Section 6.4.2.2, "MySQL Enterprise Audit Security Considerations".

The audit log file is written in XML, with auditable events encoded as <AUDIT_RECORD> elements. To select the file format, set the audit_log_format system variable at server startup. For details on file format and contents, see Section 6.4.2.3, "Audit Log File Formats".

To control what information the audit log plugin writes to its log file, set the audit_log_policy system variable. By default, this variable is set to ALL (write all auditable events), but also permits values of LOGINS or QUERIES to log only login or query events, or NONE to disable logging.

For more information about controlling how logging occurs, see Section 6.4.2.4, "Audit Log Logging Control". For descriptions of the parameters used to configure the audit log plugin, see Section 6.4.2.7, "Audit Log Options and System Variables".

If the audit log plugin is enabled, the Performance Schema (see Chapter 22, MySQL Performance Schema) has instrumentation for it. To identify the relevant instruments, use this query:

```
SELECT NAME FROM performance_schema.setup_instruments WHERE NAME LIKE '%/alog/%';
```

Changes from Older MySQL Enterprise Audit Versions

Several changes were made to the audit log plugin in MySQL 5.5.34 for better compatibility with Oracle Audit Vault.

MySQL 5.7 changed audit log file output to a new format. This format has been backported to MySQL 5.5 and it is possible to select either the old or new format using the audit_log_format system variable, which has permitted values of OLD and NEW (default OLD). The two formats differ as follows:

- Information within <AUDIT_RECORD> elements written in the old format using attributes is written in the new format using subelements.
- The new format includes more information in <AUDIT_RECORD> elements. Every element includes a RECORD_ID value providing a unique identifier. The TIMESTAMP value includes time zone information. Query records include HOST, IP, OS_LOGIN, and USER information, as well as COMMAND_CLASS and STATUS_CODE values.

Example of old <AUDIT_RECORD> format:

```
<AUDIT_RECORD
```
Example of new `<AUDIT_RECORD>` format:

```
<TIMESTAMP>2013-09-15T15:27:27 UTC</TIMESTAMP>
<RECORD_ID>3998_2013-09-15T15:27:27</RECORD_ID>
<NAME>Query</NAME>
<CONNECTION_ID>3</CONNECTION_ID>
<STATUS>0</STATUS>
<STATUS_CODE>0</STATUS_CODE>
<User>root[root] @ localhost [127.0.0.1]</User>
<OS_LOGIN></OS_LOGIN>
<HOST>localhost</HOST>
<IP>127.0.0.1</IP>
<COMMAND_CLASS>select</COMMAND_CLASS>
<SQLTEXT>SELECT 1</SQLTEXT>
</AUDIT_RECORD>
```

When the audit log plugin rotates the audit log file, it uses a different file name format. For a log file named `audit.log`, the plugin previously renamed the file to `audit.log_TIMESTAMP`. The plugin now renames the file to `audit.log_TIMESTAMP.xml` to indicate that it is an XML file.

If you change the value of `audit_log_format`, use this procedure to avoid writing log entries in one format to an existing log file that contains entries in a different format:

1. Stop the server.
2. Rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin will create a new log file, which will contain log entries in the selected format.

The API for writing audit plugins has also changed. The `mysql_event_general` structure has new members to represent client host name and IP address, command class, and external user. For more information, see Section 24.2.4.8, “Writing Audit Plugins”.

### 6.4.2.1 Installing MySQL Enterprise Audit

This section describes how to install MySQL Enterprise Audit, which is implemented using the `audit_log` plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

**Note**

If installed, the `audit_log` plugin involves some minimal overhead even when disabled. To avoid this overhead, do not install MySQL Enterprise Audit unless you plan to use it.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, configure the plugin directory location by setting the value of `plugin_dir` at server startup.

The plugin library file base name is `audit_log`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).
To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put the following lines in the server `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=audit_log.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to load the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN audit_log SONAME 'audit_log.so';
```

`INSTALL PLUGIN` loads the plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup without the need for `--plugin-load`.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
    FROM INFORMATION_SCHEMA.PLUGINS
    WHERE PLUGIN_NAME LIKE 'audit%';
```

<table>
<thead>
<tr>
<th>PLUGIN_NAME</th>
<th>PLUGIN_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>audit_log</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

If the plugin failed to initialize, check the server error log for diagnostic messages.

If the plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`, you can use the `--audit-log` option at server startup to control plugin activation. For example, to load the plugin at startup and prevent it from being removed at runtime, use these options:

```
[mysqld]
plugin-load=audit_log.so
audit-log=FORCE_PLUS_PERMANENT
```

If it is desired to prevent the server from running without the audit plugin, use `--audit-log` with a value of `FORCE` or `FORCE_PLUS_PERMANENT` to force server startup to fail if the plugin does not initialize successfully.

For additional information about the parameters used to configure operation of the `audit_log` plugin, see Section 6.4.2.7, “Audit Log Options and System Variables”.

Audit log file contents are not encrypted. See Section 6.4.2.2, “MySQL Enterprise Audit Security Considerations”.

### 6.4.2.2 MySQL Enterprise Audit Security Considerations

Contents of audit log files produced by the audit log plugin are not encrypted and may contain sensitive information, such as the text of SQL statements. For security reasons, audit log files should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log. The default file name is `audit.log` in the data directory. This can be changed by setting the `audit_log_file` system variable at server startup. Other audit log files may exist due to log rotation.

### 6.4.2.3 Audit Log File Formats

The MySQL server calls the audit log plugin to write an audit record to its log file whenever an auditable event occurs. Typically the first audit record written after plugin startup contains the server description
MySQL Enterprise Audit

and startup options. Elements following that one represent events such as client connect and disconnect events, executed SQL statements, and so forth. Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures. Contents of files referenced by statements such as `LOAD DATA` are not logged.

To select the log format that the audit log plugin uses to write its log file, set the `audit_log_format` system variable at server startup. These formats are available:

- **New-style XML format** (`audit_log_format=NEW`): An XML format that has better compatibility with Oracle Audit Vault than old-style XML format. MySQL 5.7 introduced this format, which was backported to MySQL 5.5 as of MySQL 5.5.34.

- **Old-style XML format** (`audit_log_format=OLD`): The original audit log format used by default in older MySQL series. MySQL 5.5 uses old-style XML format by default.

**Note**

Changing the value of `audit_log_format` can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the procedure described at Audit Log File Format.

Audit log file contents are not encrypted. See Section 6.4.2.2, “MySQL Enterprise Audit Security Considerations”.

The following sections describe the available audit logging formats:

- **New-Style XML Audit Log File Format**
- **Old-Style XML Audit Log File Format**

**New-Style XML Audit Log File Format**

Here is a sample log file in new-style XML format (`audit_log_format=NEW`), reformatted slightly for readability:

```xml
<?xml version="1.0" encoding="utf-8"?>
<AUDIT>
  <AUDIT_RECORD>
    <TIMESTAMP>2017-10-16T14:06:33 UTC</TIMESTAMP>
    <RECORD_ID>1_2017-10-16T14:06:33</RECORD_ID>
    <NAME>Audit</NAME>
    <SERVER_ID>1</SERVER_ID>
    <VERSION>1</VERSION>
    <STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
     --socket=/usr/local/mysql/mysql.sock
     --port=3306</STARTUP_OPTIONS>
    <OS_VERSION>i686-Linux</OS_VERSION>
    <MYSQL_VERSION>5.5.59-log</MYSQL_VERSION>
  </AUDIT_RECORD>
  <AUDIT_RECORD>
    <TIMESTAMP>2017-10-16T14:09:38 UTC</TIMESTAMP>
    <RECORD_ID>2_2017-10-16T14:06:33</RECORD_ID>
    <NAME>Connect</NAME>
    <CONNECTION_ID>5</CONNECTION_ID>
    <STATUS>0</STATUS>
    <STATUS_CODE>0</STATUS_CODE>
    <USER>root</USER>
    <OS_LOGIN/>
    <HOST>localhost</HOST>
    <IP>127.0.0.1</IP>
    <COMMAND_CLASS>connect</COMMAND_CLASS>
  </AUDIT_RECORD>
</AUDIT>
```
The audit log file is written as XML, using UTF-8 (up to 4 bytes per character). The root element is `<AUDIT>`. The root element contains `<AUDIT_RECORD>` elements, each of which provides information about an audited event. When the audit log plugin begins writing a new log file, it writes the XML declaration and opening `<AUDIT>` root element tag. When the plugin closes a log file, it writes the closing `</AUDIT>` root element tag. The closing tag is not present while the file is open.
Elements within `<AUDIT_RECORD>` elements have these characteristics:

- Some elements appear in every `<AUDIT_RECORD>` element. Others are optional and may appear depending on the audit record type.

- Order of elements within an `<AUDIT_RECORD>` element is not guaranteed.

- Element values are not fixed length. Long values may be truncated as indicated in the element descriptions given later.

- The `<`, `>`, `"`, and `&` characters are encoded as `<`, `>`, `"`, and `&`, respectively. NUL bytes (U+00) are encoded as the `?` character.

- Characters not valid as XML characters are encoded using numeric character references. Valid XML characters are:

\[
\text{#x9 | #xA | #xD | [#x20-#x7E] | [#xE000-#xFFFD] | [#x10000-#x10FFFF]}
\]

The following elements are mandatory in every `<AUDIT_RECORD>` element:

- `<NAME>`

  A string representing the type of instruction that generated the audit event, such as a command that the server received from a client.

  Example:

  `<NAME>Query</NAME>`

  Some common `<NAME>` values:

<table>
<thead>
<tr>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audit</td>
</tr>
<tr>
<td>Connect</td>
</tr>
<tr>
<td>Query</td>
</tr>
<tr>
<td>Prepare</td>
</tr>
<tr>
<td>Execute</td>
</tr>
<tr>
<td>Shutdown</td>
</tr>
<tr>
<td>Quit</td>
</tr>
<tr>
<td>NoAudit</td>
</tr>
</tbody>
</table>

  The possible values are Audit, Binlog Dump, Change user, Close stmt, Connect Out, Connect, Create DB, Daemon, Debug, Delayed insert, Drop DB, Execute, Fetch, Field List, Init DB, Kill, Long Data, NoAudit, Ping, Prepare, Processlist, Query, Quit, Refresh, Register Slave, Reset stmt, Set option, Shutdown, Sleep, Statistics, Table Dump, Time.

  With the exception of Audit and NoAudit, these values correspond to the COM_xxx command values listed in the `mysql_com.h` header file. For example, Create DB and Change user correspond to COM_CREATE_DB and COM_CHANGE_USER, respectively.

- `<RECORD_ID>`

  A unique identifier for the audit record. The value is composed from a sequence number and timestamp, in the format `SEQ_TIMESTAMP`. When the audit log plugin opens the audit log file, it initializes the sequence number to the size of the audit log file, then increments the sequence by 1 for each record logged. The timestamp is a UTC value in `YYYY-MM-DDThh:mm:ss` format indicating the date and time when the audit log plugin opened the file.

  Example:
MySQL Enterprise Audit

• **<TIMESTAMP>**

A string representing a UTC value in `YYYY-MM-DDThh:mm:ss UTC` format indicating the date and time when the audit event was generated. For example, the event corresponding to execution of an SQL statement received from a client has a `<TIMESTAMP>` value occurring after the statement finishes, not when it was received.

Example:

```xml
<TIMESTAMP>2017-10-16T14:09:45 UTC</TIMESTAMP>
```

The following elements are optional in `<AUDIT_RECORD>` elements. Many of them occur only with specific `<NAME>` element values.

• **<COMMAND_CLASS>**

A string that indicates the type of action performed.

Example:

```xml
<COMMAND_CLASS>drop_table</COMMAND_CLASS>
```

The values correspond to the `Com_` status variables that indicate command counts; for example `Com_drop_table` and `Com_select` count `DROP TABLE` and `SELECT` statements, respectively. The following statement displays the possible names:

```sql
SELECT LOWER(REPLACE(VARIABLE_NAME, 'COM_', '')) AS name
FROM INFORMATION_SCHEMA.GLOBAL_STATUS
WHERE VARIABLE_NAME LIKE 'COM%'
ORDER BY name;
```

• **<CONNECTION_ID>**

An unsigned integer representing the client connection identifier. This is the same as the value returned by the `CONNECTION_ID()` function within the session.

Example:

```xml
<CONNECTION_ID>127</CONNECTION_ID>
```

• **<DB>**

A string representing the default database name.

Example:

```xml
<DB>test</DB>
```

• **<HOST>**

A string representing the client host name.

Example:

```xml
<HOST>localhost</HOST>
```

• **<IP>**
A string representing the client IP address.
Example:

<IP>127.0.0.1</IP>

- `<MYSQL_VERSION>`

A string representing the MySQL server version. This is the same as the value of the `VERSION()` function or `version` system variable.
Example:

<MYSQL_VERSION>5.5.59-log</MYSQL_VERSION>

- `<OS_LOGIN>`

A string representing the external user (empty if none). The value may differ from the `<USER>` value, for example, if the server authenticates the client using an external authentication method.
Example:

<OS_LOGIN>jeffrey</OS_LOGIN>

- `<OS_VERSION>`

A string representing the operating system on which the server was built or is running.
Example:

<OS_VERSION>x86_64-Linux</OS_VERSION>

- `<PRIV_USER>`

A string representing the user that the server authenticated the client as. This is the user name that the server uses for privilege checking, and may differ from the `<USER>` value.
Example:

<PRIV_USER>jeffrey</PRIV_USER>

- `<PROXY_USER>`

A string representing the proxy user (see Section 6.2.11, “Proxy Users”). The value is empty if user proxying is not in effect.
Example:

<PROXY_USER>developer</PROXY_USER>

- `<SERVER_ID>`

An unsigned integer representing the server ID. This is the same as the value of the `server_id` system variable.
Example:

<SERVER_ID>1</SERVER_ID>

- `<SQLTEXT>`
A string representing the text of an SQL statement. The value can be empty. Long values may be truncated. The string, like the audit log file itself, is written using UTF-8 (up to 4 bytes per character), so the value may be the result of conversion. For example, the original statement might have been received from the client as an SJIS string.

Example:

```xml
<SQLTEXT>DELETE FROM t1</SQLTEXT>
```

- `<STARTUP_OPTIONS>`

A string representing the options that were given on the command line or in option files when the MySQL server was started. The first option is the path to the server executable.

Example:

```xml
<STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
   --port=3306 --log_output=FILE</STARTUP_OPTIONS>
```

- `<STATUS>`

An unsigned integer representing the command status: 0 for success, nonzero if an error occurred. This is the same as the value of the `mysql_errno()` C API function. See the description for `<STATUS_CODE>` for information about how it differs from `<STATUS>`.

The audit log does not contain the SQLSTATE value or error message. To see the associations between error codes, SQLSTATE values, and messages, see Section B.3.1, “Server Error Message Reference”.

Warnings are not logged.

Example:

```xml
<STATUS>1051</STATUS>
```

- `<STATUS_CODE>`

An unsigned integer representing the command status: 0 for success, 1 if an error occurred.

The `STATUS_CODE` value differs from the `STATUS` value: `STATUS_CODE` is 0 for success and 1 for error, which is compatible with the EZ_collector consumer for Audit Vault. `STATUS` is the value of the `mysql_errno()` C API function. This is 0 for success and nonzero for error, and thus is not necessarily 1 for error.

Example:

```xml
<STATUS_CODE>0</STATUS_CODE>
```

- `<USER>`

A string representing the user name sent by the client. This may differ from the `<PRIV_USER>` value.

Example:

```xml
<User>root[root] @ localhost [127.0.0.1]</USER>
```
• `<VERSION>`

An unsigned integer representing the version of the audit log file format.

Example:

```
<VERSION>1</VERSION>
```

Old-Style XML Audit Log File Format

Here is a sample log file in old-style XML format (`audit_log_format=OLD`), reformatted slightly for readability:

```xml
<?xml version="1.0" encoding="utf-8"?>
<AUDIT>
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:00 UTC"
    RECORD_ID="1_2017-10-16T14:25:00"
    NAME="Audit"
    SERVER_ID="1"
    VERSION="1"
    STARTUP_OPTIONS="--port=3306"
    OS_VERSION="i686-Linux"
    MYSQL_VERSION="5.5.59-log"/>
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="2_2017-10-16T14:25:00"
    NAME="Connect"
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root"
    OS_LOGIN=""
    HOST="localhost"
    IP="127.0.0.1"
    COMMAND_CLASS="connect"
    PRIV_USER="root"
    PROXY_USER=""
    DB="test"/>
  ...
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="6_2017-10-16T14:25:00"
    NAME="Query"
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root[root] @ localhost [127.0.0.1]"
    OS_LOGIN=""
    HOST="localhost"
    IP="127.0.0.1"
    COMMAND_CLASS="drop_table"
    SQLTEXT="DROP TABLE IF EXISTS t"/>
  ...
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="8_2017-10-16T14:25:00"
    NAME="Quit"
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root"
```

839
The audit log file is written as XML, using UTF-8 (up to 4 bytes per character). The root element is `<AUDIT>`. The root element contains `<AUDIT_RECORD>` elements, each of which provides information about an audited event. When the audit log plugin begins writing a new log file, it writes the XML declaration and opening `<AUDIT>` root element tag. When the plugin closes a log file, it writes the closing `</AUDIT>` root element tag. The closing tag is not present while the file is open.

Attributes of `<AUDIT_RECORD>` elements have these characteristics:

- Some attributes appear in every `<AUDIT_RECORD>` element. Others are optional and may appear depending on the audit record type.
- Order of attributes within an `<AUDIT_RECORD>` element is not guaranteed.
- Attribute values are not fixed length. Long values may be truncated as indicated in the attribute descriptions given later.
- The `<`, `>`, `"`, and `&` characters are encoded as `&lt;`, `&gt;`, `&quot;`, and `&amp;`, respectively. NUL bytes (U+00) are encoded as the `?` character.
- Characters not valid as XML characters are encoded using numeric character references. Valid XML characters are:

  \[
  \text{#x9} \mid \text{#xA} \mid \text{#xD} \mid \text{[#x20-#xD7FF]} \mid \text{[#xE000-#xFFFD]} \mid \text{[#x10000-#x10FFFF]}
  \]

The following attributes are mandatory in every `<AUDIT_RECORD>` element:

- **NAME**
  A string representing the type of instruction that generated the audit event, such as a command that the server received from a client.

  **Example**: NAME="Query"

Some common **NAME** values:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audit</td>
<td>When auditing starts, which may be server startup time</td>
</tr>
<tr>
<td>Connect</td>
<td>When a client connects, also known as logging in</td>
</tr>
<tr>
<td>Query</td>
<td>An SQL statement (executed directly)</td>
</tr>
<tr>
<td>Prepare</td>
<td>Preparation of an SQL statement; usually followed by Execute</td>
</tr>
<tr>
<td>Execute</td>
<td>Execution of an SQL statement; usually follows Prepare</td>
</tr>
<tr>
<td>Shutdown</td>
<td>Server shutdown</td>
</tr>
<tr>
<td>Quit</td>
<td>When a client disconnects</td>
</tr>
<tr>
<td>NoAudit</td>
<td>Auditing has been turned off</td>
</tr>
</tbody>
</table>

With the exception of "Audit" and "NoAudit", these values correspond to the COM_XXX command values listed in the mysql_com.h header file. For example, "Create DB" and "Change user" correspond to COM_CREATE_DB and COM_CHANGE_USER, respectively.

- **RECORD_ID**

A unique identifier for the audit record. The value is composed from a sequence number and timestamp, in the format SEQ_TIMESTAMP. When the audit log plugin opens the audit log file, it initializes the sequence number to the size of the audit log file, then increments the sequence by 1 for each record logged. The timestamp is a UTC value in YYYY-MM-DD hh:mm:ss format indicating the date and time when the audit log plugin opened the file.

Example: RECORD_ID="12_2017-10-16T14:25:00"

- **TIMESTAMP**

A string representing a UTC value in YYYY-MM-DD hh:mm:ss UTC format indicating the date and time when the audit event was generated. For example, the event corresponding to execution of an SQL statement received from a client has a TIMESTAMP value occurring after the statement finishes, not when it was received.

Example: TIMESTAMP="2017-10-16T14:25:32 UTC"

The following attributes are optional in <AUDIT_RECORD> elements. Many of them occur only for elements with specific values of the NAME attribute.

- **COMMAND_CLASS**

A string that indicates the type of action performed.

Example: COMMAND_CLASS="drop_table"

The values correspond to the Com_XXX status variables that indicate command counts; for example Com_drop_table and Com_select count DROP TABLE and SELECT statements, respectively. The following statement displays the possible names:

```
SELECT LOWER(REPLACE(VARIABLE_NAME, 'COM_', '')) AS name
FROM INFORMATION_SCHEMA.GLOBAL_STATUS
WHERE VARIABLE_NAME LIKE 'COM%'
ORDER BY name;
```

- **CONNECTION_ID**

An unsigned integer representing the client connection identifier. This is the same as the value returned by the CONNECTION_ID() function within the session.

Example: CONNECTION_ID="127"

- **DB**

A string representing the default database name.

Example: DB="test"

- **HOST**

A string representing the client host name.
Example: HOST="localhost"

- **IP**
  A string representing the client IP address.
  
  Example: IP="127.0.0.1"

- **MYSQL_VERSION**
  A string representing the MySQL server version. This is the same as the value of the VERSION() function or version system variable.
  
  Example: MYSQL_VERSION="5.5.31-log"

- **OS_LOGIN**
  A string representing the external user (empty if none). The value may differ from USER, for example, if the server authenticates the client using an external authentication method.
  
  Example: OS_LOGIN="jeffrey"

- **OS_VERSION**
  A string representing the operating system on which the server was built or is running.
  
  Example: OS_VERSION="x86_64-Linux"

- **PRIV_USER**
  A string representing the user that the server authenticated the client as. This is the user name that the server uses for privilege checking, and it may differ from the USER value.
  
  Example: PRIV_USER="jeffrey"

- **PROXY_USER**
  A string representing the proxy user (see Section 6.2.11, “Proxy Users”). The value is empty if user proxying is not in effect.
  
  Example: PROXY_USER="developer"

- **SERVER_ID**
  An unsigned integer representing the server ID. This is the same as the value of the server_id system variable.
  
  Example: SERVER_ID="1"

- **SQLTEXT**
  A string representing the text of an SQL statement. The value can be empty. Long values may be truncated. The string, like the audit log file itself, is written using UTF-8 (up to 4 bytes per character), so the value may be the result of conversion. For example, the original statement might have been received from the client as an SJIS string.
  
  Example: SQLTEXT="DELETE FROM t1"
MySQL Enterprise Audit

• STARTUP_OPTIONS

A string representing the options that were given on the command line or in option files when the MySQL server was started.

Example: `STARTUP_OPTIONS="--port=3306 --log_output=FILE"`

• STATUS

An unsigned integer representing the command status: 0 for success, nonzero if an error occurred. This is the same as the value of the `mysql_errno()` C API function. See the description for `STATUS_CODE` for information about how it differs from `STATUS`.

The audit log does not contain the SQLSTATE value or error message. To see the associations between error codes, SQLSTATE values, and messages, see Section B.3.1, “Server Error Message Reference”.

Warnings are not logged.

Example: `STATUS="1051"

• STATUS_CODE

An unsigned integer representing the command status: 0 for success, 1 if an error occurred.

The `STATUS_CODE` value differs from the `STATUS` value: `STATUS_CODE` is 0 for success and 1 for error, which is compatible with the EZ_collector consumer for Audit Vault. `STATUS` is the value of the `mysql_errno()` C API function. This is 0 for success and nonzero for error, and thus is not necessarily 1 for error.

Example: `STATUS_CODE="0"

• USER

A string representing the user name sent by the client. This may differ from the `PRIV_USER` value.

• VERSION

An unsigned integer representing the version of the audit log file format.

Example: `VERSION="1"

6.4.2.4 Audit Log Logging Control

This section describes how to control general characteristics of audit logging, such as the file to which the audit log plugin writes events and the format of written events.

• Audit Log File Name

• Audit Log File Format

• Audit Logging Write Strategy

• Audit Log File Space Management and Name Rotation

For additional information about the system variables that affect audit logging, see Section 6.4.2.7, “Audit Log Options and System Variables”. 
Audit Log File Name

To control the audit log file name, set the `audit_log_file` system variable at server startup. By default, the name is `audit.log` in the server data directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log.

When the audit plugin initializes, it checks whether a file with the audit log file name already exists. If so, the plugin checks whether the file ends with an `</AUDIT>` tag and truncates the tag before writing any `<AUDIT_RECORD>` elements. If the log file exists but does not end with `</AUDIT>` or the `</AUDIT>` tag cannot be truncated, the plugin considers the file malformed and fails to initialize. This can occur if the server exits unexpectedly with the audit log plugin running. No logging occurs until the problem is rectified.

Check the error log for diagnostic information:

```
[ERROR] Plugin 'audit_log' init function returned error.
```

To deal with this problem, either remove or rename the malformed log file and restart the server.

Audit Log File Format

To control the audit log file format, set the `audit_log_format` system variable at server startup. By default, the format is `OLD` (old-style XML format). For information about available formats, see Section 6.4.2.3, “Audit Log File Formats”.

**Note**

Changing the value of `audit_log_format` can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the following procedure:

1. Stop the server.
2. Either change the value of the `audit_log_file` system variable so the plugin writes to a different file, or rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin creates a new log file and writes entries to it in the selected format.

Audit Logging Write Strategy

The audit log plugin can use any of several strategies for log writes. Regardless of strategy, logging occurs on a best-effort basis, with no guarantee of consistency.

To specify a write strategy, set the `audit_log_strategy` system variable at server startup. By default, the strategy value is `ASYNCHRONOUS` and the plugin logs asynchronously to a buffer, waiting if the buffer is full. It's possible to tell the plugin not to wait (PERFORMANCE) or to log synchronously, either using file system caching (SEMISYNCHRONOUS) or forcing output with a `sync()` call after each write request (SYNCHRONOUS).

For asynchronous write strategy, the `audit_log_buffer_size` system variable is the buffer size in bytes. Set this variable at server startup to change the buffer size. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin does not allocate this buffer for nonasynchronous write strategies.

Asynchronous logging strategy has these characteristics:

- Minimal impact on server performance and scalability.
MySQL Enterprise Audit

- Blocking of threads that generate audit events for the shortest possible time; that is, time to allocate the buffer plus time to copy the event to the buffer.

- Output goes to the buffer. A separate thread handles writes from the buffer to the log file.

With asynchronous logging, the integrity of the log file may be compromised if a problem occurs during a write to the file or if the plugin does not shut down cleanly (for example, in the event that the server host exits unexpectedly). To reduce this risk, set `audit_log_strategy` to use synchronous logging.

A disadvantage of `PERFORMANCE` strategy is that it drops events when the buffer is full. For a heavily loaded server, the audit log may have events missing.

Audit Log File Space Management and Name Rotation

The audit log file has the potential to grow very large and consume a lot of disk space. To enable management of the space used by its log files, the audit log plugin provides the `audit_log_rotate_on_size` and `audit_log_flush` system variables, which control audit log file rotation and flushing. Rotation can be done manually, or automatically based on file size.

**Manual audit log file rotation.** By default, `audit_log_rotate_on_size=0` and there is no log rotation except that which you perform manually. In this case, the audit log plugin closes and reopens the log file when the `audit_log_flush` value changes from disabled to enabled. Log file renaming must be done externally to the server. Suppose that the log file name is `audit.log` and you want to maintain the three most recent log files, cycling through the names `audit.log.1` through `audit.log.3`. On Unix, perform rotation manually like this:

1. From the command line, rename the current log files:

   ```
   mv audit.log.2 audit.log.3
   mv audit.log.1 audit.log.2
   mv audit.log audit.log.1
   ```

   At this point, the plugin is still writing to the current log file, which has been renamed to `audit.log.1`.

2. Connect to the server and flush the log file so the plugin closes it and reopens a new `audit.log` file:

   ```
   SET GLOBAL audit_log_flush = ON;
   ```

**Automatic size-based audit log file rotation.** If `audit_log_rotate_on_size` is greater than 0, setting `audit_log_flush` has no effect. Instead, whenever a write to the log file causes its size to exceed the `audit_log_rotate_on_size` value, the audit log plugin closes the file, renames it, and opens a new log file.

The renamed file has a timestamp and `.xml` added to the end. For example, if the file name is `audit.log`, the plugin renames it to a value such as `audit.log.15081807937726520.xml`. The last 7 digits are a fractional second part. The first 10 digits are a Unix timestamp value that can be interpreted using the `FROM_UNIXTIME()` function:

```sql
mysql> SELECT FROM_UNIXTIME(1508180793);+
| FROM_UNIXTIME(1508180793) |
+---------------------------+
| 2017-10-16 14:06:33       |
+---------------------------+
```

**Note**

With size-based log file rotation, renamed log files do not rotate off the end of the name sequence. Instead, they have unique names and accumulate indefinitely. To...
avoid excessive space use, remove old files periodically, backing them up first as necessary.

6.4.2.5 Audit Log Filtering

The *audit_log_policy* system variable controls what kinds of information the plugin writes. By default, this variable is set to *ALL* (write all auditable events), but also permits values of *LOGINS* or *QUERIES* to log only login or query events, or *NONE* to disable logging.

6.4.2.6 Audit Log Option and Variable Reference

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>audit-log</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>audit_log_buffer_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>audit_log_file</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>audit_log_flush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>audit_log_format</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>audit_log_policy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>audit_log_rotate_on_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>audit_log_strategy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
</tbody>
</table>

6.4.2.7 Audit Log Options and System Variables

This section describes the command options and system variables that control operation of MySQL Enterprise Audit. If values specified at startup time are incorrect, the audit log plugin may fail to initialize properly and the server does not load it. In this case, the server may also produce error messages for other audit log settings because it will not recognize them.

To control activation of the *audit_log* plugin, use this option:

- `--audit-log=value`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--audit-log=[value]</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>FORCE</td>
</tr>
<tr>
<td></td>
<td>FORCE_PLUS_PERMANENT</td>
</tr>
</tbody>
</table>

This option controls how the server loads the *audit_log* plugin at startup. It is available only if the plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`. See Section 6.4.2.1, “Installing MySQL Enterprise Audit”.

846
The option value should be one of those available for plugin-loading options, as described in Section 5.5.1, “Installing and Uninstalling Plugins”. For example, `--audit-log=FORCE_PLUS_PERMANENT` tells the server to load the plugin at startup and prevents it from being removed while the server is running.

This option was added in MySQL 5.5.28.

If the audit log plugin is enabled, it exposes several system variables that permit control over logging:

```mysql
mysql> SHOW VARIABLES LIKE 'audit_log%';
+--------------------------+--------------+
| Variable_name            | Value        |
+--------------------------+--------------+
| audit_log_buffer_size    | 1048576      |
| audit_log_file           | audit.log    |
| audit_log_flush          | OFF          |
| audit_log_policy         | ALL          |
| audit_log_rotate_on_size | 0            |
| audit_log_strategy       | ASYNCHRONOUS |
+--------------------------+--------------+
```

You can set any of these variables at server startup, and some of them at runtime.

- **audit_log_buffer_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--audit-log-buffer-size=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>audit_log_buffer_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1048576</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709547520</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

When the audit log plugin writes events to the log asynchronously, it uses a buffer to store event contents prior to writing them. This variable controls the size of that buffer, in bytes. The server adjusts the value to a multiple of 4096. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin allocates this buffer only if logging is asynchronous.

This variable was added in MySQL 5.5.28.

- **audit_log_file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--audit-log-file=file_name</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>audit_log_file</code></td>
</tr>
</tbody>
</table>
The name of the file to which the audit log plugin writes events. The default value is `audit.log`. If the file name is a relative path, the server interprets it relative to the data directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log.

This variable was added in MySQL 5.5.28.

- `audit_log_flush`

When this variable is set to enabled (1 or `ON`), the audit log plugin closes and reopens its log file to flush it. (The value remains `OFF` so that you need not disable it explicitly before enabling it again to perform another flush.) Enabling this variable has no effect unless `audit_log_rotate_on_size` is 0.

This variable was added in MySQL 5.5.28.

- `audit_log_format`
**Property** | **Value**
---|---
| NEW

The audit log file format. Permitted values are OLD and NEW (default OLD). For details about each format, see Section 6.4.2.3, “Audit Log File Formats”.

Changing the value of audit_log_format can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the procedure described at Audit Log File Format.

This variable was added in MySQL 5.5.34.

- **audit_log_policy**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--audit-log-policy=value</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>System Variable</td>
<td>audit_log_policy</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>ALL</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ALL</td>
</tr>
<tr>
<td></td>
<td>LOGINS</td>
</tr>
<tr>
<td></td>
<td>QUERIES</td>
</tr>
<tr>
<td></td>
<td>NONE</td>
</tr>
</tbody>
</table>

The policy controlling the information written by the audit log plugin to its log file. The following table shows the permitted values.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>Log all events</td>
</tr>
<tr>
<td>NONE</td>
<td>Log nothing (disable the audit stream)</td>
</tr>
<tr>
<td>LOGINS</td>
<td>Log only login events</td>
</tr>
<tr>
<td>QUERIES</td>
<td>Log only query events</td>
</tr>
</tbody>
</table>

This variable was added in MySQL 5.5.28.

- **audit_log_rotate_on_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--audit-log-rotate-on-size=#</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>System Variable</td>
<td>audit_log_rotate_on_size</td>
</tr>
</tbody>
</table>
If the `audit_log_rotate_on_size` value is 0, the audit log plugin does not perform automatic log file rotation. Instead, use `audit_log_flush` to close and reopen the log on demand. In this case, manually rename the file externally to the server before flushing it.

If the `audit_log_rotate_on_size` value is greater than 0, automatic size-based log file rotation occurs. Whenever a write to the log file causes its size to exceed the `audit_log_rotate_on_size` value, the audit log plugin closes the current log file, renames it, and opens a new log file.

For more information about audit log file rotation, see Audit Log File Space Management and Name Rotation.

If you set this variable to a value that is not a multiple of 4096, it is truncated to the nearest multiple. (Thus, setting it to a value less than 4096 has the effect of setting it to 0 and no rotation occurs, except manually.)

This variable was added in MySQL 5.5.28.

- `audit_log_strategy`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--audit-log-strategy=value</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>audit_log_strategy</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>ASYNCHRONOUS</code></td>
</tr>
</tbody>
</table>
| Valid Values              | `ASYNCHRONOUS
PERFORMANCE
SEMISYNCHRONOUS
SYNCHRONOUS` |

The logging method used by the audit log plugin. These strategy values are permitted:

- `ASYNCHRONOUS`: Log asynchronously. Wait for space in the output buffer.
- `PERFORMANCE`: Log asynchronously. Drop requests for which there is insufficient space in the output buffer.
- `SEMISYNCHRONOUS`: Log synchronously. Permit caching by the operating system.
• **SYNCHRONOUS**: Log synchronously. Call `sync()` after each request.

This variable was added in MySQL 5.5.28.

### 6.4.2.8 Audit Log Restrictions

MySQL Enterprise Audit is subject to these general restrictions:

- Only SQL statements are logged. Changes made by no-SQL APIs, such as memcached, Node.js, and the NDB API, are not logged.

- Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures.

- Contents of files referenced by statements such as `LOAD DATA` are not logged.

**NDB Cluster.** It is possible to use MySQL Enterprise Audit with MySQL NDB Cluster, subject to the following conditions:

- All changes to be logged must be done using the SQL interface. Changes using no-SQL interfaces, such as those provided by the NDB API, memcached, or ClusterJ, are not logged.

- The plugin must be installed on each MySQL server that is used to execute SQL on the cluster.

- Audit plugin data must be aggregated amongst all MySQL servers used with the cluster. This aggregation is the responsibility of the application or user.
Chapter 7 Backup and Recovery

Table of Contents

7.1 Backup and Recovery Types .......................................................... 854
7.2 Database Backup Methods ......................................................... 857
7.3 Example Backup and Recovery Strategy ...................................... 859
  7.3.1 Establishing a Backup Policy .................................................. 860
  7.3.2 Using Backups for Recovery .................................................... 862
  7.3.3 Backup Strategy Summary ...................................................... 862
7.4 Using mysqldump for Backups .................................................... 863
  7.4.1 Dumping Data in SQL Format with mysqldump ......................... 863
  7.4.2 Reloading SQL-Format Backups ............................................. 864
  7.4.3 Dumping Data in Delimited-Text Format with mysqldump ......... 865
  7.4.4 Reloading Delimited-Text Format Backups .............................. 866
  7.4.5 mysqldump Tips .................................................................. 866
7.5 Point-in-Time (Incremental) Recovery Using the Binary Log .......... 868
  7.5.1 Point-in-Time Recovery Using Event Times ......................... 870
  7.5.2 Point-in-Time Recovery Using Event Positions ................. 870
7.6 MyISAM Table Maintenance and Crash Recovery .......................... 871
  7.6.1 Using myisamchk for Crash Recovery ..................................... 871
  7.6.2 How to Check MyISAM Tables for Errors .............................. 872
  7.6.3 How to Repair MyISAM Tables .............................................. 873
  7.6.4 MyISAM Table Optimization .................................................. 875
  7.6.5 Setting Up a MyISAM Table Maintenance Schedule ................ 876

It is important to back up your databases so that you can recover your data and be up and running again in case problems occur, such as system crashes, hardware failures, or users deleting data by mistake. Backups are also essential as a safeguard before upgrading a MySQL installation, and they can be used to transfer a MySQL installation to another system or to set up replication slave servers.

MySQL offers a variety of backup strategies from which you can choose the methods that best suit the requirements for your installation. This chapter discusses several backup and recovery topics with which you should be familiar:

- Types of backups: Logical versus physical, full versus incremental, and so forth.
- Methods for creating backups.
- Recovery methods, including point-in-time recovery.
- Backup scheduling, compression, and encryption.
- Table maintenance, to enable recovery of corrupt tables.

Additional Resources

Resources related to backup or to maintaining data availability include the following:

- Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product for backups. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.
Backup and Recovery Types

• A forum dedicated to backup issues is available at https://forums.mysql.com/list.php?28.

• Details for mysqldump, mysqlhotcopy, and other MySQL backup programs can be found in Chapter 4, MySQL Programs.

• The syntax of the SQL statements described here is given in Chapter 13, SQL Statements.

• For additional information about InnoDB backup procedures, see Section 14.21.1, “InnoDB Backup”.

• Replication enables you to maintain identical data on multiple servers. This has several benefits, such as enabling client query load to be distributed over servers, availability of data even if a given server is taken offline or fails, and the ability to make backups with no impact on the master by using a slave server. See Chapter 17, Replication.

• NDB Cluster provides a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. See Chapter 18, MySQL NDB Cluster 7.2. For information specifically about NDB Cluster backup, see Section 18.5.3, “Online Backup of NDB Cluster”.

• Distributed Replicated Block Device (DRBD) is another high-availability solution. It works by replicating a block device from a primary server to a secondary server at the block level. See Chapter 16, High Availability and Scalability.

7.1 Backup and Recovery Types

This section describes the characteristics of different types of backups.

Physical (Raw) Versus Logical Backups

Physical backups consist of raw copies of the directories and files that store database contents. This type of backup is suitable for large, important databases that need to be recovered quickly when problems occur.

Logical backups save information represented as logical database structure (CREATE DATABASE, CREATE TABLE statements) and content (INSERT statements or delimited-text files). This type of backup is suitable for smaller amounts of data where you might edit the data values or table structure, or recreate the data on a different machine architecture.

Physical backup methods have these characteristics:

• The backup consists of exact copies of database directories and files. Typically this is a copy of all or part of the MySQL data directory.

• Physical backup methods are faster than logical because they involve only file copying without conversion.

• Output is more compact than for logical backup.

• Because backup speed and compactness are important for busy, important databases, the MySQL Enterprise Backup product performs physical backups. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.

• Backup and restore granularity ranges from the level of the entire data directory down to the level of individual files. This may or may not provide for table-level granularity, depending on storage engine. For example, InnoDB tables can each be in a separate file, or share file storage with other InnoDB tables; each MyISAM table corresponds uniquely to a set of files.

• In addition to databases, the backup can include any related files such as log or configuration files.
Online Versus Offline Backups

- Data from MEMORY tables is tricky to back up this way because their contents are not stored on disk. (The MySQL Enterprise Backup product has a feature where you can retrieve data from MEMORY tables during a backup.)

- Backups are portable only to other machines that have identical or similar hardware characteristics.

- Backups can be performed while the MySQL server is not running. If the server is running, it is necessary to perform appropriate locking so that the server does not change database contents during the backup. MySQL Enterprise Backup does this locking automatically for tables that require it.

- Physical backup tools include the mysqlbackup of MySQL Enterprise Backup for InnoDB or any other tables, file system-level commands (such as cp, scp, tar, rsync), or mysqlhotcopy for MyISAM tables.

- For restore:
  - MySQL Enterprise Backup restores InnoDB and other tables that it backed up.
  - ndb_restore restores NDB tables.
  - Files copied at the file system level or with mysqlhotcopy can be copied back to their original locations with file system commands.

Logical backup methods have these characteristics:

- The backup is done by querying the MySQL server to obtain database structure and content information.

- Backup is slower than physical methods because the server must access database information and convert it to logical format. If the output is written on the client side, the server must also send it to the backup program.

- Output is larger than for physical backup, particularly when saved in text format.

- Backup and restore granularity is available at the server level (all databases), database level (all tables in a particular database), or table level. This is true regardless of storage engine.

- The backup does not include log or configuration files, or other database-related files that are not part of databases.

- Backups stored in logical format are machine independent and highly portable.

- Logical backups are performed with the MySQL server running. The server is not taken offline.

- Logical backup tools include the mysqldump program and the SELECT ... INTO OUTFILE statement. These work for any storage engine, even MEMORY.

- To restore logical backups, SQL-format dump files can be processed using the mysql client. To load delimited-text files, use the LOAD DATA statement or the mysqlimport client.

Online Versus Offline Backups

Online backups take place while the MySQL server is running so that the database information can be obtained from the server. Offline backups take place while the server is stopped. This distinction can also be described as “hot” versus “cold” backups; a “warm” backup is one where the server remains running but locked against modifying data while you access database files externally.

Online backup methods have these characteristics:
• The backup is less intrusive to other clients, which can connect to the MySQL server during the backup and may be able to access data depending on what operations they need to perform.

• Care must be taken to impose appropriate locking so that data modifications do not take place that would compromise backup integrity. The MySQL Enterprise Backup product does such locking automatically.

Offline backup methods have these characteristics:

• Clients can be affected adversely because the server is unavailable during backup. For that reason, such backups are often taken from a replication slave server that can be taken offline without harming availability.

• The backup procedure is simpler because there is no possibility of interference from client activity.

A similar distinction between online and offline applies for recovery operations, and similar characteristics apply. However, it is more likely that clients will be affected for online recovery than for online backup because recovery requires stronger locking. During backup, clients might be able to read data while it is being backed up. Recovery modifies data and does not just read it, so clients must be prevented from accessing data while it is being restored.

Local Versus Remote Backups

A local backup is performed on the same host where the MySQL server runs, whereas a remote backup is done from a different host. For some types of backups, the backup can be initiated from a remote host even if the output is written locally on the server.

• `mysqldump` can connect to local or remote servers. For SQL output (`CREATE` and `INSERT` statements), local or remote dumps can be done and generate output on the client. For delimited-text output (with the `--tab` option), data files are created on the server host.

• `mysqlhotcopy` performs only local backups: It connects to the server to lock it against data modifications and then copies local table files.

• `SELECT ... INTO OUTFILE` can be initiated from a local or remote client host, but the output file is created on the server host.

• Physical backup methods typically are initiated locally on the MySQL server host so that the server can be taken offline, although the destination for copied files might be remote.

Snapshot Backups

Some file system implementations enable “snapshots” to be taken. These provide logical copies of the file system at a given point in time, without requiring a physical copy of the entire file system. (For example, the implementation may use copy-on-write techniques so that only parts of the file system modified after the snapshot time need be copied.) MySQL itself does not provide the capability for taking file system snapshots. It is available through third-party solutions such as Veritas, LVM, or ZFS.

Full Versus Incremental Backups

A full backup includes all data managed by a MySQL server at a given point in time. An incremental backup consists of the changes made to the data during a given time span (from one point in time to another). MySQL has different ways to perform full backups, such as those described earlier in this section. Incremental backups are made possible by enabling the server's binary log, which the server uses to record data changes.
Full Versus Point-in-Time (Incremental) Recovery

A full recovery restores all data from a full backup. This restores the server instance to the state that it had when the backup was made. If that state is not sufficiently current, a full recovery can be followed by recovery of incremental backups made since the full backup, to bring the server to a more up-to-date state.

Incremental recovery is recovery of changes made during a given time span. This is also called point-in-time recovery because it makes a server’s state current up to a given time. Point-in-time recovery is based on the binary log and typically follows a full recovery from the backup files that restores the server to its state when the backup was made. Then the data changes written in the binary log files are applied as incremental recovery to redo data modifications and bring the server up to the desired point in time.

Table Maintenance

Data integrity can be compromised if tables become corrupt. For InnoDB tables, this is not a typical issue. For programs to check MyISAM tables and repair them if problems are found, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

Backup Scheduling, Compression, and Encryption

Backup scheduling is valuable for automating backup procedures. Compression of backup output reduces space requirements, and encryption of the output provides better security against unauthorized access of backed-up data. MySQL itself does not provide these capabilities. The MySQL Enterprise Backup product can compress InnoDB backups, and compression or encryption of backup output can be achieved using file system utilities. Other third-party solutions may be available.

7.2 Database Backup Methods

This section summarizes some general methods for making backups.

Making a Hot Backup with MySQL Enterprise Backup

Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product to do physical backups of entire instances or selected databases, tables, or both. This product includes features for incremental and compressed backups. Backing up the physical database files makes restore much faster than logical techniques such as the mysqldump command. InnoDB tables are copied using a hot backup mechanism. (Ideally, the InnoDB tables should represent a substantial majority of the data.) Tables from other storage engines are copied using a warm backup mechanism. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.

Making Backups with mysqldump or mysqlhotcopy

The mysqldump program and the mysqlhotcopy script can make backups. mysqldump is more general because it can back up all kinds of tables. mysqlhotcopy works only with some storage engines. (See Section 7.4, “Using mysqldump for Backups”, and Section 4.6.9, “mysqlhotcopy — A Database Backup Program”.)

For InnoDB tables, it is possible to perform an online backup that takes no locks on tables using the --single-transaction option to mysqldump. See Section 7.3.1, “Establishing a Backup Policy”.

Making Backups by Copying Table Files

For storage engines that represent each table using its own files, tables can be backed up by copying those files. For example, MyISAM tables are stored as files, so it is easy to do a backup by copying files...
Making Delimited-Text File Backups

To get a consistent backup, stop the server or lock and flush the relevant tables:

``` sql
FLUSH TABLES tbl_list WITH READ LOCK;
```

You need only a read lock; this enables other clients to continue to query the tables while you are making a copy of the files in the database directory. The flush is needed to ensure that the all active index pages are written to disk before you start the backup. See Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”, and Section 13.7.6.3, “FLUSH Statement”.

You can also create a binary backup simply by copying all table files, as long as the server isn't updating anything. The `mysqlhotcopy` script uses this method. (But note that table file copying methods do not work if your database contains InnoDB tables. `mysqlhotcopy` does not work for InnoDB tables because InnoDB does not necessarily store table contents in database directories. Also, even if the server is not actively updating data, InnoDB may still have modified data cached in memory and not flushed to disk.)

### Making Delimited-Text File Backups

To create a text file containing a table's data, you can use `SELECT * INTO OUTFILE 'file_name' FROM tbl_name`. The file is created on the MySQL server host, not the client host. For this statement, the output file cannot already exist because permitting files to be overwritten constitutes a security risk. See Section 13.2.9, “SELECT Statement”. This method works for any kind of data file, but saves only table data, not the table structure.

Another way to create text data files (along with files containing `CREATE TABLE` statements for the backed up tables) is to use `mysqldump` with the `--tab` option. See Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”.

To reload a delimited-text data file, use `LOAD DATA` or `mysqlimport`.

### Making Incremental Backups by Enabling the Binary Log

MySQL supports incremental backups: You must start the server with the `--log-bin` option to enable binary logging; see Section 5.4.4, “The Binary Log”. The binary log files provide you with the information you need to replicate changes to the database that are made subsequent to the point at which you performed a backup. At the moment you want to make an incremental backup (containing all changes that happened since the last full or incremental backup), you should rotate the binary log by using `FLUSH LOGS`. This done, you need to copy to the backup location all binary logs which range from the one of the moment of the last full or incremental backup to the last but one. These binary logs are the incremental backup; at restore time, you apply them as explained in Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”. The next time you do a full backup, you should also rotate the binary log using `FLUSH LOGS`, `mysqldump --flush-logs`, or `mysqlhotcopy --flushlog`. See Section 4.5.4, "mysqldump — A Database Backup Program", and Section 4.6.9, "mysqlhotcopy — A Database Backup Program".

### Making Backups Using Replication Slaves

If you have performance problems with your master server while making backups, one strategy that can help is to set up replication and perform backups on the slave rather than on the master. See Section 17.3.1, “Using Replication for Backups”.

If you are backing up a slave replication server, you should back up its `master.info` and `relay-log.info` files when you back up the slave's databases, regardless of the backup method you choose. These information files are always needed to resume replication after you restore the slave's data. If your slave is replicating `LOAD DATA` statements, you should also back up any `SQL_LOAD--*` files that exist in
Recovering Corrupt Tables

the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted \texttt{LOAD DATA} operations. The location of this directory is the value of the \texttt{slave_load_tmpdir} system variable. If the server was not started with that variable set, the directory location is the value of the \texttt{tmpdir} system variable.

Recovering Corrupt Tables

If you have to restore MyISAM tables that have become corrupt, try to recover them using \texttt{REPAIR TABLE} or \texttt{myisamchk -r} first. That should work in 99.9\% of all cases. If \texttt{myisamchk} fails, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

Making Backups Using a File System Snapshot

If you are using a Veritas file system, you can make a backup like this:

1. From a client program, execute \texttt{FLUSH TABLES WITH READ LOCK}.
2. From another shell, execute \texttt{mount vxfs snapshot}.
3. From the first client, execute \texttt{UNLOCK TABLES}.
4. Copy files from the snapshot.
5. Unmount the snapshot.

Similar snapshot capabilities may be available in other file systems, such as LVM or ZFS.

7.3 Example Backup and Recovery Strategy

This section discusses a procedure for performing backups that enables you to recover data after several types of crashes:

- Operating system crash
- Power failure
- File system crash
- Hardware problem (hard drive, motherboard, and so forth)

The example commands do not include options such as \texttt{--user} and \texttt{--password} for the \texttt{mysqldump} and \texttt{mysql} client programs. You should include such options as necessary to enable client programs to connect to the MySQL server.

Assume that data is stored in the InnoDB storage engine, which has support for transactions and automatic crash recovery. Assume also that the MySQL server is under load at the time of the crash. If it were not, no recovery would ever be needed.

For cases of operating system crashes or power failures, we can assume that MySQL’s disk data is available after a restart. The InnoDB data files might not contain consistent data due to the crash, but InnoDB reads its logs and finds in them the list of pending committed and noncommitted transactions that have not been flushed to the data files. InnoDB automatically rolls back those transactions that were not committed, and flushes to its data files those that were committed. Information about this recovery process is conveyed to the user through the MySQL error log. The following is an example log excerpt:

```plaintext
InnoDB: Database was not shut down normally.
InnoDB: Starting recovery from log files...
```
For the cases of file system crashes or hardware problems, we can assume that the MySQL disk data is not available after a restart. This means that MySQL fails to start successfully because some blocks of disk data are no longer readable. In this case, it is necessary to reformat the disk, install a new one, or otherwise correct the underlying problem. Then it is necessary to recover our MySQL data from backups, which means that backups must already have been made. To make sure that is the case, design and implement a backup policy.

### 7.3.1 Establishing a Backup Policy

To be useful, backups must be scheduled regularly. A full backup (a snapshot of the data at a point in time) can be done in MySQL with several tools. For example, MySQL Enterprise Backup can perform a physical backup of an entire instance, with optimizations to minimize overhead and avoid disruption when backing up InnoDB data files; mysqldump provides online logical backup. This discussion uses mysqldump.

Assume that we make a full backup of all our InnoDB tables in all databases using the following command on Sunday at 1 p.m., when load is low:

```shell
mysqldump --all-databases --master-data --single-transaction > backup_sunday_1_PM.sql
```

The resulting `.sql` file produced by mysqldump contains a set of SQL INSERT statements that can be used to reload the dumped tables at a later time.

This backup operation acquires a global read lock on all tables at the beginning of the dump (using `FLUSH TABLES WITH READ LOCK`). As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the `FLUSH` statement is issued, the backup operation may stall until those statements finish. After that, the dump becomes lock-free and does not disturb reads and writes on the tables.

It was assumed earlier that the tables to back up are InnoDB tables, so `--single-transaction` uses a consistent read and guarantees that data seen by mysqldump does not change. (Changes made by other clients to InnoDB tables are not seen by the mysqldump process.) If the backup operation includes nontransactional tables, consistency requires that they do not change during the backup. For example, for the MyISAM tables in the mysql database, there must be no administrative changes to MySQL accounts during the backup.

Full backups are necessary, but it is not always convenient to create them. They produce large backup files and take time to generate. They are not optimal in the sense that each successive full backup includes all data, even that part that has not changed since the previous full backup. It is more efficient to make an initial full backup, and then to make incremental backups. The incremental backups are smaller and take

---

InnoDB: Starting log scan based on checkpoint at
InnoDB: log sequence number 0 13674004
InnoDB: Doing recovery: scanned up to log sequence number 0 13805056
InnoDB: Doing recovery: scanned up to log sequence number 0 13870592
InnoDB: Doing recovery: scanned up to log sequence number 0 13936128
...
Establishing a Backup Policy

less time to produce. The tradeoff is that, at recovery time, you cannot restore your data just by reloading the full backup. You must also process the incremental backups to recover the incremental changes.

To make incremental backups, we need to save the incremental changes. In MySQL, these changes are represented in the binary log, so the MySQL server should always be started with the --log-bin option to enable that log. With binary logging enabled, the server writes each data change into a file while it updates data. Looking at the data directory of a MySQL server that was started with the --log-bin option and that has been running for some days, we find these MySQL binary log files:

```
-rw-rw---- 1 guilhem guilhem   1277324 Nov 10 23:59 gbichot2-bin.000001
-rw-rw---- 1 guilhem guilhem       4 Nov 10 23:59 gbichot2-bin.000002
-rw-rw---- 1 guilhem guilhem       79 Nov 11 11:06 gbichot2-bin.000003
-rw-rw---- 1 guilhem guilhem       508 Nov 11 11:08 gbichot2-bin.000004
-rw-rw---- 1 guilhem guilhem 220047446 Nov 12 16:47 gbichot2-bin.000005
-rw-rw---- 1 guilhem guilhem       988412 Nov 14 10:08 gbichot2-bin.000006
-rw-rw---- 1 guilhem guilhem       361 Nov 14 10:07 gbichot2-bin.index
```

Each time it restarts, the MySQL server creates a new binary log file using the next number in the sequence. While the server is running, you can also tell it to close the current binary log file and begin a new one manually by issuing a FLUSH LOGS SQL statement or with a mysqladmin flush-logs command. mysqldump also has an option to flush the logs. The .index file in the data directory contains the list of all MySQL binary logs in the directory.

The MySQL binary logs are important for recovery because they form the set of incremental backups. If you make sure to flush the logs when you make your full backup, the binary log files created afterward contain all the data changes made since the backup. Let’s modify the previous mysqldump command a bit so that it flushes the MySQL binary logs at the moment of the full backup, and so that the dump file contains the name of the new current binary log:

```
shell> mysqldump --single-transaction --flush-logs --master-data=2 --all-databases > backup_sunday_1_PM.sql
```

After executing this command, the data directory contains a new binary log file, gbichot2-bin.000007, because the --flush-logs option causes the server to flush its logs. The --master-data option causes mysqldump to write binary log information to its output, so the resulting .sql dump file includes these lines:

```
-- Position to start replication or point-in-time recovery from
-- CHANGE MASTER TO MASTER_LOG_FILE='gbichot2-bin.000007',MASTER_LOG_POS=4;
```

Because the mysqldump command made a full backup, those lines mean two things:

- The dump file contains all changes made before any changes written to the gbichot2-bin.000007 binary log file or higher.
- All data changes logged after the backup are not present in the dump file, but are present in the gbichot2-bin.000007 binary log file or higher.

On Monday at 1 p.m., we can create an incremental backup by flushing the logs to begin a new binary log file. For example, executing a mysqladmin flush-logs command creates gbichot2-bin.000008. All changes between the Sunday 1 p.m. full backup and Monday 1 p.m. will be in the gbichot2-bin.000008 file. This incremental backup is important, so it is a good idea to copy it to a safe place. (For example, back it up on tape or DVD, or copy it to another machine.) On Tuesday at 1 p.m., execute another mysqladmin flush-logs command. All changes between Monday 1 p.m. and Tuesday 1 p.m. will be in the gbichot2-bin.000008 file (which also should be copied somewhere safe).

The MySQL binary logs take up disk space. To free up space, purge them from time to time. One way to do this is by deleting the binary logs that are no longer needed, such as when we make a full backup:
7.3.2 Using Backups for Recovery

Now, suppose that we have a catastrophic crash on Wednesday at 8 a.m. that requires recovery from backups. To recover, first we restore the last full backup we have (the one from Sunday 1 p.m.). The full backup file is just a set of SQL statements, so restoring it is very easy:

```
shell> mysql < backup_sunday_1_PM.sql
```

At this point, the data is restored to its state as of Sunday 1 p.m.. To restore the changes made since then, we must use the incremental backups; that is, the gbichot2-bin.000007 and gbichot2-bin.000008 binary log files. Fetch the files if necessary from where they were backed up, and then process their contents like this:

```
shell> mysqlbinlog gbichot2-bin.000007 gbichot2-bin.000008 | mysql
```

We now have recovered the data to its state as of Tuesday 1 p.m., but still are missing the changes from that date to the date of the crash. To not lose them, we would have needed to have the MySQL server store its MySQL binary logs into a safe location (RAID disks, SAN, ...) different from the place where it stores its data files, so that these logs were not on the destroyed disk. (That is, we can start the server with a --log-bin option that specifies a location on a different physical device from the one on which the data directory resides. That way, the logs are safe even if the device containing the directory is lost.) If we had done this, we would have the gbichot2-bin.000009 file (and any subsequent files) at hand, and we could apply them using mysqlbinlog and mysql to restore the most recent data changes with no loss up to the moment of the crash:

```
shell> mysqlbinlog gbichot2-bin.000009 ... | mysql
```

For more information about using mysqlbinlog to process binary log files, see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

7.3.3 Backup Strategy Summary

In case of an operating system crash or power failure, InnoDB itself does all the job of recovering data. But to make sure that you can sleep well, observe the following guidelines:

- Always run the MySQL server with the --log-bin option, or even --log-bin=log_name, where the log file name is located on some safe media different from the drive on which the data directory is located. If you have such safe media, this technique can also be good for disk load balancing (which results in a performance improvement).

- Make periodic full backups, using the mysqldump command shown earlier in Section 7.3.1, “Establishing a Backup Policy”, that makes an online, nonblocking backup.

- Make periodic incremental backups by flushing the logs with FLUSH LOGS or mysqladmin flush-logs.
7.4 Using mysqldump for Backups

This section describes how to use mysqldump to produce dump files, and how to reload dump files. A dump file can be used in several ways:

- As a backup to enable data recovery in case of data loss.
- As a source of data for setting up replication slaves.
- As a source of data for experimentation:
  - To make a copy of a database that you can use without changing the original data.
  - To test potential upgrade incompatibilities.

mysqldump produces two types of output, depending on whether the --tab option is given:

- Without --tab, mysqldump writes SQL statements to the standard output. This output consists of CREATE statements to create dumped objects (databases, tables, stored routines, and so forth), and INSERT statements to load data into tables. The output can be saved in a file and reloaded later using mysql to recreate the dumped objects. Options are available to modify the format of the SQL statements, and to control which objects are dumped.

- With --tab, mysqldump produces two output files for each dumped table. The server writes one file as tab-delimited text, one line per table row. This file is named tbl_name.txt in the output directory. The server also sends a CREATE TABLE statement for the table to mysqldump, which writes it as a file named tbl_name.sql in the output directory.

7.4.1 Dumping Data in SQL Format with mysqldump

This section describes how to use mysqldump to create SQL-format dump files. For information about reloading such dump files, see Section 7.4.2, “Reloading SQL-Format Backups”.

By default, mysqldump writes information as SQL statements to the standard output. You can save the output in a file:

shell> mysqldump [arguments] > file_name

To dump all databases, invoke mysqldump with the --all-databases option:

shell> mysqldump --all-databases > dump.sql

To dump only specific databases, name them on the command line and use the --databases option:

shell> mysqldump --databases db1 db2 db3 > dump.sql

The --databases option causes all names on the command line to be treated as database names. Without this option, mysqldump treats the first name as a database name and those following as table names.

With --all-databases or --databases, mysqldump writes CREATE DATABASE and USE statements prior to the dump output for each database. This ensures that when the dump file is reloaded, it creates each database if it does not exist and makes it the default database so database contents are loaded into the same database from which they came. If you want to cause the dump file to force a drop of each database before recreating it, use the --add-drop-database option as well. In this case, mysqldump writes a DROP DATABASE statement preceding each CREATE DATABASE statement.

To dump a single database, name it on the command line:
Reloading SQL-Format Backups

```
shell> mysqldump --databases test > dump.sql
```

In the single-database case, it is permissible to omit the `--databases` option:

```
shell> mysqldump test > dump.sql
```

The difference between the two preceding commands is that without `--databases`, the dump output contains no `CREATE DATABASE` or `USE` statements. This has several implications:

- When you reload the dump file, you must specify a default database name so that the server knows which database to reload.
- For reloading, you can specify a database name different from the original name, which enables you to reload the data into a different database.
- If the database to be reloaded does not exist, you must create it first.
- Because the output will contain no `CREATE DATABASE` statement, the `--add-drop-database` option has no effect. If you use it, it produces no `DROP DATABASE` statement.

To dump only specific tables from a database, name them on the command line following the database name:

```
shell> mysqldump test t1 t3 t7 > dump.sql
```

### 7.4.2 Reloading SQL-Format Backups

To reload a dump file written by `mysqldump` that consists of SQL statements, use it as input to the `mysql` client. If the dump file was created by `mysqldump` with the `--all-databases` or `--databases` option, it contains `CREATE DATABASE` and `USE` statements and it is not necessary to specify a default database into which to load the data:

```
shell> mysql < dump.sql
```

Alternatively, from within `mysql`, use a `source` command:

```
mysql> source dump.sql
```

If the file is a single-database dump not containing `CREATE DATABASE` and `USE` statements, create the database first (if necessary):

```
shell> mysqladmin create db1
```

Then specify the database name when you load the dump file:

```
shell> mysql db1 < dump.sql
```

Alternatively, from within `mysql`, create the database, select it as the default database, and load the dump file:

```
mysql> CREATE DATABASE IF NOT EXISTS db1;
mysql> USE db1;
mysql> source dump.sql
```

---

**Note**

For Windows PowerShell users: Because the "<" character is reserved for future use in PowerShell, an alternative approach is required, such as using quotes `cmd.exe /c "mysql < dump.sql"`. 

864
7.4.3 Dumping Data in Delimited-Text Format with mysqldump

This section describes how to use `mysqldump` to create delimited-text dump files. For information about reloading such dump files, see Section 7.4.4, "Reloading Delimited-Text Format Backups".

If you invoke `mysqldump` with the `--tab=dir_name` option, it uses `dir_name` as the output directory and dumps tables individually in that directory using two files for each table. The table name is the base name for these files. For a table named `t1`, the files are named `t1.sql` and `t1.txt`. The `.sql` file contains a `CREATE TABLE` statement for the table. The `.txt` file contains the table data, one line per table row.

The following command dumps the contents of the `db1` database to files in the `/tmp` database:

```
shell> mysqldump --tab=/tmp db1
```

The `.txt` files containing table data are written by the server, so they are owned by the system account used for running the server. The server uses `SELECT ... INTO OUTFILE` to write the files, so you must have the `FILE` privilege to perform this operation, and an error occurs if a given `.txt` file already exists.

The server sends the `CREATE` definitions for dumped tables to `mysqldump`, which writes them to `.sql` files. These files therefore are owned by the user who executes `mysqldump`.

It is best that `--tab` be used only for dumping a local server. If you use it with a remote server, the `--tab` directory must exist on both the local and remote hosts, and the `.txt` files will be written by the server in the remote directory (on the server host), whereas the `.sql` files will be written by `mysqldump` in the local directory (on the client host).

For `mysqldump --tab`, the server by default writes table data to `.txt` files one line per row with tabs between column values, no quotation marks around column values, and newline as the line terminator. (These are the same defaults as for `SELECT ... INTO OUTFILE`.)

To enable data files to be written using a different format, `mysqldump` supports these options:

- `--fields-terminated-by=str`
  The string for separating column values (default: tab).

- `--fields-enclosed-by=char`
  The character within which to enclose column values (default: no character).

- `--fields-optionally-enclosed-by=char`
  The character within which to enclose non-numeric column values (default: no character).

- `--fields-escaped-by=char`
  The character for escaping special characters (default: no escaping).

- `--lines-terminated-by=str`
  The line-termination string (default: newline).

Depending on the value you specify for any of these options, it might be necessary on the command line to quote or escape the value appropriately for your command interpreter. Alternatively, specify the value using hex notation. Suppose that you want `mysqldump` to quote column values within double quotation marks. To do so, specify double quote as the value for the `--fields-enclosed-by` option. But this character is often special to command interpreters and must be treated specially. For example, on Unix, you can quote the double quote like this:
On any platform, you can specify the value in hex:

```bash
--fields-enclosed-by=0x22
```

It is common to use several of the data-formatting options together. For example, to dump tables in comma-separated values format with lines terminated by carriage-return/newline pairs (\r\n), use this command (enter it on a single line):

```bash
shell> mysqldump --tab=/tmp --fields-terminated-by=,
               --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1
```

Should you use any of the data-formatting options to dump table data, you will need to specify the same format when you reload data files later, to ensure proper interpretation of the file contents.

### 7.4.4 Reloading Delimited-Text Format Backups

For backups produced with `mysqldump --tab`, each table is represented in the output directory by an `.sql` file containing the `CREATE TABLE` statement for the table, and a `.txt` file containing the table data. To reload a table, first change location into the output directory. Then process the `.sql` file with `mysql` to create an empty table and process the `.txt` file to load the data into the table:

```bash
shell> mysql db1 < t1.sql
shell> mysqlimport db1 t1.txt
```

An alternative to using `mysqlimport` to load the data file is to use the `LOAD DATA` statement from within the `mysql` client:

```sql
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1;
```

If you used any data-formatting options with `mysqldump` when you initially dumped the table, you must use the same options with `mysqlimport` or `LOAD DATA` to ensure proper interpretation of the data file contents:

```bash
shell> mysqlimport --fields-terminated-by=,
            --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1 t1.txt
```

Or:

```sql
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1
            FIELDS TERMINATED BY ',' FIELDS ENCLOSED BY '"'
            LINES TERMINATED BY '\r\n';
```

### 7.4.5 mysqldump Tips

This section surveys techniques that enable you to use `mysqldump` to solve specific problems:

- How to make a copy a database
- How to copy a database from one server to another
- How to dump stored programs (stored procedures and functions, triggers, and events)
- How to dump definitions and data separately

### 7.4.5.1 Making a Copy of a Database

```bash
shell> mysqldump db1 > dump.sql
```
mysqldump Tips

shell> mysqladmin create db2
shell> mysql db2 < dump.sql

Do not use \texttt{--databases} on the \texttt{mysqldump} command line because that causes \texttt{USE db1} to be included in the dump file, which overrides the effect of naming \texttt{db2} on the \texttt{mysql} command line.

7.4.5.2 Copy a Database from one Server to Another

On Server 1:

\begin{verbatim}
shell> mysqldump \--databases db1 > dump.sql
\end{verbatim}

Copy the dump file from Server 1 to Server 2.

On Server 2:

\begin{verbatim}
shell> mysql < dump.sql
\end{verbatim}

Use of \texttt{--databases} with the \texttt{mysqldump} command line causes the dump file to include \texttt{CREATE DATABASE} and \texttt{USE} statements that create the database if it does exist and make it the default database for the reloaded data.

Alternatively, you can omit \texttt{--databases} from the \texttt{mysqldump} command. Then you will need to create the database on Server 2 (if necessary) and specify it as the default database when you reload the dump file.

On Server 1:

\begin{verbatim}
shell> mysqldump db1 > dump.sql
\end{verbatim}

On Server 2:

\begin{verbatim}
shell> mysqladmin create db1
shell> mysql db1 < dump.sql
\end{verbatim}

You can specify a different database name in this case, so omitting \texttt{--databases} from the \texttt{mysqldump} command enables you to dump data from one database and load it into another.

7.4.5.3 Dumping Stored Programs

Several options control how \texttt{mysqldump} handles stored programs (stored procedures and functions, triggers, and events):

\begin{itemize}
  \item \texttt{--events}: Dump Event Scheduler events
  \item \texttt{--routines}: Dump stored procedures and functions
  \item \texttt{--triggers}: Dump triggers for tables
\end{itemize}

The \texttt{--triggers} option is enabled by default so that when tables are dumped, they are accompanied by any triggers they have. The other options are disabled by default and must be specified explicitly to dump the corresponding objects. To disable any of these options explicitly, use its skip form: \texttt{--skip-events}, \texttt{--skip-routines}, or \texttt{--skip-triggers}.

7.4.5.4 Dumping Table Definitions and Content Separately

The \texttt{--no-data} option tells \texttt{mysqldump} not to dump table data, resulting in the dump file containing only statements to create the tables. Conversely, the \texttt{--no-create-info} option tells \texttt{mysqldump} to suppress \texttt{CREATE} statements from the output, so that the dump file contains only table data.
For example, to dump table definitions and data separately for the test database, use these commands:

```shell
mysqldump --no-data test > dump-defs.sql
mysqldump --no-create-info test > dump-data.sql
```

For a definition-only dump, add the --routines and --events options to also include stored routine and event definitions:

```shell
mysqldump --no-data --routines --events test > dump-defs.sql
```

### 7.4.5.5 Using mysqldump to Test for Upgrade Incompatibilities

When contemplating a MySQL upgrade, it is prudent to install the newer version separately from your current production version. Then you can dump the database and database object definitions from the production server and load them into the new server to verify that they are handled properly. (This is also useful for testing downgrades.)

On the production server:

```shell
mysqldump --all-databases --no-data --routines --events > dump-defs.sql
```

On the upgraded server:

```shell
mysql < dump-defs.sql
```

Because the dump file does not contain table data, it can be processed quickly. This enables you to spot potential incompatibilities without waiting for lengthy data-loading operations. Look for warnings or errors while the dump file is being processed.

After you have verified that the definitions are handled properly, dump the data and try to load it into the upgraded server.

On the production server:

```shell
mysqldump --all-databases --no-create-info > dump-data.sql
```

On the upgraded server:

```shell
mysql < dump-data.sql
```

Now check the table contents and run some test queries.

### 7.5 Point-in-Time (Incremental) Recovery Using the Binary Log

Point-in-time recovery refers to recovery of data changes made since a given point in time. Typically, this type of recovery is performed after restoring a full backup that brings the server to its state as of the time the backup was made. (The full backup can be made in several ways, such as those listed in Section 7.2, “Database Backup Methods”.) Point-in-time recovery then brings the server up to date incrementally from the time of the full backup to a more recent time.

**Note**

Many of the examples here use the `mysql` client to process binary log output produced by `mysqlbinlog`. If your binary log contains `\0` (null) characters, that output cannot be parsed by `mysql` unless you invoke it with the `--binary-mode` option (available in MySQL 5.6).

Point-in-time recovery is based on these principles:
Point-in-Time (Incremental) Recovery Using the Binary Log

• The source of information for point-in-time recovery is the set of incremental backups represented by the binary log files generated subsequent to the full backup operation. Therefore, the server must be started with the `--log-bin` option to enable binary logging (see Section 5.4.4, “The Binary Log”).

To restore data from the binary log, you must know the name and location of the current binary log files. By default, the server creates binary log files in the data directory, but a path name can be specified with the `--log-bin` option to place the files in a different location. Section 5.4.4, “The Binary Log”.

To see a listing of all binary log files, use this statement:

```sql
SHOW BINARY LOGS;
```

To determine the name of the current binary log file, issue the following statement:

```sql
SHOW MASTER STATUS;
```

• The `mysqlbinlog` utility converts the events in the binary log files from binary format to text so that they can be executed or viewed. `mysqlbinlog` has options for selecting sections of the binary log based on event times or position of events within the log. See Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”.

• Executing events from the binary log causes the data modifications they represent to be redone. This enables recovery of data changes for a given span of time. To execute events from the binary log, process `mysqlbinlog` output using the `mysql` client:

```shell
mysqlbinlog binlog_files | mysql -u root -p
```

• Viewing log contents can be useful when you need to determine event times or positions to select partial log contents prior to executing events. To view events from the log, send `mysqlbinlog` output into a paging program:

```shell
mysqlbinlog binlog_files | more
```

Alternatively, save the output in a file and view the file in a text editor:

```shell
touch tmpfile
echo "" > tmpfile
```

```shell
... edit tmpfile ...
```

• Saving the output in a file is useful as a preliminary to executing the log contents with certain events removed, such as an accidental `DROP DATABASE`. You can delete from the file any statements not to be executed before executing its contents. After editing the file, execute the contents as follows:

```shell
mysql -u root -p < tmpfile
```

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be `unsafe`:

```shell
mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using different connections to the server causes problems if the first log file contains a `CREATE TEMPORARY TABLE` statement and the second log contains a statement that uses the temporary table. When the first `mysql` process terminates, the server drops the temporary table. When the second `mysql` process attempts to use the table, the server reports “unknown table.”

To avoid problems like this, use a `single` connection to execute the contents of all binary logs that you want to process. Here is one way to do so:

```shell
mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```
Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 > /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
shell> mysql -u root -p -e "source /tmp/statements.sql"
```

### 7.5.1 Point-in-Time Recovery Using Event Times

To indicate the start and end times for recovery, specify the `--start-datetime` and `--stop-datetime` options for `mysqlbinlog`, in DATETIME format. As an example, suppose that exactly at 10:00 a.m. on April 20, 2005 an SQL statement was executed that deleted a large table. To restore the table and data, you could restore the previous night's backup, and then execute the following command:

```
shell> mysqlbinlog --stop-datetime="2005-04-20 9:59:59" \
/var/log/mysql/bin.123456 | mysql -u root -p
```

This command recovers all of the data up until the date and time given by the `--stop-datetime` option. If you did not detect the erroneous SQL statement that was entered until hours later, you will probably also want to recover the activity that occurred afterward. Based on this, you could run `mysqlbinlog` again with a start date and time, like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 10:01:00" \
/var/log/mysql/bin.123456 | mysql -u root -p
```

In this command, the SQL statements logged from 10:01 a.m. on will be re-executed. The combination of restoring the previous night's dump file and the two `mysqlbinlog` commands restores everything up until one second before 10:00 a.m. and everything from 10:01 a.m. on.

To use this method of point-in-time recovery, you should examine the log to be sure of the exact times to specify for the commands. To display the log file contents without executing them, use this command:

```
shell> mysqlbinlog /var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

Then open the `/tmp/mysql_restore.sql` file with a text editor to examine it.

Excluding specific changes by specifying times for `mysqlbinlog` does not work well if multiple statements executed at the same time as the one to be excluded.

### 7.5.2 Point-in-Time Recovery Using Event Positions

Instead of specifying dates and times, the `--start-position` and `--stop-position` options for `mysqlbinlog` can be used for specifying log positions. They work the same as the start and stop date options, except that you specify log position numbers rather than dates. Using positions may enable you to be more precise about which part of the log to recover, especially if many transactions occurred around the same time as a damaging SQL statement. To determine the position numbers, run `mysqlbinlog` for a range of times near the time when the unwanted transaction was executed, but redirect the results to a text file for examination. This can be done like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 9:55:00" \
--stop-datetime="2005-04-20 10:05:00" \
/var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

This command creates a small text file in the `/tmp` directory that contains the SQL statements around the time that the deleterious SQL statement was executed. Open this file with a text editor and look for the statement that you do not want to repeat. Determine the positions in the binary log for stopping and resuming the recovery and make note of them. Positions are labeled as `log_pos` followed by a number. After restoring the previous backup file, use the position numbers to process the binary log file. For example, you would use commands something like these:
The first command recovers all the transactions up until the stop position given. The second command recovers all transactions from the starting position given until the end of the binary log. Because the output of mysqlbinlog includes SET TIMESTAMP statements before each SQL statement recorded, the recovered data and related MySQL logs will reflect the original times at which the transactions were executed.

7.6 MyISAM Table Maintenance and Crash Recovery

This section discusses how to use myisamchk to check or repair MyISAM tables (tables that have .MYD and .MYI files for storing data and indexes). For general myisamchk background, see Section 4.6.3, "myisamchk — MyISAM Table-Maintenance Utility". Other table-repair information can be found at Section 2.11.7, "Rebuilding or Repairing Tables or Indexes".

You can use myisamchk to check, repair, or optimize database tables. The following sections describe how to perform these operations and how to set up a table maintenance schedule. For information about using myisamchk to get information about your tables, see Section 4.6.3.5, "Obtaining Table Information with myisamchk".

Even though table repair with myisamchk is quite secure, it is always a good idea to make a backup before doing a repair or any maintenance operation that could make a lot of changes to a table.

Myisamchk operations that affect indexes can cause FULLTEXT indexes to be rebuilt with full-text parameters that are incompatible with the values used by the MySQL server. To avoid this problem, follow the guidelines in Section 4.6.3.1, "myisamchk General Options".

MyISAM table maintenance can also be done using the SQL statements that perform operations similar to what myisamchk can do:

- To check MyISAM tables, use CHECK TABLE.
- To repair MyISAM tables, use REPAIR TABLE.
- To optimize MyISAM tables, use OPTIMIZE TABLE.
- To analyze MyISAM tables, use ANALYZE TABLE.

For additional information about these statements, see Section 13.7.2, "Table Maintenance Statements".

These statements can be used directly or by means of the mysqlcheck client program. One advantage of these statements over myisamchk is that the server does all the work. With myisamchk, you must make sure that the server does not use the tables at the same time so that there is no unwanted interaction between myisamchk and the server.

7.6.1 Using myisamchk for Crash Recovery

This section describes how to check for and deal with data corruption in MySQL databases. If your tables become corrupted frequently, you should try to find the reason why. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

For an explanation of how MyISAM tables can become corrupted, see Section 15.3.4, "MyISAM Table Problems".
If you run `mysqld` with external locking disabled (which is the default), you cannot reliably use `myisamchk` to check a table when `mysqld` is using the same table. If you can be certain that no one will access the tables through `mysqld` while you run `myisamchk`, you only have to execute `mysqladmin flush-tables` before you start checking the tables. If you cannot guarantee this, you must stop `mysqld` while you check the tables. If you run `myisamchk` to check tables that `mysqld` is updating at the same time, you may get a warning that a table is corrupt even when it is not.

If the server is run with external locking enabled, you can use `myisamchk` to check tables at any time. In this case, if the server tries to update a table that `myisamchk` is using, the server will wait for `myisamchk` to finish before it continues.

If you use `myisamchk` to repair or optimize tables, you *must* always ensure that the `mysqld` server is not using the table (this also applies if external locking is disabled). If you do not stop `mysqld`, you should at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables may become corrupted if the server and `myisamchk` access the tables simultaneously.

When performing crash recovery, it is important to understand that each MyISAM table `tbl_name` in a database corresponds to the three files in the database directory shown in the following table.

<table>
<thead>
<tr>
<th>File</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tbl_name.frm</code></td>
<td>Definition (format) file</td>
</tr>
<tr>
<td><code>tbl_name.MYD</code></td>
<td>Data file</td>
</tr>
<tr>
<td><code>tbl_name.MYI</code></td>
<td>Index file</td>
</tr>
</tbody>
</table>

Each of these three file types is subject to corruption in various ways, but problems occur most often in data files and index files.

`myisamchk` works by creating a copy of the `.MYD` data file row by row. It ends the repair stage by removing the old `.MYD` file and renaming the new file to the original file name. If you use `--quick`, `myisamchk` does not create a temporary `.MYD` file, but instead assumes that the `.MYD` file is correct and generates only a new index file without touching the `.MYD` file. This is safe, because `myisamchk` automatically detects whether the `.MYD` file is corrupt and aborts the repair if it is. You can also specify the `--quick` option twice to `myisamchk`. In this case, `myisamchk` does not abort on some errors (such as duplicate-key errors) but instead tries to resolve them by modifying the `.MYD` file. Normally the use of two `--quick` options is useful only if you have too little free disk space to perform a normal repair. In this case, you should at least make a backup of the table before running `myisamchk`.

### 7.6.2 How to Check MyISAM Tables for Errors

To check a MyISAM table, use the following commands:

- **myisamchk `tbl_name`**
  
  This finds 99.99% of all errors. What it cannot find is corruption that involves only the data file (which is very unusual). If you want to check a table, you should normally run `myisamchk` without options or with the `-s` (silent) option.

- **myisamchk --m `tbl_name`**
  
  This finds 99.999% of all errors. It first checks all index entries for errors and then reads through all rows. It calculates a checksum for all key values in the rows and verifies that the checksum matches the checksum for the keys in the index tree.

- **myisamchk --e `tbl_name`**
  
  This finds 99.999% of all errors. It first checks all index entries for errors and then reads through all rows. It calculates a checksum for all key values in the rows and verifies that the checksum matches the checksum for the keys in the index tree.
This does a complete and thorough check of all data (\(-e\) means “extended check”). It does a check-read of every key for each row to verify that they indeed point to the correct row. This may take a long time for a large table that has many indexes. Normally, \texttt{myisamchk} stops after the first error it finds. If you want to obtain more information, you can add the \(-v\) (verbose) option. This causes \texttt{myisamchk} to keep going, up through a maximum of 20 errors.

\begin{itemize}
  \item \texttt{myisamchk -e -i tbl_name}
\end{itemize}

This is like the previous command, but the \(-i\) option tells \texttt{myisamchk} to print additional statistical information.

In most cases, a simple \texttt{myisamchk} command with no arguments other than the table name is sufficient to check a table.

### 7.6.3 How to Repair MyISAM Tables

The discussion in this section describes how to use \texttt{myisamchk} on MyISAM tables (extensions \texttt{.MYI} and \texttt{.MYD}).

You can also use the \texttt{CHECK TABLE} and \texttt{REPAIR TABLE} statements to check and repair MyISAM tables. See Section 13.7.2.2, “CHECK TABLE Statement”, and Section 13.7.2.5, “REPAIR TABLE Statement”.

Symptoms of corrupted tables include queries that abort unexpectedly and observable errors such as these:

\begin{itemize}
  \item \texttt{tbl_name.frm} is locked against change
  \item Can't find file \texttt{tbl_name.MYI} (Errcode: \texttt{nnn})
  \item Unexpected end of file
  \item Record file is crashed
  \item Got error \texttt{nnn} from table handler
\end{itemize}

To get more information about the error, run \texttt{perror nnn}, where \texttt{nnn} is the error number. The following example shows how to use \texttt{perror} to find the meanings for the most common error numbers that indicate a problem with a table:

\begin{verbatim}
shell> perror 126 127 132 134 135 136 141 144 145
MySQL error code 126 = Index file is crashed
MySQL error code 127 = Record-file is crashed
MySQL error code 132 = Old database file
MySQL error code 134 = Record was already deleted (or record file crashed)
MySQL error code 135 = No more room in record file
MySQL error code 136 = No more room in index file
MySQL error code 141 = Duplicate unique key or constraint on write or update
MySQL error code 144 = Table is crashed and last repair failed
MySQL error code 145 = Table was marked as crashed and should be repaired
\end{verbatim}

Note that error 135 (no more room in record file) and error 136 (no more room in index file) are not errors that can be fixed by a simple repair. In this case, you must use \texttt{ALTER TABLE} to increase the \texttt{MAX_ROWS} and \texttt{AVG_ROW_LENGTH} table option values:

\begin{verbatim}
ALTER TABLE tbl_name MAX_ROWS=xxx AVG_ROW_LENGTH=yyy;
\end{verbatim}

If you do not know the current table option values, use \texttt{SHOW CREATE TABLE}.
How to Repair MyISAM Tables

For the other errors, you must repair your tables. `myisamchk` can usually detect and fix most problems that occur.

The repair process involves up to four stages, described here. Before you begin, you should change location to the database directory and check the permissions of the table files. On Unix, make sure that they are readable by the user that `mysqld` runs as (and to you, because you need to access the files you are checking). If it turns out you need to modify files, they must also be writable by you.

This section is for the cases where a table check fails (such as those described in Section 7.6.2, "How to Check MyISAM Tables for Errors"), or you want to use the extended features that `myisamchk` provides.

The `myisamchk` options used for table maintenance with are described in Section 4.6.3, "myisamchk — MyISAM Table-Maintenance Utility". `myisamchk` also has variables that you can set to control memory allocation that may improve performance. See Section 4.6.3.6, "myisamchk Memory Usage".

If you are going to repair a table from the command line, you must first stop the `mysqld` server. Note that when you do `mysqladmin shutdown` on a remote server, the `mysqld` server is still available for a while after `mysqladmin` returns, until all statement-processing has stopped and all index changes have been flushed to disk.

Stage 1: Checking your tables

Run `myisamchk *.MYI` or `myisamchk -e *.MYI` if you have more time. Use the `--s` (silent) option to suppress unnecessary information.

If the `mysqld` server is stopped, you should use the `--update-state` option to tell `myisamchk` to mark the table as "checked."

You have to repair only those tables for which `myisamchk` announces an error. For such tables, proceed to Stage 2.

If you get unexpected errors when checking (such as out of memory errors), or if `myisamchk` crashes, go to Stage 3.

Stage 2: Easy safe repair

First, try `myisamchk -r -q tbl_name` (`-r -q` means "quick recovery mode"). This attempts to repair the index file without touching the data file. If the data file contains everything that it should and the delete links point at the correct locations within the data file, this should work, and the table is fixed. Start repairing the next table. Otherwise, use the following procedure:

1. Make a backup of the data file before continuing.

2. Use `myisamchk -r tbl_name` (`-r` means "recovery mode"). This removes incorrect rows and deleted rows from the data file and reconstructs the index file.

3. If the preceding step fails, use `myisamchk --safe-recover tbl_name`. Safe recovery mode uses an old recovery method that handles a few cases that regular recovery mode does not (but is slower).

Note
If you want a repair operation to go much faster, you should set the values of the `sort_buffer_size` and `key_buffer_size` variables each to about 25% of your available memory when running `myisamchk`.

If you get unexpected errors when repairing (such as out of memory errors), or if `myisamchk` crashes, go to Stage 3.
Stage 3: Difficult repair

You should reach this stage only if the first 16KB block in the index file is destroyed or contains incorrect information, or if the index file is missing. In this case, it is necessary to create a new index file. Do so as follows:

1. Move the data file to a safe place.
2. Use the table description file to create new (empty) data and index files:

   ```sh
   shell> mysql db_name
   mysql> SET autocommit=1;
   mysql> TRUNCATE TABLE tbl_name;
   mysql> quit
   ```

3. Copy the old data file back onto the newly created data file. (Do not just move the old file back onto the new file. You want to retain a copy in case something goes wrong.)

   **Important**
   
   If you are using replication, you should stop it prior to performing the above procedure, since it involves file system operations, and these are not logged by MySQL.

   Go back to Stage 2. `myisamchk -r -q` should work. (This should not be an endless loop.)

   You can also use the `REPAIR TABLE tbl_name USE_FRM` SQL statement, which performs the whole procedure automatically. There is also no possibility of unwanted interaction between a utility and the server, because the server does all the work when you use `REPAIR TABLE`. See Section 13.7.2.5, "REPAIR TABLE Statement".

Stage 4: Very difficult repair

You should reach this stage only if the `.frm` description file has also crashed. That should never happen, because the description file is not changed after the table is created:

1. Restore the description file from a backup and go back to Stage 3. You can also restore the index file and go back to Stage 2. In the latter case, you should start with `myisamchk -r`.
2. If you do not have a backup but know exactly how the table was created, create a copy of the table in another database. Remove the new data file, and then move the `.frm` description and `.MYI` index files from the other database to your crashed database. This gives you new description and index files, but leaves the `.MYD` data file alone. Go back to Stage 2 and attempt to reconstruct the index file.

7.6.4 MyISAM Table Optimization

To coalesce fragmented rows and eliminate wasted space that results from deleting or updating rows, run `myisamchk` in recovery mode:

   ```sh
   shell> myisamchk -r tbl_name
   ```

   You can optimize a table in the same way by using the `OPTIMIZE TABLE` SQL statement. `OPTIMIZE TABLE` does a table repair and a key analysis, and also sorts the index tree so that key lookups are faster. There is also no possibility of unwanted interaction between a utility and the server, because the server does all the work when you use `OPTIMIZE TABLE`. See Section 13.7.2.4, "OPTIMIZE TABLE Statement".

   `myisamchk` has a number of other options that you can use to improve the performance of a table:
• `--analyze` or `-a`: Perform key distribution analysis. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use.

• `--sort-index` or `-S`: Sort the index blocks. This optimizes seeks and makes table scans that use indexes faster.

• `--sort-records=index_num` or `-R index_num`: Sort data rows according to a given index. This makes your data much more localized and may speed up range-based `SELECT` and `ORDER BY` operations that use this index.

For a full description of all available options, see Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

### 7.6.5 Setting Up a MyISAM Table Maintenance Schedule

It is a good idea to perform table checks on a regular basis rather than waiting for problems to occur. One way to check and repair MyISAM tables is with the `CHECK TABLE` and `REPAIR TABLE` statements. See Section 13.7.2, “Table Maintenance Statements”.

Another way to check tables is to use `myisamchk`. For maintenance purposes, you can use `myisamchk -s`. The `-s` option (short for `--silent`) causes `myisamchk` to run in silent mode, printing messages only when errors occur.

It is also a good idea to enable automatic MyISAM table checking. For example, whenever the machine has done a restart in the middle of an update, you usually need to check each table that could have been affected before it is used further. (These are “expected crashed tables.”) To cause the server to check MyISAM tables automatically, start it with the `myisam_recover_options` system variable set. See Section 5.1.7, “Server System Variables”.

You should also check your tables regularly during normal system operation. For example, you can run a `cron` job to check important tables once a week, using a line like this in a `crontab` file:

```
35 0 * * 0 /path/to/myisamchk --fast --silent /path/to/datadir/*/*.MYI
```

This prints out information about crashed tables so that you can examine and repair them as necessary.

To start with, execute `myisamchk -s` each night on all tables that have been updated during the last 24 hours. As you see that problems occur infrequently, you can back off the checking frequency to once a week or so.

Normally, MySQL tables need little maintenance. If you are performing many updates to MyISAM tables with dynamic-sized rows (tables with `VARCHAR`, `BLOB`, or `TEXT` columns) or have tables with many deleted rows you may want to defragment/reclaim space from the tables from time to time. You can do this by using `OPTIMIZE TABLE` on the tables in question. Alternatively, if you can stop the `mysqld` server for a while, change location into the data directory and use this command while the server is stopped:

```
shell> myisamchk -r -s --sort-index --myisam_sort_buffer_size=16M */*.MYI
```
Chapter 8 Optimization

Table of Contents

8.1 Optimization Overview ................................................................. 878
8.2 Optimizing SQL Statements ......................................................... 880
  8.2.1 Optimizing SELECT Statements ............................................. 880
  8.2.2 Subquery Optimization ....................................................... 914
  8.2.3 Optimizing INFORMATION_SCHEMA Queries ............................... 918
  8.2.4 Optimizing Data Change Statements ..................................... 924
  8.2.5 Optimizing Database Privileges .......................................... 925
  8.2.6 Other Optimization Tips .................................................... 925
8.3 Optimization and Indexes .......................................................... 926
  8.3.1 How MySQL Uses Indexes .................................................... 926
  8.3.2 Primary Key Optimization ................................................... 927
  8.3.3 Foreign Key Optimization .................................................. 927
  8.3.4 Column Indexes .............................................................. 928
  8.3.5 Multiple-Column Indexes ................................................... 929
  8.3.6 Verifying Index Usage ........................................................ 930
  8.3.7 InnoDB and MyISAM Index Statistics Collection ......................... 931
  8.3.8 Comparison of B-Tree and Hash Indexes ................................. 932
  8.3.9 Indexed Lookups from TIMESTAMP Columns ............................... 934
8.4 Optimizing Database Structure .................................................. 936
  8.4.1 Optimizing Data Size ....................................................... 936
  8.4.2 Optimizing MySQL Data Types ............................................. 938
  8.4.3 Optimizing for Many Tables .............................................. 939
  8.4.4 Internal Temporary Table Use in MySQL ................................ 941
  8.4.5 Limits on Number of Databases and Tables .............................. 943
  8.4.6 Limits on Table Size ........................................................ 943
  8.4.7 Limits on Table Column Count and Row Size ............................ 944
8.5 Optimizing for InnoDB Tables .................................................... 947
  8.5.1 Optimizing Storage Layout for InnoDB Tables ......................... 947
  8.5.2 Optimizing InnoDB Transaction Management ............................ 948
  8.5.3 Optimizing InnoDB Redo Logging ......................................... 949
  8.5.4 Bulk Data Loading for InnoDB Tables ................................... 949
  8.5.5 Optimizing InnoDB Queries ............................................... 950
  8.5.6 Optimizing InnoDB DDL Operations ..................................... 950
  8.5.7 Optimizing InnoDB Disk I/O ............................................... 951
  8.5.8 Optimizing InnoDB Configuration Variables ........................... 953
  8.5.9 Optimizing InnoDB for Systems with Many Tables ..................... 954
8.6 Optimizing for MyISAM Tables ................................................... 954
  8.6.1 Optimizing MyISAM Queries ............................................... 954
  8.6.2 Bulk Data Loading for MyISAM Tables .................................. 956
  8.6.3 Optimizing REPAIR TABLE Statements ................................ 957
8.7 Optimizing for MEMORY Tables .................................................. 958
8.8 Understanding the Query Execution Plan ...................................... 959
  8.8.1 Optimizing Queries with EXPLAIN ...................................... 959
  8.8.2 EXPLAIN Output Format .................................................... 960
  8.8.3 Extended EXPLAIN Output Format ....................................... 971
  8.8.4 Estimating Query Performance ........................................... 972
8.9 Controlling the Query Optimizer ............................................... 973
8.1 Optimization Overview

Database performance depends on several factors at the database level, such as tables, queries, and configuration settings. These software constructs result in CPU and I/O operations at the hardware level, which you must minimize and make as efficient as possible. As you work on database performance, you start by learning the high-level rules and guidelines for the software side, and measuring performance using wall-clock time. As you become an expert, you learn more about what happens internally, and start measuring things such as CPU cycles and I/O operations.
Typical users aim to get the best database performance out of their existing software and hardware configurations. Advanced users look for opportunities to improve the MySQL software itself, or develop their own storage engines and hardware appliances to expand the MySQL ecosystem.

- **Optimizing at the Database Level**
- **Optimizing at the Hardware Level**
- **Balancing Portability and Performance**

**Optimizing at the Database Level**

The most important factor in making a database application fast is its basic design:

- Are the tables structured properly? In particular, do the columns have the right data types, and does each table have the appropriate columns for the type of work? For example, applications that perform frequent updates often have many tables with few columns, while applications that analyze large amounts of data often have few tables with many columns.

- Are the right indexes in place to make queries efficient?

- Are you using the appropriate storage engine for each table, and taking advantage of the strengths and features of each storage engine you use? In particular, the choice of a transactional storage engine such as **InnoDB** or a nontransactional one such as **MyISAM** can be very important for performance and scalability.

  **Note**
  
  **InnoDB** is the default storage engine for new tables. In practice, the advanced **InnoDB** performance features mean that **InnoDB** tables often outperform the simpler **MyISAM** tables, especially for a busy database.

- Does each table use an appropriate row format? This choice also depends on the storage engine used for the table. In particular, compressed tables use less disk space and so require less disk I/O to read and write the data. Compression is available for all kinds of workloads with **InnoDB** tables, and for read-only **MyISAM** tables.

- Does the application use an appropriate locking strategy? For example, by allowing shared access when possible so that database operations can run concurrently, and requesting exclusive access when appropriate so that critical operations get top priority. Again, the choice of storage engine is significant. The **InnoDB** storage engine handles most locking issues without involvement from you, allowing for better concurrency in the database and reducing the amount of experimentation and tuning for your code.

- Are all memory areas used for caching sized correctly? That is, large enough to hold frequently accessed data, but not so large that they overload physical memory and cause paging. The main memory areas to configure are the **InnoDB** buffer pool, the **MyISAM** key cache, and the MySQL query cache.

**Optimizing at the Hardware Level**

Any database application eventually hits hardware limits as the database becomes more and more busy. A DBA must evaluate whether it is possible to tune the application or reconfigure the server to avoid these bottlenecks, or whether more hardware resources are required. System bottlenecks typically arise from these sources:

- Disk seeks. It takes time for the disk to find a piece of data. With modern disks, the mean time for this is usually lower than 10ms, so we can in theory do about 100 seeks a second. This time improves
Balancing Portability and Performance

To use performance-oriented SQL extensions in a portable MySQL program, you can wrap MySQL-specific keywords in a statement within /*! */ comment delimiters. Other SQL servers ignore the commented keywords. For information about writing comments, see Section 9.6, “Comment Syntax”.

8.2 Optimizing SQL Statements

The core logic of a database application is performed through SQL statements, whether issued directly through an interpreter or submitted behind the scenes through an API. The tuning guidelines in this section help to speed up all kinds of MySQL applications. The guidelines cover SQL operations that read and write data, the behind-the-scenes overhead for SQL operations in general, and operations used in specific scenarios such as database monitoring.

8.2.1 Optimizing SELECT Statements

Queries, in the form of SELECT statements, perform all the lookup operations in the database. Tuning these statements is a top priority, whether to achieve sub-second response times for dynamic web pages, or to chop hours off the time to generate huge overnight reports.

Besides SELECT statements, the tuning techniques for queries also apply to constructs such as CREATE TABLE...AS SELECT, INSERT INTO...SELECT, and WHERE clauses in DELETE statements. Those statements have additional performance considerations because they combine write operations with the read-oriented query operations.

In MySQL NDB Cluster 7.2 and later, the NDB storage engine supports a join pushdown optimization whereby a qualifying join is sent in its entirety to NDB Cluster data nodes, where it can be distributed among them and executed in parallel. For more information about this optimization, see Conditions for NDB pushdown joins.

The main considerations for optimizing queries are:

- To make a slow SELECT ... WHERE query faster, the first thing to check is whether you can add an index. Set up indexes on columns used in the WHERE clause, to speed up evaluation, filtering, and the final retrieval of results. To avoid wasted disk space, construct a small set of indexes that speed up many related queries used in your application.

Indexes are especially important for queries that reference different tables, using features such as joins and foreign keys. You can use the EXPLAIN statement to determine which indexes are used for a SELECT. See Section 8.3.1, “How MySQL Uses Indexes” and Section 8.8.1, “Optimizing Queries with EXPLAIN”.

slowly with new disks and is very hard to optimize for a single table. The way to optimize seek time is to distribute the data onto more than one disk.

- Disk reading and writing. When the disk is at the correct position, we need to read or write the data. With modern disks, one disk delivers at least 10–20MB/s throughput. This is easier to optimize than seeks because you can read in parallel from multiple disks.

- CPU cycles. When the data is in main memory, we must process it to get our result. Having large tables compared to the amount of memory is the most common limiting factor. But with small tables, speed is usually not the problem.

- Memory bandwidth. When the CPU needs more data than can fit in the CPU cache, main memory bandwidth becomes a bottleneck. This is an uncommon bottleneck for most systems, but one to be aware of.
Optimizing SELECT Statements

- Isolate and tune any part of the query, such as a function call, that takes excessive time. Depending on how the query is structured, a function could be called once for every row in the result set, or even once for every row in the table, greatly magnifying any inefficiency.

- Minimize the number of full table scans in your queries, particularly for big tables.

- Keep table statistics up to date by using the `ANALYZE TABLE` statement periodically, so the optimizer has the information needed to construct an efficient execution plan.

- Learn the tuning techniques, indexing techniques, and configuration parameters that are specific to the storage engine for each table. Both InnoDB and MyISAM have sets of guidelines for enabling and sustaining high performance in queries. For details, see Section 8.5.5, “Optimizing InnoDB Queries” and Section 8.6.1, “Optimizing MyISAM Queries”.

- Avoid transforming the query in ways that make it hard to understand, especially if the optimizer does some of the same transformations automatically.

- If a performance issue is not easily solved by one of the basic guidelines, investigate the internal details of the specific query by reading the `EXPLAIN` plan and adjusting your indexes, WHERE clauses, join clauses, and so on. (When you reach a certain level of expertise, reading the `EXPLAIN` plan might be your first step for every query.)

- Adjust the size and properties of the memory areas that MySQL uses for caching. With efficient use of the InnoDB buffer pool, MyISAM key cache, and the MySQL query cache, repeated queries run faster because the results are retrieved from memory the second and subsequent times.

- Even for a query that runs fast using the cache memory areas, you might still optimize further so that they require less cache memory, making your application more scalable. Scalability means that your application can handle more simultaneous users, larger requests, and so on without experiencing a big drop in performance.

- Deal with locking issues, where the speed of your query might be affected by other sessions accessing the tables at the same time.

8.2.1.1 WHERE Clause Optimization

This section discusses optimizations that can be made for processing WHERE clauses. The examples use `SELECT` statements, but the same optimizations apply for WHERE clauses in DELETE and UPDATE statements.

Some examples of queries that are very fast:

```sql
SELECT COUNT(*) FROM tbl_name;

SELECT MIN(key_part1), MAX(key_part1) FROM tbl_name;

SELECT MAX(key_part2) FROM tbl_name
WHERE key_part1 = constant;

SELECT ... FROM tbl_name
ORDER BY key_part1, key_part2,... LIMIT 10;

SELECT ... FROM tbl_name
ORDER BY key_part1 DESC, key_part2 DESC, ... LIMIT 10;
```

MySQL resolves the following queries using only the entries from a secondary index, if the indexed columns are numeric:

```sql
SELECT key_part1,key_part2 FROM tbl_name WHERE key_part1=val;
```
Optimizing SELECT Statements

SELECT COUNT(*) FROM `tbl_name`
   WHERE `key_part1`=val1 AND `key_part2`=val2;
SELECT `key_part2` FROM `tbl_name` GROUP BY `key_part1`;

The following queries use the index data to retrieve the rows in sorted order without a separate sorting pass:

SELECT ... FROM `tbl_name`
   ORDER BY `key_part1`, `key_part2`, ... ;
SELECT ... FROM `tbl_name`
   ORDER BY `key_part1` DESC, `key_part2` DESC, ... ;

You might be tempted to rewrite your queries to make arithmetic operations faster, while sacrificing readability. Because MySQL does similar optimizations automatically, you can often avoid this work, and leave the query in a more understandable and maintainable form. Some of the optimizations performed by MySQL follow:

Note
Because work on the MySQL optimizer is ongoing, not all of the optimizations that MySQL performs are documented here.

- Removal of unnecessary parentheses:

  ```sql
  ((a AND b) AND c OR (((a AND b) AND (c AND d))))
  -> (a AND b AND c) OR (a AND b AND c AND d)
  ```

- Constant folding:

  ```sql
  (a<b AND b=c) AND a=5
  -> b>5 AND b=c AND a=5
  ```

- Constant condition removal:

  ```sql
  (b>=5 AND b=5) OR (b=6 AND 5=5) OR (b=7 AND 5=6)
  -> b=5 OR b=6
  ```

- Constant expressions used by indexes are evaluated only once.

  - `COUNT(*)` on a single table without a `WHERE` is retrieved directly from the table information for `MyISAM` and `MEMORY` tables. This is also done for any `NOT NULL` expression when used with only one table.

  - Early detection of invalid constant expressions. MySQL quickly detects that some `SELECT` statements are impossible and returns no rows.

  - `HAVING` is merged with `WHERE` if you do not use `GROUP BY` or aggregate functions (`COUNT()`, `MIN()`, and so on).

  - For each table in a join, a simpler `WHERE` is constructed to get a fast `WHERE` evaluation for the table and also to skip rows as soon as possible.

  - All constant tables are read first before any other tables in the query. A constant table is any of the following:

  - An empty table or a table with one row.

  - A table that is used with a `WHERE` clause on a `PRIMARY KEY` or a `UNIQUE` index, where all index parts are compared to constant expressions and are defined as `NOT NULL`. 

882
All of the following tables are used as constant tables:

```sql
SELECT * FROM t WHERE primary_key=1;
SELECT * FROM t1,t2
WHERE t1.primary_key=1 AND t2.primary_key=t1.id;
```

- The best join combination for joining the tables is found by trying all possibilities. If all columns in ORDER BY and GROUP BY clauses come from the same table, that table is preferred first when joining.
- If there is an ORDER BY clause and a different GROUP BY clause, or if the ORDER BY or GROUP BY contains columns from tables other than the first table in the join queue, a temporary table is created.
- If you use the SQL_SMALL_RESULT modifier, MySQL uses an in-memory temporary table.
- Each table index is queried, and the best index is used unless the optimizer believes that it is more efficient to use a table scan. At one time, a scan was used based on whether the best index spanned more than 30% of the table, but a fixed percentage no longer determines the choice between using an index or a scan. The optimizer now is more complex and bases its estimate on additional factors such as table size, number of rows, and I/O block size.
- In some cases, MySQL can read rows from the index without even consulting the data file. If all columns used from the index are numeric, only the index tree is used to resolve the query.
- Before each row is output, those that do not match the HAVING clause are skipped.

### 8.2.1.2 Range Optimization

The range access method uses a single index to retrieve a subset of table rows that are contained within one or several index value intervals. It can be used for a single-part or multiple-part index. The following sections give a detailed description of how intervals are extracted from the WHERE clause.

- **Range Access Method for Multiple-Part Indexes**

#### Range Access Method for Single-Part Indexes

For a single-part index, index value intervals can be conveniently represented by corresponding conditions in the WHERE clause, denoted as *range conditions* rather than “intervals.”

The definition of a range condition for a single-part index is as follows:

- For both BTREE and HASH indexes, comparison of a key part with a constant value is a range condition when using the =, <=, IN(), IS NULL, or IS NOT NULL operators.
- Additionally, for BTREE indexes, comparison of a key part with a constant value is a range condition when using the >, <, >=, <=, BETWEEN, !=, or <> operators, or LIKE comparisons if the argument to LIKE is a constant string that does not start with a wildcard character.
- For all index types, multiple range conditions combined with OR or AND form a range condition.

“Constant value” in the preceding descriptions means one of the following:

- A constant from the query string
- A column of a const or system table from the same join
- The result of an uncorrelated subquery
• Any expression composed entirely from subexpressions of the preceding types

Here are some examples of queries with range conditions in the `WHERE` clause:

```sql
SELECT * FROM t1
WHERE key_col > 1
AND key_col < 10;
```

```sql
SELECT * FROM t1
WHERE key_col = 1
OR key_col IN (15,18,20);
```

```sql
SELECT * FROM t1
WHERE key_col LIKE 'ab'
OR key_col BETWEEN 'bar' AND 'foo';
```

Some nonconstant values may be converted to constants during the optimizer constant propagation phase.

MySQL tries to extract range conditions from the `WHERE` clause for each of the possible indexes. During the extraction process, conditions that cannot be used for constructing the range condition are dropped, conditions that produce overlapping ranges are combined, and conditions that produce empty ranges are removed.

Consider the following statement, where `key1` is an indexed column and `nonkey` is not indexed:

```sql
SELECT * FROM t1 WHERE
(key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
(key1 < 'bar' AND nonkey = 4) OR
(key1 < 'uux' AND key1 > 'z');
```

The extraction process for key `key1` is as follows:

1. Start with original `WHERE` clause:

   ```sql
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
   (key1 < 'bar' AND nonkey = 4) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

2. Remove `nonkey = 4` and `key1 LIKE '%b'` because they cannot be used for a range scan. The correct way to remove them is to replace them with `TRUE`, so that we do not miss any matching rows when doing the range scan. Replacing them with `TRUE` yields:

   ```sql
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR TRUE)) OR
   (key1 < 'bar' AND TRUE) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

3. Collapse conditions that are always true or false:

   • `(key1 LIKE 'abcde%' OR TRUE)` is always true
   • `(key1 < 'uux' AND key1 > 'z')` is always false

   Replacing these conditions with constants yields:

   ```sql
   (key1 < 'abc' AND TRUE) OR (key1 < 'bar' AND TRUE) OR (FALSE)
   ```

   Removing unnecessary `TRUE` and `FALSE` constants yields:

   ```sql
   (key1 < 'abc') OR (key1 < 'bar')
   ```

4. Combining overlapping intervals into one yields the final condition to be used for the range scan:

   ```sql
   (key1 < 'bar')
   ```
In general (and as demonstrated by the preceding example), the condition used for a range scan is less restrictive than the **WHERE** clause. MySQL performs an additional check to filter out rows that satisfy the range condition but not the full **WHERE** clause.

The range condition extraction algorithm can handle nested **AND/OR** constructs of arbitrary depth, and its output does not depend on the order in which conditions appear in **WHERE** clause.

MySQL does not support merging multiple ranges for the range access method for spatial indexes. To work around this limitation, you can use a **UNION** with identical **SELECT** statements, except that you put each spatial predicate in a different **SELECT**.

**Range Access Method for Multiple-Part Indexes**

Range conditions on a multiple-part index are an extension of range conditions for a single-part index. A range condition on a multiple-part index restricts index rows to lie within one or several key tuple intervals. Key tuple intervals are defined over a set of key tuples, using ordering from the index.

For example, consider a multiple-part index defined as `key1(key_part1, key_part2, key_part3)`, and the following set of key tuples listed in key order:

<table>
<thead>
<tr>
<th>key_part1</th>
<th>key_part2</th>
<th>key_part3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>1</td>
<td>'abc'</td>
</tr>
<tr>
<td>NULL</td>
<td>1</td>
<td>'xyz'</td>
</tr>
<tr>
<td>NULL</td>
<td>2</td>
<td>'foo'</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>'abc'</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>'xyz'</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>'abc'</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>'aaa'</td>
</tr>
</tbody>
</table>

The condition `key_part1 = 1` defines this interval:

$$(1,-\infty,-\infty) \leq (key_part1, key_part2, key_part3) < (1, +\infty, +\infty)$$

The interval covers the 4th, 5th, and 6th tuples in the preceding data set and can be used by the range access method.

By contrast, the condition `key_part3 = 'abc'` does not define a single interval and cannot be used by the range access method.

The following descriptions indicate how range conditions work for multiple-part indexes in greater detail.

- For **HASH** indexes, each interval containing identical values can be used. This means that the interval can be produced only for conditions in the following form:

  ```
  key_part1 cmp const1
  AND key_part2 cmp const2
  AND ...
  AND key_partN cmp constN;
  ```

  Here, `const1, const2, ...` are constants, `cmp` is one of the `=, <=, IS NULL` comparison operators, and the conditions cover all index parts. (That is, there are `N` conditions, one for each part of an `N`-part index.) For example, the following is a range condition for a three-part **HASH** index:

  ```
  key_part1 = 1 AND key_part2 IS NULL AND key_part3 = 'foo'
  ```

  For the definition of what is considered to be a constant, see **Range Access Method for Single-Part Indexes**.

- For a **BTREE** index, an interval might be usable for conditions combined with **AND**, where each condition compares a key part with a constant value using `=, <=, IS NULL, >, <, >=, <=, !=, <>, BETWEEN`,...
Optimizing SELECT Statements

or LIKE 'pattern' (where 'pattern' does not start with a wildcard). An interval can be used as long as it is possible to determine a single key tuple containing all rows that match the condition (or two intervals if <> or != is used).

The optimizer attempts to use additional key parts to determine the interval as long as the comparison operator is =, <=>, or IS NULL. If the operator is >, >=, =, !=, <>, BETWEEN, or LIKE, the optimizer uses it but considers no more key parts. For the following expression, the optimizer uses = from the first comparison. It also uses >= from the second comparison but considers no further key parts and does not use the third comparison for interval construction:

\[ \text{key}_1 = 'foo' \text{ AND key}_2 >= 10 \text{ AND key}_3 > 10 \]

The single interval is:

\[ ('foo',10,-\infty) < (\text{key}_1,\text{key}_2,\text{key}_3) < ('foo',+\infty,+\infty) \]

It is possible that the created interval contains more rows than the initial condition. For example, the preceding interval includes the value ('foo', 11, 0), which does not satisfy the original condition.

• If conditions that cover sets of rows contained within intervals are combined with OR, they form a condition that covers a set of rows contained within the union of their intervals. If the conditions are combined with AND, they form a condition that covers a set of rows contained within the intersection of their intervals. For example, for this condition on a two-part index:

\[ (\text{key}_1 = 1 \text{ AND key}_2 < 2) \text{ OR } (\text{key}_1 > 5) \]

The intervals are:

\[ (1,-\infty) < (\text{key}_1,\text{key}_2) < (1,2) \]
\[ (5,-\infty) < (\text{key}_1,\text{key}_2) \]

In this example, the interval on the first line uses one key part for the left bound and two key parts for the right bound. The interval on the second line uses only one key part. The key_len column in the EXPLAIN output indicates the maximum length of the key prefix used.

In some cases, key_len may indicate that a key part was used, but that might be not what you would expect. Suppose that key_part1 and key_part2 can be NULL. Then the key_len column displays two key part lengths for the following condition:

\[ \text{key}_1 >= 1 \text{ AND key}_2 < 2 \]

But, in fact, the condition is converted to this:

\[ \text{key}_1 >= 1 \text{ AND key}_2 \text{ IS NOT NULL} \]

For a description of how optimizations are performed to combine or eliminate intervals for range conditions on a single-part index, see Range Access Method for Single-Part Indexes. Analogous steps are performed for range conditions on multiple-part indexes.

8.2.1.3 Index Merge Optimization

The Index Merge access method retrieves rows with multiple range scans and merges their results into one. This access method merges index scans from a single table only, not scans across multiple tables. The merge can produce unions, intersections, or unions-of-intersections of its underlying scans.

Example queries for which Index Merge may be used:

SELECT * FROM tbl_name WHERE key1 = 10 OR key2 = 20;
SELECT * FROM tbl_name
  WHERE (key1 = 10 OR key2 = 20) AND non_key = 30;

SELECT * FROM t1, t2
  WHERE (t1.key1 IN (1,2) OR t1.key2 LIKE 'value%')
  AND t2.key1 = t1.some_col;

SELECT * FROM t1, t2
  WHERE t1.key1 = 1
  AND (t2.key1 = t1.some_col OR t2.key2 = t1.some_col2);

Note

The Index Merge optimization algorithm has the following known limitations:

• If your query has a complex WHERE clause with deep AND/OR nesting and MySQL does not choose the optimal plan, try distributing terms using the following identity transformations:

\[
\begin{align*}
(x \text{ AND } y) \text{ OR } z & \rightarrow (x \text{ OR } z) \text{ AND } (y \text{ OR } z) \\
(x \text{ OR } y) \text{ AND } z & \rightarrow (x \text{ AND } z) \text{ OR } (y \text{ AND } z)
\end{align*}
\]

• Index Merge is not applicable to full-text indexes.

• If a range scan is possible on some key, the optimizer will not consider using Index Merge Union or Index Merge Sort-Union algorithms. For example, consider this query:

```sql
SELECT * FROM t1 WHERE (goodkey1 < 10 OR goodkey2 < 20) AND badkey < 30;
```

For this query, two plans are possible:

• An Index Merge scan using the (goodkey1 < 10 OR goodkey2 < 20) condition.

• A range scan using the badkey < 30 condition.

However, the optimizer considers only the second plan.

In EXPLAIN output, the Index Merge method appears as index_merge in the type column. In this case, the key column contains a list of indexes used, and key_len contains a list of the longest key parts for those indexes.

The Index Merge access method has several algorithms, which are displayed in the Extra field of EXPLAIN output:

• Using intersect(...)

• Using union(...)

• Using sort_union(...)

The following sections describe these algorithms in greater detail. The optimizer chooses between different possible Index Merge algorithms and other access methods based on cost estimates of the various available options.

Use of Index Merge is subject to the value of the index_merge, index_merge_intersection, index_merge_union, and index_merge_sort_union flags of the optimizer_switch system variable. See Section 8.9.2, “Switchable Optimizations”. By default, all those flags are on. To enable only certain algorithms, set index_merge to off, and enable only such of the others as should be permitted.
Optimizing SELECT Statements

- Index Merge Intersection Access Algorithm
- Index Merge Union Access Algorithm
- Index Merge Sort-Union Access Algorithm

**Index Merge Intersection Access Algorithm**

This access algorithm is applicable when a `WHERE` clause is converted to several range conditions on different keys combined with `AND`, and each condition is one of the following:

- An $N$-part expression of this form, where the index has exactly $N$ parts (that is, all index parts are covered):

  ```sql
  key_part1 = const1 AND key_part2 = const2 ... AND key_partN = constN
  ```

- Any range condition over the primary key of an InnoDB table.

Examples:

```sql
SELECT * FROM innodb_table
WHERE primary_key < 10 AND key_col1 = 20;

SELECT * FROM tbl_name
WHERE key1_part1 = 1 AND key1_part2 = 2 AND key2 = 2;
```

The Index Merge intersection algorithm performs simultaneous scans on all used indexes and produces the intersection of row sequences that it receives from the merged index scans.

If all columns used in the query are covered by the used indexes, full table rows are not retrieved (EXPLAIN output contains `Using index` in `Extra` field in this case). Here is an example of such a query:

```sql
SELECT COUNT(*) FROM t1 WHERE key1 = 1 AND key2 = 1;
```

If the used indexes do not cover all columns used in the query, full rows are retrieved only when the range conditions for all used keys are satisfied.

If one of the merged conditions is a condition over the primary key of an InnoDB table, it is not used for row retrieval, but is used to filter out rows retrieved using other conditions.

**Index Merge Union Access Algorithm**

The criteria for this algorithm are similar to those for the Index Merge intersection algorithm. The algorithm is applicable when the table's `WHERE` clause is converted to several range conditions on different keys combined with `OR`, and each condition is one of the following:

- An $N$-part expression of this form, where the index has exactly $N$ parts (that is, all index parts are covered):

  ```sql
  key_part1 = const1 AND key_part2 = const2 ... AND key_partN = constN
  ```

- Any range condition over a primary key of an InnoDB table.

- A condition for which the Index Merge intersection algorithm is applicable.

Examples:

```sql
SELECT * FROM t1
WHERE key1 = 1 OR key2 = 2 OR key3 = 3;
```
Index Merge Sort-Union Access Algorithm

This access algorithm is applicable when the `WHERE` clause is converted to several range conditions combined by `OR`, but the Index Merge union algorithm is not applicable.

Examples:

```sql
SELECT * FROM tbl_name
  WHERE key_col1 < 10 OR key_col2 < 20;
SELECT * FROM tbl_name
  WHERE (key_col1 > 10 OR key_col2 = 20) AND nonkey_col = 30;
```

The difference between the sort-union algorithm and the union algorithm is that the sort-union algorithm must first fetch row IDs for all rows and sort them before returning any rows.

### 8.2.1.4 Engine Condition Pushdown Optimization

This optimization improves the efficiency of direct comparisons between a nonindexed column and a constant. In such cases, the condition is “pushed down” to the storage engine for evaluation. This optimization can be used only by the NDB storage engine.

For NDB Cluster, this optimization can eliminate the need to send nonmatching rows over the network between the cluster’s data nodes and the MySQL server that issued the query, and can speed up queries where it is used by a factor of 5 to 10 times over cases where condition pushdown could be but is not used.

Suppose that an NDB Cluster table is defined as follows:

```sql
CREATE TABLE t1 (
  a INT,
  b INT,
  KEY(a)
) ENGINE=NDB;
```

Condition pushdown can be used with queries such as the one shown here, which includes a comparison between a nonindexed column and a constant:

```sql
SELECT a, b FROM t1 WHERE b = 10;
```

The use of condition pushdown can be seen in the output of `EXPLAIN`:

```sql
mysql> EXPLAIN SELECT a, b FROM t1 WHERE b = 10\G
*************************** 1. row ***************************
id: 1
select_type: SIMPLE
table: t1
type: ALL
possible_keys: NULL
key: NULL
key_len: NULL
ref: NULL
rows: 10
Extra: Using where with pushed condition
```

However, condition pushdown cannot be used with either of these two queries:

```sql
SELECT a, b FROM t1 WHERE a = 10;
```
Optimizing SELECT Statements

SELECT a, b FROM t1 WHERE b + 1 = 10;

Condition pushdown is not applicable to the first query because an index exists on column a. (An index access method would be more efficient and so would be chosen in preference to condition pushdown.) Condition pushdown cannot be employed for the second query because the comparison involving the nonindexed column b is indirect. (However, condition pushdown could be applied if you were to reduce b + 1 = 10 to b = 9 in the WHERE clause.)

Condition pushdown may also be employed when an indexed column is compared with a constant using a > or < operator:

mysql> EXPLAIN SELECT a, b FROM t1 WHERE a < 2\G
*************************** 1. row ***************************
    id: 1
  select_type: SIMPLE
    table: t1
      type: range
possible_keys: a
    key: a
  key_len: 5
    ref: NULL
  rows: 2
  Extra: Using where with pushed condition

Other supported comparisons for condition pushdown include the following:

- column [NOT] LIKE pattern
  pattern must be a string literal containing the pattern to be matched; for syntax, see Section 12.7.1, “String Comparison Functions and Operators”.

- column IS [NOT] NULL
- column IN (value_list)
  Each item in the value_list must be a constant, literal value.

- column BETWEEN constant1 AND constant2
  constant1 and constant2 must each be a constant, literal value.

In all of the cases in the preceding list, it is possible for the condition to be converted into the form of one or more direct comparisons between a column and a constant.

Engine condition pushdown is enabled by default. To disable it at server startup, set the optimizer_switch system variable. For example, in a my.cnf file, use these lines:

```
[mysqld]
optimizer_switch=engine_condition_pushdown=off
```

At runtime, disable condition pushdown like this:

```
SET optimizer_switch='engine_condition_pushdown=off';
```

Limitations. Condition pushdown is subject to the following limitations:

- Condition pushdown is supported only by the NDB storage engine.
- Columns may be compared with constants only; however, this includes expressions which evaluate to constant values.
• Columns used in comparisons cannot be of any of the BLOB or TEXT types. This exclusion extends to BIT and ENUM columns as well.

• A string value to be compared with a column must use the same collation as the column.

• Joins are not directly supported; conditions involving multiple tables are pushed separately where possible. Use extended EXPLAIN output to determine which conditions are actually pushed down. See Section 8.8.3, “Extended EXPLAIN Output Format”.

8.2.1.5 Nested-Loop Join Algorithms

MySQL executes joins between tables using a nested-loop algorithm or variations on it.

- Nested-Loop Join Algorithm
- Block Nested-Loop Join Algorithm

Nested-Loop Join Algorithm

A simple nested-loop join (NLJ) algorithm reads rows from the first table in a loop one at a time, passing each row to a nested loop that processes the next table in the join. This process is repeated as many times as there remain tables to be joined.

Assume that a join between three tables t1, t2, and t3 is to be executed using the following join types:

<table>
<thead>
<tr>
<th>Table</th>
<th>Join Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>range</td>
</tr>
<tr>
<td>t2</td>
<td>ref</td>
</tr>
<tr>
<td>t3</td>
<td>ALL</td>
</tr>
</tbody>
</table>

If a simple NLJ algorithm is used, the join is processed like this:

```sql
for each row in t1 matching range {
    for each row in t2 matching reference key {
        for each row in t3 {
            if row satisfies join conditions, send to client
        }
    }
}
```

Because the NLJ algorithm passes rows one at a time from outer loops to inner loops, it typically reads tables processed in the inner loops many times.

Block Nested-Loop Join Algorithm

A Block Nested-Loop (BNL) join algorithm uses buffering of rows read in outer loops to reduce the number of times that tables in inner loops must be read. For example, if 10 rows are read into a buffer and the buffer is passed to the next inner loop, each row read in the inner loop can be compared against all 10 rows in the buffer. This reduces by an order of magnitude the number of times the inner table must be read.

MySQL join buffering has these characteristics:

- Join buffering can be used when the join is of type ALL or index (in other words, when no possible keys can be used, and a full scan is done, of either the data or index rows, respectively), or range.

- A join buffer is never allocated for the first nonconstant table, even if it would be of type ALL or index.

- Only columns of interest to a join are stored in its join buffer, not whole rows.
- The `join_buffer_size` system variable determines the size of each join buffer used to process a query.

- One buffer is allocated for each join that can be buffered, so a given query might be processed using multiple join buffers.

- A join buffer is allocated prior to executing the join and freed after the query is done.

For the example join described previously for the NLJ algorithm (without buffering), the join is done as follows using join buffering:

```sql
for each row in t1 matching range {
  for each row in t2 matching reference key {
    store used columns from t1, t2 in join buffer
    if buffer is full {
      for each row in t3 {
        for each t1, t2 combination in join buffer {
          if row satisfies join conditions, send to client
        }
        empty join buffer
      }
    }
  }
}

if buffer is not empty {
  for each row in t3 {
    for each t1, t2 combination in join buffer {
      if row satisfies join conditions, send to client
    }
  }
}
```

If $S$ is the size of each stored $t1, t2$ combination in the join buffer and $C$ is the number of combinations in the buffer, the number of times table $t3$ is scanned is:

$$(S \times C) / \text{join_buffer_size} + 1$$

The number of $t3$ scans decreases as the value of `join_buffer_size` increases, up to the point when `join_buffer_size` is large enough to hold all previous row combinations. At that point, no speed is gained by making it larger.

### 8.2.1.6 Nested Join Optimization

The syntax for expressing joins permits nested joins. The following discussion refers to the join syntax described in Section 13.2.9.2, “JOIN Clause”.

The syntax of `table_factor` is extended in comparison with the SQL Standard. The latter accepts only `table_reference`, not a list of them inside a pair of parentheses. This is a conservative extension if we consider each comma in a list of `table_reference` items as equivalent to an inner join. For example:

```sql
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
  ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

Is equivalent to:

```sql
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3 CROSS JOIN t4)
  ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

In MySQL, `CROSS JOIN` is syntactically equivalent to `INNER JOIN`; they can replace each other. In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause; `CROSS JOIN` is used otherwise.
In general, parentheses can be ignored in join expressions containing only inner join operations. Consider this join expression:

```
t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL) ON t1.a=t2.a
```

After removing parentheses and grouping operations to the left, that join expression transforms into this expression:

```
(t1 LEFT JOIN t2 ON t1.a=t2.a) LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL
```

Yet, the two expressions are not equivalent. To see this, suppose that the tables \( t_1, t_2, \) and \( t_3 \) have the following state:

- Table \( t_1 \) contains rows \((1), (2)\)
- Table \( t_2 \) contains row \((1,101)\)
- Table \( t_3 \) contains row \((101)\)

In this case, the first expression returns a result set including the rows \((1,1,101,101)\), \((2,NULL,NULL,NULL)\), whereas the second expression returns the rows \((1,1,101,101)\), \((2,NULL,NULL,101)\):

```
mysql> SELECT * FROM t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL) ON t1.a=t2.a;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL | NULL |
+------+------+------+------+

mysql> SELECT * FROM (t1 LEFT JOIN t2 ON t1.a=t2.a) LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
| 1    | 1    | 101  | 101  |
| 2    | NULL | NULL | 101  |
+------+------+------+------+
```

In the following example, an outer join operation is used together with an inner join operation:

```
t1 LEFT JOIN (t2, t3) ON t1.a=t2.a
```

That expression cannot be transformed into the following expression:

```
t1 LEFT JOIN t2 ON t1.a=t2.a, t3
```

For the given table states, the two expressions return different sets of rows:

```
mysql> SELECT * FROM t1 LEFT JOIN (t2, t3) ON t1.a=t2.a;
+------+------+------+
| a    | a    | b    |
+------+------+------+
| 1    | 1    | 101  |
| 2    | NULL | 101  |
+------+------+------+
```
Therefore, if we omit parentheses in a join expression with outer join operators, we might change the result set for the original expression.

More exactly, we cannot ignore parentheses in the right operand of the left outer join operation and in the left operand of a right join operation. In other words, we cannot ignore parentheses for the inner table expressions of outer join operations. Parentheses for the other operand (operand for the outer table) can be ignored.

The following expression:

\[(t_1,t_2) \text{ LEFT JOIN } t_3 \text{ ON } P(t_2.b,t_3.b)\]

Is equivalent to this expression for any tables \(t_1,t_2,t_3\) and any condition \(P\) over attributes \(t_2.b\) and \(t_3.b\):

\[t_1, t_2 \text{ LEFT JOIN } t_3 \text{ ON } P(t_2.b,t_3.b)\]

Whenever the order of execution of join operations in a join expression (\(\text{joined_table}\)) is not from left to right, we talk about nested joins. Consider the following queries:

\[
\begin{align*}
\text{SELECT * FROM } t_1 \text{ LEFT JOIN (}t_2 \text{ LEFT JOIN } t_3 \text{ ON } t_2.b=t_3.b\text{) ON } t_1.a=t_2.a \\
&\text{WHERE } t_1.a > 1
\end{align*}
\]

\[
\begin{align*}
\text{SELECT * FROM } t_1 \text{ LEFT JOIN (}t_2, t_3\text{) ON } t_1.a=t_2.a \\
&\text{WHERE (}t_2.b=t_3.b \text{ OR } t_2.b \text{ IS NULL) AND } t_1.a > 1
\end{align*}
\]

Those queries are considered to contain these nested joins:

\[
\begin{align*}
t_2 \text{ LEFT JOIN } t_3 \text{ ON } t_2.b=t_3.b \\
t_2, t_3
\end{align*}
\]

In the first query, the nested join is formed with a left join operation. In the second query, it is formed with an inner join operation.

In the first query, the parentheses can be omitted: The grammatical structure of the join expression will dictate the same order of execution for join operations. For the second query, the parentheses cannot be omitted, although the join expression here can be interpreted unambiguously without them. In our extended syntax, the parentheses in \((t_2, t_3)\) of the second query are required, although theoretically the query could be parsed without them: We still would have unambiguous syntactical structure for the query because \text{LEFT JOIN} and \text{ON} play the role of the left and right delimiters for the expression \((t_2, t_3)\).

The preceding examples demonstrate these points:

- For join expressions involving only inner joins (and not outer joins), parentheses can be removed and joins evaluated left to right. In fact, tables can be evaluated in any order.

- The same is not true, in general, for outer joins or for outer joins mixed with inner joins. Removal of parentheses may change the result.
Queries with nested outer joins are executed in the same pipeline manner as queries with inner joins. More exactly, a variation of the nested-loop join algorithm is exploited. Recall the algorithm by which the nested-loop join executes a query (see Section 8.2.1.5, “Nested-Loop Join Algorithms”). Suppose that a join query over 3 tables \( T_1, T_2, T_3 \) has this form:

```sql
SELECT * FROM T1 INNER JOIN T2 ON P1(T1,T2)
   INNER JOIN T3 ON P2(T2,T3)
   WHERE P(T1,T2,T3)
```

Here, \( P_1(T_1,T_2) \) and \( P_2(T_3,T_3) \) are some join conditions (on expressions), whereas \( P(T_1,T_2,T_3) \) is a condition over columns of tables \( T_1, T_2, T_3 \).

The nested-loop join algorithm would execute this query in the following manner:

```sql
FOR each row t1 in T1 {
    FOR each row t2 in T2 such that P1(t1,t2) {
        FOR each row t3 in T3 such that P2(t2,t3) {
            IF P(t1,t2,t3) {
                t:=t1||t2||t3; OUTPUT t;
            }
            f2=TRUE;
        }
        f1=TRUE;
    }
    IF (!f2) {
        IF P(t1,t2,NULL) {
            t:=t1||t2||NULL; OUTPUT t;
        }
        f1=TRUE;
    }
}
IF (!f1) {
    IF P(t1,NULL,NULL) {
        t:=t1||NULL||NULL; OUTPUT t;
    }
}
```

The notation \( t_1||t_2||t_3 \) indicates a row constructed by concatenating the columns of rows \( t_1, t_2, \) and \( t_3 \). In some of the following examples, \( \text{NULL} \) where a table name appears means a row in which \( \text{NULL} \) is used for each column of that table. For example, \( t_1||t_2||\text{NULL} \) indicates a row constructed by concatenating the columns of rows \( t_1 \) and \( t_2 \), and \( \text{NULL} \) for each column of \( t_3 \). Such a row is said to be \( \text{NULL} \)-complemented.

Now consider a query with nested outer joins:

```sql
SELECT * FROM T1 LEFT JOIN
   (T2 LEFT JOIN T3 ON P2(T2,T3))
   ON P1(T1,T2)
   WHERE P(T1,T2,T3)
```

For this query, modify the nested-loop pattern to obtain:

```sql
FOR each row t1 in T1 {
    BOOL f1=FALSE;
    FOR each row t2 in T2 such that P1(t1,t2) {
        BOOL f2=FALSE;
        FOR each row t3 in T3 such that P2(t2,t3) {
            IF P(t1,t2,t3) {
                t:=t1||t2||t3; OUTPUT t;
            }
            f2=TRUE;
            f1=TRUE;
        }
        IF (!f2) {
            IF P(t1,t2,NULL) {
                t:=t1||t2||NULL; OUTPUT t;
            }
            f1=TRUE;
        }
    }
    IF (!f1) {
        IF P(t1,NULL,NULL) {
            t:=t1||NULL||NULL; OUTPUT t;
        }
    }
}
```
In general, for any nested loop for the first inner table in an outer join operation, a flag is introduced that is turned off before the loop and is checked after the loop. The flag is turned on when for the current row from the outer table a match from the table representing the inner operand is found. If at the end of the loop cycle the flag is still off, no match has been found for the current row of the outer table. In this case, the row is complemented by NULL values for the columns of the inner tables. The result row is passed to the final check for the output or into the next nested loop, but only if the row satisfies the join condition of all embedded outer joins.

In the example, the outer join table expressed by the following expression is embedded:

\[
(T2 \text{ LEFT JOIN } T3 \text{ ON } P2(T2,T3))
\]

For the query with inner joins, the optimizer could choose a different order of nested loops, such as this one:

\[
\begin{aligned}
&\text{FOR each row } t3 \text{ in } T3 \{ } \\
&\quad \text{FOR each row } t2 \text{ in } T2 \text{ such that } P2(t2,t3) \{ } \\
&\quad\quad \text{FOR each row } t1 \text{ in } T1 \text{ such that } P1(t1,t2) \{ } \\
&\quad\quad\quad \text{IF } P(t1,t2,t3) \{ } \\
&\quad\quad\quad\quad t:=t1\|t2\|t3; \text{ OUTPUT } t; \\
&\quad\quad\quad\} \\
&\quad\} \\
&\} \\
\end{aligned}
\]

For queries with outer joins, the optimizer can choose only such an order where loops for outer tables precede loops for inner tables. Thus, for our query with outer joins, only one nesting order is possible. For the following query, the optimizer evaluates two different nestings. In both nestings, \( T1 \) must be processed in the outer loop because it is used in an outer join. \( T2 \) and \( T3 \) are used in an inner join, so that join must be processed in the inner loop. However, because the join is an inner join, \( T2 \) and \( T3 \) can be processed in either order.

\[
\begin{aligned}
&\text{SELECT } * \ T1 \text{ LEFT JOIN } (T2,T3) \text{ ON } P1(T1,T2) \text{ AND } P2(T1,T3) \\
&\text{WHERE } P(T1,T2,T3)
\end{aligned}
\]

One nesting evaluates \( T2 \), then \( T3 \):

\[
\begin{aligned}
&\text{FOR each row } t1 \text{ in } T1 \{ } \\
&\quad \text{BOOL } f1:=\text{FALSE}; \\
&\quad \text{FOR each row } t2 \text{ in } T2 \text{ such that } P1(t1,t2) \{ } \\
&\quad\quad \text{FOR each row } t3 \text{ in } T3 \text{ such that } P2(t1,t3) \{ } \\
&\quad\quad\quad \text{IF } P(t1,t2,t3) \{ } \\
&\quad\quad\quad\quad t:=t1\|t2\|t3; \text{ OUTPUT } t; \\
&\quad\quad\quad\} \\
&\quad\quad f1:=\text{TRUE} \\
&\quad\} \\
&\quad \text{IF } (!f1) \{ } \\
&\quad\quad \text{IF } P(t1,\text{NULL},\text{NULL}) \{ } \\
&\quad\quad\quad t:=t1\|\text{NULL}|\text{NULL}; \text{ OUTPUT } t; \\
&\quad\} \\
&\} \\
\end{aligned}
\]

The other nesting evaluates \( T3 \), then \( T2 \):

\[
\begin{aligned}
&\text{FOR each row } t1 \text{ in } T1 \{ } \\
&\quad \text{BOOL } f1:=\text{FALSE}; \\
&\quad \text{FOR each row } t3 \text{ in } T3 \text{ such that } P2(t1,t3) \{ } \\
\end{aligned}
\]
Optimizing SELECT Statements

FOR each row \( t2 \) in \( T2 \) such that \( P1(t1, t2) \) {
    IF \( P(t1, t2, t3) \) {
        \( t := t1 || t2 || t3; \) OUTPUT \( t \);
    }
    f1:=TRUE
}
}

IF (!f1) {
    IF \( P(t1, \text{NULL}, \text{NULL}) \) {
        \( t := t1 || \text{NULL} || \text{NULL}; \) OUTPUT \( t \);
    }
}

When discussing the nested-loop algorithm for inner joins, we omitted some details whose impact on the performance of query execution may be huge. We did not mention so-called “pushed-down” conditions. Suppose that our WHERE condition \( P(T1, T2, T3) \) can be represented by a conjunctive formula:

\[
P(T1, T2, T3) = C1(T1) \text{ AND } C2(T2) \text{ AND } C3(T3).
\]

In this case, MySQL actually uses the following nested-loop algorithm for the execution of the query with inner joins:

FOR each row \( t1 \) in \( T1 \) such that \( C1(t1) \) {
    FOR each row \( t2 \) in \( T2 \) such that \( P1(t1, t2) \text{ AND } C2(t2) \) {
        FOR each row \( t3 \) in \( T3 \) such that \( P2(t2, t3) \text{ AND } C3(t3) \) {
            IF \( P(t1, t2, t3) \) {
                \( t := t1 || t2 || t3; \) OUTPUT \( t \);
            }
        }
    }
}

You see that each of the conjuncts \( C1(T1), C2(T2), C3(T3) \) are pushed out of the most inner loop to the most outer loop where it can be evaluated. If \( C1(T1) \) is a very restrictive condition, this condition pushdown may greatly reduce the number of rows from table \( T1 \) passed to the inner loops. As a result, the execution time for the query may improve immensely.

For a query with outer joins, the WHERE condition is to be checked only after it has been found that the current row from the outer table has a match in the inner tables. Thus, the optimization of pushing conditions out of the inner nested loops cannot be applied directly to queries with outer joins. Here we must introduce conditional pushed-down predicates guarded by the flags that are turned on when a match has been encountered.

Recall this example with outer joins:

\[
P(T1, T2, T3) = C1(T1) \text{ AND } C(T2) \text{ AND } C3(T3)
\]

For that example, the nested-loop algorithm using guarded pushed-down conditions looks like this:

FOR each row \( t1 \) in \( T1 \) such that \( C1(t1) \) {
    BOOL \( f1 = \text{FALSE} \);
    FOR each row \( t2 \) in \( T2 \) such that \( P1(t1, t2) \text{ AND } (f1?C2(t2):\text{TRUE}) \) {
        BOOL \( f2 = \text{FALSE} \);
        FOR each row \( t3 \) in \( T3 \) such that \( P2(t2, t3) \text{ AND } (f1 && f2?C3(t3):\text{TRUE}) \) {
            IF \( (f1 && f2?\text{TRUE}:\text{C2(t2) AND C3(t3)}) \) {
                \( t := t1 || t2 || t3; \) OUTPUT \( t \);
            }
        }
    }
    f2 := TRUE;
    f1 := TRUE;

In general, pushed-down predicates can be extracted from join conditions such as \( P_1(T_1,T_2) \) and \( P(T_2,T_3) \). In this case, a pushed-down predicate is guarded also by a flag that prevents checking the predicate for the NULL-complemented row generated by the corresponding outer join operation.

Access by key from one inner table to another in the same nested join is prohibited if it is induced by a predicate from the \texttt{WHERE} condition.

### 8.2.1.7 Outer Join Optimization

Outer joins include \texttt{LEFT JOIN} and \texttt{RIGHT JOIN}.

MySQL implements an \texttt{A LEFT JOIN B join_specification} as follows:

- Table \texttt{B} is set to depend on table \texttt{A} and all tables on which \texttt{A} depends.
- Table \texttt{A} is set to depend on all tables (except \texttt{B}) that are used in the \texttt{LEFT JOIN} condition.
- The \texttt{LEFT JOIN} condition is used to decide how to retrieve rows from table \texttt{B}. (In other words, any condition in the \texttt{WHERE} clause is not used.)
- All standard join optimizations are performed, with the exception that a table is always read after all tables on which it depends. If there is a circular dependency, an error occurs.
- All standard \texttt{WHERE} optimizations are performed.
- If there is a row in \texttt{A} that matches the \texttt{WHERE} clause, but there is no row in \texttt{B} that matches the \texttt{ON} condition, an extra \texttt{B} row is generated with all columns set to \texttt{NULL}.
- If you use \texttt{LEFT JOIN} to find rows that do not exist in some table and you have the following test: \texttt{col_name IS NULL} in the \texttt{WHERE} part, where \texttt{col_name} is a column that is declared as \texttt{NOT NULL}, MySQL stops searching for more rows (for a particular key combination) after it has found one row that matches the \texttt{LEFT JOIN} condition.

The \texttt{RIGHT JOIN} implementation is analogous to that of \texttt{LEFT JOIN} with the table roles reversed. Right joins are converted to equivalent left joins, as described in Section 8.2.1.8, “Outer Join Simplification”.

For a \texttt{LEFT JOIN}, if the \texttt{WHERE} condition is always false for the generated \texttt{NULL} row, the \texttt{LEFT JOIN} is changed to an inner join. For example, the \texttt{WHERE} clause would be false in the following query if \texttt{t2.column1} were \texttt{NULL}:

```sql
SELECT * FROM t1 LEFT JOIN t2 ON (column1) WHERE t2.column2=5;
```

Therefore, it is safe to convert the query to an inner join:

```sql
SELECT * FROM t1, t2 WHERE t2.column2=5 AND t1.column1=t2.column1;
```
Now the optimizer can use table `t2` before table `t1` if doing so would result in a better query plan. To provide a hint about the table join order, use `STRAIGHT_JOIN`; see Section 13.2.9, “SELECT Statement”.

### 8.2.1.8 Outer Join Simplification

Table expressions in the `FROM` clause of a query are simplified in many cases.

At the parser stage, queries with right outer join operations are converted to equivalent queries containing only left join operations. In the general case, the conversion is performed such that this right join:

```
(T1, ...) RIGHT JOIN (T2, ...) ON P(T1, ..., T2, ...)
```

Becomes this equivalent left join:

```
(T2, ...) LEFT JOIN (T1, ...) ON P(T1, ..., T2, ...)
```

All inner join expressions of the form `T1 INNER JOIN T2 ON P(T1,T2)` are replaced by the list `T1,T2`, `P(T1,T2)` being joined as a conjunct to the `WHERE` condition (or to the join condition of the embedding join, if there is any).

When the optimizer evaluates plans for outer join operations, it takes into consideration only plans where, for each such operation, the outer tables are accessed before the inner tables. The optimizer choices are limited because only such plans enable outer joins to be executed using the nested-loop algorithm.

Consider a query of this form, where `R(T2)` greatly narrows the number of matching rows from table `T2`:

```
SELECT * T1 LEFT JOIN T2 ON P1(T1,T2)
WHERE P(T1,T2) AND R(T2)
```

If the query is executed as written, the optimizer has no choice but to access the less-restricted table `T1` before the more-restricted table `T2`, which may produce a very inefficient execution plan.

Instead, MySQL converts the query to a query with no outer join operation if the `WHERE` condition is null-rejected. (That is, it converts the outer join to an inner join.) A condition is said to be null-rejected for an outer join operation if it evaluates to `FALSE` or `UNKNOWN` for any `NULL`-complemented row generated for the operation.

Thus, for this outer join:

```
T1 LEFT JOIN T2 ON T1.A=T2.A
```

Conditions such as these are null-rejected because they cannot be true for any `NULL`-complemented row (with `T2` columns set to `NULL`):

- `T2.B IS NOT NULL`
- `T2.B > 3`
- `T2.C <= T1.C`
- `T2.B < 2 OR T2.C > 1`

Conditions such as these are not null-rejected because they might be true for a `NULL`-complemented row:

- `T2.B IS NULL`
- `T1.B < 3 OR T2.B IS NOT NULL`
- `T1.B < 3 OR T2.B > 3`

The general rules for checking whether a condition is null-rejected for an outer join operation are simple:

- It is of the form `A IS NOT NULL`, where `A` is an attribute of any of the inner tables
• It is a predicate containing a reference to an inner table that evaluates to **UNKNOWN** when one of its arguments is **NULL**

• It is a conjunction containing a null-rejected condition as a conjunct

• It is a disjunction of null-rejected conditions

A condition can be null-rejected for one outer join operation in a query and not null-rejected for another. In this query, the **WHERE** condition is null-rejected for the second outer join operation but is not null-rejected for the first one:

```sql
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
            LEFT JOIN T3 ON T3.B=T1.B
     WHERE T3.C > 0
```

If the **WHERE** condition is null-rejected for an outer join operation in a query, the outer join operation is replaced by an inner join operation.

For example, in the preceding query, the second outer join is null-rejected and can be replaced by an inner join:

```sql
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
            INNER JOIN T3 ON T3.B=T1.B
     WHERE T3.C > 0
```

For the original query, the optimizer evaluates only plans compatible with the single table-access order **T1,T2,T3**. For the rewritten query, it additionally considers the access order **T3,T1,T2**.

A conversion of one outer join operation may trigger a conversion of another. Thus, the query:

```sql
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
            LEFT JOIN T3 ON T3.B=T2.B
     WHERE T3.C > 0
```

Is first converted to the query:

```sql
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
            INNER JOIN T3 ON T3.B=T2.B
     WHERE T3.C > 0
```

Which is equivalent to the query:

```sql
SELECT * FROM (T1 LEFT JOIN T2 ON T2.A=T1.A), T3
     WHERE T3.C > 0 AND T3.B=T2.B
```

The remaining outer join operation can also be replaced by an inner join because the condition **T3.B=T2.B** is null-rejected. This results in a query with no outer joins at all:

```sql
SELECT * FROM (T1 INNER JOIN T2 ON T2.A=T1.A), T3
     WHERE T3.C > 0 AND T3.B=T2.B
```

Sometimes the optimizer succeeds in replacing an embedded outer join operation, but cannot convert the embedding outer join. The following query:

```sql
SELECT * FROM T1 LEFT JOIN
            (T2 LEFT JOIN T3 ON T3.B=T2.B)
       ON T2.A=T1.A
     WHERE T3.C > 0
```

Is converted to:

```sql
SELECT * FROM T1 LEFT JOIN
```
Optimizing SELECT Statements

(T2 INNER JOIN T3 ON T3.B=T2.B)
ON T2.A=T1.A
WHERE T3.C > 0

That can be rewritten only to the form still containing the embedding outer join operation:

SELECT * FROM T1 LEFT JOIN (T2,T3)
WHERE T3.C > 0

Any attempt to convert an embedded outer join operation in a query must take into account the join condition for the embedding outer join together with the WHERE condition. In this query, the WHERE condition is not null-rejected for the embedded outer join, but the join condition of the embedding outer join T2.A=T1.A AND T3.C=T1.C is null-rejected:

SELECT * FROM T1 LEFT JOIN (T2 LEFT JOIN T3 ON T3.B=T2.B)
WHERE T3.D > 0 OR T1.D > 0

Consequently, the query can be converted to:

SELECT * FROM T1 LEFT JOIN (T2, T3)
WHERE T3.D > 0 OR T1.D > 0

8.2.1.9 IS NULL Optimization

MySQL can perform the same optimization on col_name IS NULL that it can use for col_name = constant_value. For example, MySQL can use indexes and ranges to search for NULL with IS NULL.

Examples:

SELECT * FROM tbl_name WHERE key_col IS NULL;
SELECT * FROM tbl_name WHERE key_col <=> NULL;
SELECT * FROM tbl_name
WHERE key_col=const1 OR key_col=const2 OR key_col IS NULL;

If a WHERE clause includes a col_name IS NULL condition for a column that is declared as NOT NULL, that expression is optimized away. This optimization does not occur in cases when the column might produce NULL anyway (for example, if it comes from a table on the right side of a LEFT JOIN).

MySQL can also optimize the combination col_name = expr OR col_name IS NULL, a form that is common in resolved subqueries. EXPLAIN shows ref_or_null when this optimization is used.

This optimization can handle one IS NULL for any key part.

Some examples of queries that are optimized, assuming that there is an index on columns a and b of table t2:

SELECT * FROM t1 WHERE t1.a=expr OR t1.a IS NULL;
SELECT * FROM t1, t2 WHERE t1.a=t2.a OR t2.a IS NULL;
SELECT * FROM t1, t2
WHERE (t1.a=t2.a OR t2.a IS NULL) AND t2.b=t1.b;
SELECT * FROM t1, t2
WHERE t1.a=t2.a AND (t2.b=t1.b OR t2.b IS NULL);

SELECT * FROM t1, t2
WHERE (t1.a=t2.a AND t2.a IS NULL AND ...)
OR (t1.a=t2.a AND t2.a IS NULL AND ...);

**ref_or_null** works by first doing a read on the reference key, and then a separate search for rows with a **NULL** key value.

The optimization can handle only one **IS NULL** level. In the following query, MySQL uses key lookups only on the expression **(t1.a=t2.a AND t2.a IS NULL)** and is not able to use the key part on **b**:

SELECT * FROM t1, t2
WHERE (t1.a=t2.a AND t2.a IS NULL)
OR (t1.b=t2.b AND t2.b IS NULL);

### 8.2.1.10 ORDER BY Optimization

This section describes when MySQL can use an index to satisfy an **ORDER BY** clause, the **filesort** operation used when an index cannot be used, and execution plan information available from the optimizer about **ORDER BY**.

An **ORDER BY** with and without **LIMIT** may return rows in different orders, as discussed in **Section 8.2.1.13, “LIMIT Query Optimization”**.

* Use of Indexes to Satisfy **ORDER BY**
* Use of **filesort** to Satisfy **ORDER BY**
* Influencing **ORDER BY** Optimization
* **ORDER BY** Execution Plan Information Available

**Use of Indexes to Satisfy ORDER BY**

In some cases, MySQL may use an index to satisfy an **ORDER BY** clause and avoid the extra sorting involved in performing a **filesort** operation.

The index may also be used even if the **ORDER BY** does not match the index exactly, as long as all unused portions of the index and all extra **ORDER BY** columns are constants in the **WHERE** clause. If the index does not contain all columns accessed by the query, the index is used only if index access is cheaper than other access methods.

Assuming that there is an index on **(key_part1, key_part2)**, the following queries may use the index to resolve the **ORDER BY** part. Whether the optimizer actually does so depends on whether reading the index is more efficient than a table scan if columns not in the index must also be read.

* In this query, the index on **(key_part1, key_part2)** enables the optimizer to avoid sorting:

```
SELECT * FROM t1
ORDER BY key_part1, key_part2;
```

However, the query uses **SELECT ***, which may select more columns than **key_part1** and **key_part2**. In that case, scanning an entire index and looking up table rows to find columns not in the index may be more expensive than scanning the table and sorting the results. If so, the optimizer probably will not use the index. If **SELECT *** selects only the index columns, the index will be used and sorting avoided.
Optimizing SELECT Statements

If t1 is an InnoDB table, the table primary key is implicitly part of the index, and the index can be used to resolve the ORDER BY for this query:

```sql
SELECT pk, key_part1, key_part2 FROM t1
ORDER BY key_part1, key_part2;
```

- In this query, key_part1 is constant, so all rows accessed through the index are in key_part2 order, and an index on (key_part1, key_part2) avoids sorting if the WHERE clause is selective enough to make an index range scan cheaper than a table scan:

```sql
SELECT * FROM t1
WHERE key_part1 = constant
ORDER BY key_part2;
```

- In the next two queries, whether the index is used is similar to the same queries without DESC shown previously:

```sql
SELECT * FROM t1
ORDER BY key_part1 DESC, key_part2 DESC;
SELECT * FROM t1
WHERE key_part1 = constant
ORDER BY key_part2 DESC;
```

- In the next two queries, key_part1 is compared to a constant. The index will be used if the WHERE clause is selective enough to make an index range scan cheaper than a table scan:

```sql
SELECT * FROM t1
WHERE key_part1 > constant
ORDER BY key_part1 ASC;
SELECT * FROM t1
WHERE key_part1 < constant
ORDER BY key_part1 DESC;
```

- In the next query, the ORDER BY does not name key_part1, but all rows selected have a constant key_part1 value, so the index can still be used:

```sql
SELECT * FROM t1
WHERE key_part1 = constant1 AND key_part2 > constant2
ORDER BY key_part2;
```

In some cases, MySQL cannot use indexes to resolve the ORDER BY, although it may still use indexes to find the rows that match the WHERE clause. Examples:

- The query uses ORDER BY on different indexes:

```sql
SELECT * FROM t1 ORDER BY key1, key2;
```

- The query uses ORDER BY on nonconsecutive parts of an index:

```sql
SELECT * FROM t1 WHERE key2=constant ORDER BY key1_part1, key1_part3;
```

- The query mixes ASC and DESC:

```sql
SELECT * FROM t1 ORDER BY key_part1 DESC, key_part2 ASC;
```

- The index used to fetch the rows differs from the one used in the ORDER BY:

```sql
SELECT * FROM t1 WHERE key2=constant ORDER BY key1;
```

- The query uses ORDER BY with an expression that includes terms other than the index column name:
Optimizing SELECT Statements

- The query joins many tables, and the columns in the ORDER BY are not all from the first nonconstant table that is used to retrieve rows. (This is the first table in the EXPLAIN output that does not have a const join type.)

- The query has different ORDER BY and GROUP BY expressions.

- There is an index on only a prefix of a column named in the ORDER BY clause. In this case, the index cannot be used to fully resolve the sort order. For example, if only the first 10 bytes of a CHAR(20) column are indexed, the index cannot distinguish values past the 10th byte and a filesort is needed.

- The index does not store rows in order. For example, this is true for a HASH index in a MEMORY table.

Availability of an index for sorting may be affected by the use of column aliases. Suppose that the column t1.a is indexed. In this statement, the name of the column in the select list is a. It refers to t1.a, as does the reference to a in the ORDER BY, so the index on t1.a can be used:

```
SELECT a FROM t1 ORDER BY a;
```

In this statement, the name of the column in the select list is also a, but it is the alias name. It refers to ABS(a), as does the reference to a in the ORDER BY, so the index on t1.a cannot be used:

```
SELECT ABS(a) AS a FROM t1 ORDER BY a;
```

In the following statement, the ORDER BY refers to a name that is not the name of a column in the select list. But there is a column in t1 named a, so the ORDER BY refers to t1.a and the index on t1.a can be used. (The resulting sort order may be completely different from the order for ABS(a), of course.)

```
SELECT ABS(a) AS b FROM t1 ORDER BY a;
```

By default, MySQL sorts GROUP BY col1, col2, ... queries as if you also included ORDER BY col1, col2, ... in the query. If you include an explicit ORDER BY clause that contains the same column list, MySQL optimizes it away without any speed penalty, although the sorting still occurs.

If a query includes GROUP BY but you want to avoid the overhead of sorting the result, you can suppress sorting by specifying ORDER BY NULL. For example:

```
INSERT INTO foo
SELECT a, COUNT(*) FROM bar GROUP BY a ORDER BY NULL;
```

The optimizer may still choose to use sorting to implement grouping operations. ORDER BY NULL suppresses sorting of the result, not prior sorting done by grouping operations to determine the result.

Note

GROUP BY implicitly sorts by default (that is, in the absence of ASC or DESC designators for GROUP BY columns), but relying on implicit GROUP BY sorting is deprecated. To produce a given sort order, use explicit ASC or DESC designators for GROUP BY columns or provide an ORDER BY clause. GROUP BY sorting is a MySQL extension that may change in a future release; for example, to make it possible for the optimizer to order groupings in whatever manner it deems most efficient and to avoid the sorting overhead.

Use of filesort to Satisfy ORDER BY
Optimizing SELECT Statements

If an index cannot be used to satisfy an ORDER BY clause, MySQL performs a filesort operation that reads table rows and sorts them. A filesort constitutes an extra sorting phase in query execution.

To obtain memory for filesort operations, the optimizer allocates a fixed amount of sort_buffer_size bytes up front. Individual sessions can change the session value of this variable as desired to avoid excessive memory use, or to allocate more memory as necessary.

A filesort operation uses temporary disk files as necessary if the result set is too large to fit in memory. Some types of queries are particularly suited to completely in-memory filesort operations. For example, the optimizer can use filesort to efficiently handle in memory, without temporary files, the ORDER BY operation for queries (and subqueries) of the following form:

```
SELECT ... FROM single_table ... ORDER BY non_index_column [DESC] LIMIT [M,]N;
```

Such queries are common in web applications that display only a few rows from a larger result set.

Examples:

```
SELECT col1, ... FROM t1 ... ORDER BY name LIMIT 10;
SELECT col1, ... FROM t1 ... ORDER BY RAND() LIMIT 15;
```

Influencing ORDER BY Optimization

For slow ORDER BY queries for which filesort is not used, try lowering the max_length_for_sort_data system variable to a value that is appropriate to trigger a filesort. (A symptom of setting the value of this variable too high is a combination of high disk activity and low CPU activity.)

To increase ORDER BY speed, check whether you can get MySQL to use indexes rather than an extra sorting phase. If this is not possible, try the following strategies:

- Increase the sort_buffer_size variable value. Ideally, the value should be large enough for the entire result set to fit in the sort buffer (to avoid writes to disk and merge passes), but at minimum the value must be large enough to accommodate 15 tuples. (Up to 15 temporary disk files are merged and there must be room in memory for at least one tuple per file.)

  Take into account that the size of column values stored in the sort buffer is affected by the max_sort_length system variable value. For example, if tuples store values of long string columns and you increase the value of max_sort_length, the size of sort buffer tuples increases as well and may require you to increase sort_buffer_size. For column values calculated as a result of string expressions (such as those that invoke a string-valued function), the filesort algorithm cannot tell the maximum length of expression values, so it must allocate max_sort_length bytes for each tuple.

  To monitor the number of merge passes (to merge temporary files), check the Sort_merge_passes status variable.

- Increase the read_rnd_buffer_size variable value so that more rows are read at a time.

- Use less RAM per row by declaring columns only as large as they need to be to hold the values stored in them. For example, CHAR(16) is better than CHAR(200) if values never exceed 16 characters.

- Change the tmpdir system variable to point to a dedicated file system with large amounts of free space. The variable value can list several paths that are used in round-robin fashion; you can use this feature to spread the load across several directories. Separate the paths by colon characters (:) on Unix and semicolon characters (;) on Windows. The paths should name directories in file systems located on different physical disks, not different partitions on the same disk.
Optimizing SELECT Statements

ORDER BY Execution Plan Information Available

With `EXPLAIN` (see Section 8.8.1, “Optimizing Queries with EXPLAIN”), you can check whether MySQL can use indexes to resolve an `ORDER BY` clause:

- If the `Extra` column of `EXPLAIN` output does not contain `Using filesort`, the index is used and a `filesort` is not performed.
- If the `Extra` column of `EXPLAIN` output contains `Using filesort`, the index is not used and a `filesort` is performed.

8.2.1.11 GROUP BY Optimization

The most general way to satisfy a `GROUP BY` clause is to scan the whole table and create a new temporary table where all rows from each group are consecutive, and then use this temporary table to discover groups and apply aggregate functions (if any). In some cases, MySQL is able to do much better than that and avoid creation of temporary tables by using index access.

The most important preconditions for using indexes for `GROUP BY` are that all `GROUP BY` columns reference attributes from the same index, and that the index stores its keys in order (as is true, for example, for a `BTREE` index, but not for a `HASH` index). Whether use of temporary tables can be replaced by index access also depends on which parts of an index are used in a query, the conditions specified for these parts, and the selected aggregate functions.

There are two ways to execute a `GROUP BY` query through index access, as detailed in the following sections. The first method applies the grouping operation together with all range predicates (if any). The second method first performs a range scan, and then groups the resulting tuples.

In MySQL, `GROUP BY` is used for sorting, so the server may also apply `ORDER BY` optimizations to grouping. However, relying on implicit `GROUP BY` sorting is deprecated. See Section 8.2.1.10, “ORDER BY Optimization”.

- Loose Index Scan
- Tight Index Scan

Loose Index Scan

The most efficient way to process `GROUP BY` is when an index is used to directly retrieve the grouping columns. With this access method, MySQL uses the property of some index types that the keys are ordered (for example, `BTREE`). This property enables use of lookup groups in an index without having to consider all keys in the index that satisfy all `WHERE` conditions. This access method considers only a fraction of the keys in an index, so it is called a Loose Index Scan. When there is no `WHERE` clause, a Loose Index Scan reads as many keys as the number of groups, which may be a much smaller number than that of all keys. If the `WHERE` clause contains range predicates (see the discussion of the range join type in Section 8.8.1, “Optimizing Queries with EXPLAIN”), a Loose Index Scan looks up the first key of each group that satisfies the range conditions, and again reads the smallest possible number of keys. This is possible under the following conditions:

- The query is over a single table.

- The `GROUP BY` names only columns that form a leftmost prefix of the index and no other columns. (If, instead of `GROUP BY`, the query has a `DISTINCT` clause, all distinct attributes refer to columns that form a leftmost prefix of the index.) For example, if a table `t1` has an index on `(c1,c2,c3)`, Loose Index Scan is applicable if the query has `GROUP BY c1, c2`. It is not applicable if the query has `GROUP BY c2, c3` (the columns are not a leftmost prefix) or `GROUP BY c1, c2, c4` (`c4` is not in the index).
• The only aggregate functions used in the select list (if any) are `MIN()` and `MAX()`, and all of them refer to the same column. The column must be in the index and must immediately follow the columns in the `GROUP BY`.

• Any other parts of the index than those from the `GROUP BY` referenced in the query must be constants (that is, they must be referenced in equalities with constants), except for the argument of `MIN()` or `MAX()` functions.

• For columns in the index, full column values must be indexed, not just a prefix. For example, with `c1 VARCHAR(20), INDEX (c1(10))`, the index uses only a prefix of `c1` values and cannot be used for Loose Index Scan.

If Loose Index Scan is applicable to a query, the `EXPLAIN` output shows `Using index for group-by` in the `Extra` column.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The Loose Index Scan access method can be used for the following queries:

```sql
SELECT c1, c2 FROM t1 GROUP BY c1, c2;
SELECT DISTINCT c1, c2 FROM t1;
SELECT c1, MIN(c2) FROM t1 GROUP BY c1;
SELECT c1, c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
SELECT MAX(c3), MIN(c3), c1, c2 FROM t1 WHERE c2 > const GROUP BY c1, c2;
SELECT c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
SELECT c1, c2 FROM t1 WHERE c3 = const GROUP BY c1, c2;
```

The following queries cannot be executed with this quick select method, for the reasons given:

• There are aggregate functions other than `MIN()` or `MAX()`:

```sql
SELECT c1, SUM(c2) FROM t1 GROUP BY c1;
```

• The columns in the `GROUP BY` clause do not form a leftmost prefix of the index:

```sql
SELECT c1, c2 FROM t1 GROUP BY c2, c3;
```

• The query refers to a part of a key that comes after the `GROUP BY` part, and for which there is no equality with a constant:

```sql
SELECT c1, c3 FROM t1 GROUP BY c1, c2;
```

Were the query to include `WHERE c3 = const`, Loose Index Scan could be used.

The Loose Index Scan access method can be applied to other forms of aggregate function references in the select list, in addition to the `MIN()` and `MAX()` references already supported:

• `AVG(DISTINCT)`, `SUM(DISTINCT)`, and `COUNT(DISTINCT)` are supported. `AVG(DISTINCT)` and `SUM(DISTINCT)` take a single argument. `COUNT(DISTINCT)` can have more than one column argument.

• There must be no `GROUP BY` or `DISTINCT` clause in the query.

• The Loose Index Scan limitations described previously still apply.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The Loose Index Scan access method can be used for the following queries:

```sql
SELECT COUNT(DISTINCT c1), SUM(DISTINCT c1) FROM t1;
```
Optimizing SELECT Statements

```sql
SELECT COUNT(DISTINCT c1, c2), COUNT(DISTINCT c2, c1) FROM t1;
```

**Tight Index Scan**

A Tight Index Scan may be either a full index scan or a range index scan, depending on the query conditions.

When the conditions for a Loose Index Scan are not met, it still may be possible to avoid creation of temporary tables for `GROUP BY` queries. If there are range conditions in the `WHERE` clause, this method reads only the keys that satisfy these conditions. Otherwise, it performs an index scan. Because this method reads all keys in each range defined by the `WHERE` clause, or scans the whole index if there are no range conditions, it is called a *Tight Index Scan*. With a Tight Index Scan, the grouping operation is performed only after all keys that satisfy the range conditions have been found.

For this method to work, it is sufficient that there be a constant equality condition for all columns in a query referring to parts of the key coming before or in between parts of the `GROUP BY` key. The constants from the equality conditions fill in any “gaps” in the search keys so that it is possible to form complete prefixes of the index. These index prefixes then can be used for index lookups. If the `GROUP BY` result requires sorting, and it is possible to form search keys that are prefixes of the index, MySQL also avoids extra sorting operations because searching with prefixes in an ordered index already retrieves all the keys in order.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The following queries do not work with the Loose Index Scan access method described previously, but still work with the Tight Index Scan access method.

- There is a gap in the `GROUP BY`, but it is covered by the condition `c2 = 'a'`:
  ```sql
  SELECT c1, c2, c3 FROM t1 WHERE c2 = 'a' GROUP BY c1, c3;
  ```

- The `GROUP BY` does not begin with the first part of the key, but there is a condition that provides a constant for that part:
  ```sql
  SELECT c1, c2, c3 FROM t1 WHERE c1 = 'a' GROUP BY c2, c3;
  ```

**8.2.1.12 DISTINCT Optimization**

`DISTINCT` combined with `ORDER BY` needs a temporary table in many cases.

Because `DISTINCT` may use `GROUP BY`, learn how MySQL works with columns in `ORDER BY` or `HAVING` clauses that are not part of the selected columns. See Section 12.17.3, "MySQL Handling of GROUP BY".

In most cases, a `DISTINCT` clause can be considered as a special case of `GROUP BY`. For example, the following two queries are equivalent:

```sql
SELECT DISTINCT c1, c2, c3 FROM t1
WHERE c1 > const;

SELECT c1, c2, c3 FROM t1
WHERE c1 > const GROUP BY c1, c2, c3;
```

Due to this equivalence, the optimizations applicable to `GROUP BY` queries can be also applied to queries with a `DISTINCT` clause. Thus, for more details on the optimization possibilities for `DISTINCT` queries, see Section 8.2.1.11, “GROUP BY Optimization”.

When combining `LIMIT row_count` with `DISTINCT`, MySQL stops as soon as it finds `row_count` unique rows.
If you do not use columns from all tables named in a query, MySQL stops scanning any unused tables as soon as it finds the first match. In the following case, assuming that t1 is used before t2 (which you can check with EXPLAIN), MySQL stops reading from t2 (for any particular row in t1) when it finds the first row in t2:

```
SELECT DISTINCT t1.a FROM t1, t2 WHERE t1.a=t2.a;
```

### 8.2.1.13 LIMIT Query Optimization

If you need only a specified number of rows from a result set, use a LIMIT clause in the query, rather than fetching the whole result set and throwing away the extra data.

MySQL sometimes optimizes a query that has a LIMIT row_count clause and no HAVING clause:

- If you select only a few rows with LIMIT, MySQL uses indexes in some cases when normally it would prefer to do a full table scan.
- If you combine LIMIT row_count with ORDER BY, MySQL stops sorting as soon as it has found the first row_count rows of the sorted result, rather than sorting the entire result. If ordering is done by using an index, this is very fast. If a filesort must be done, all rows that match the query without the LIMIT clause are selected, and most or all of them are sorted, before the first row_count are found. After the initial rows have been found, MySQL does not sort any remainder of the result set.

One manifestation of this behavior is that an ORDER BY query with and without LIMIT may return rows in different order, as described later in this section.

- If you combine LIMIT row_count with DISTINCT, MySQL stops as soon as it finds row_count unique rows.
- In some cases, a GROUP BY can be resolved by reading the index in order (or doing a sort on the index), then calculating summaries until the index value changes. In this case, LIMIT row_count does not calculate any unnecessary GROUP BY values.
- As soon as MySQL has sent the required number of rows to the client, it aborts the query unless you are using SQL_CALC_FOUND_ROWS. In that case, the number of rows can be retrieved with SELECT FOUND_ROWS(). See Section 12.15, “Information Functions”.
- LIMIT 0 quickly returns an empty set. This can be useful for checking the validity of a query. It can also be employed to obtain the types of the result columns within applications that use a MySQL API that makes result set metadata available. With the mysql client program, you can use the --column-type-info option to display result column types.
- If the server uses temporary tables to resolve a query, it uses the LIMIT row_count clause to calculate how much space is required.

If multiple rows have identical values in the ORDER BY columns, the server is free to return those rows in any order, and may do so differently depending on the overall execution plan. In other words, the sort order of those rows is nondeterministic with respect to the nonordered columns.

One factor that affects the execution plan is LIMIT, so an ORDER BY query with and without LIMIT may return rows in different orders. Consider this query, which is sorted by the category column but nondeterministic with respect to the id and rating columns:

```
mysql> SELECT * FROM ratings ORDER BY category;
+----+----------+--------+
| id | category | rating |
+----+----------+--------+
| 909 |
```
Including **LIMIT** may affect order of rows within each **category** value. For example, this is a valid query result:

```sql
mysql> SELECT * FROM ratings ORDER BY category LIMIT 5;
```

<table>
<thead>
<tr>
<th>id</th>
<th>category</th>
<th>rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3.7</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5.0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

In each case, the rows are sorted by the **ORDER BY** column, which is all that is required by the SQL standard.

If it is important to ensure the same row order with and without **LIMIT**, include additional columns in the **ORDER BY** clause to make the order deterministic. For example, if **id** values are unique, you can make rows for a given **category** value appear in **id** order by sorting like this:

```sql
mysql> SELECT * FROM ratings ORDER BY category, id;
```

```sql
mysql> SELECT * FROM ratings ORDER BY category, id LIMIT 5;
```

<table>
<thead>
<tr>
<th>id</th>
<th>category</th>
<th>rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3.7</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5.0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

### 8.2.1.14 Function Call Optimization

MySQL functions are tagged internally as deterministic or nondeterministic. A function is nondeterministic if, given fixed values for its arguments, it can return different results for different invocations. Examples of nondeterministic functions: **RAND()**, **UUID()**.

If a function is tagged nondeterministic, a reference to it in a **WHERE** clause is evaluated for every row (when selecting from one table) or combination of rows (when selecting from a multiple-table join).
MySQL also determines when to evaluate functions based on types of arguments, whether the arguments are table columns or constant values. A deterministic function that takes a table column as argument must be evaluated whenever that column changes value.

Nondeterministic functions may affect query performance. For example, some optimizations may not be available, or more locking might be required. The following discussion uses \texttt{RAND()} but applies to other nondeterministic functions as well.

Suppose that a table \texttt{t} has this definition:

\begin{verbatim}
CREATE TABLE t (id INT NOT NULL PRIMARY KEY, col_a VARCHAR(100));
\end{verbatim}

Consider these two queries:

\begin{verbatim}
SELECT * FROM t WHERE id = POW(1,2);
SELECT * FROM t WHERE id = FLOOR(1 + RAND() * 49);
\end{verbatim}

Both queries appear to use a primary key lookup because of the equality comparison against the primary key, but that is true only for the first of them:

- The first query always produces a maximum of one row because \texttt{POW()} with constant arguments is a constant value and is used for index lookup.

- The second query contains an expression that uses the nondeterministic function \texttt{RAND()}, which is not constant in the query but in fact has a new value for every row of table \texttt{t}. Consequently, the query reads every row of the table, evaluates the predicate for each row, and outputs all rows for which the primary key matches the random value. This might be zero, one, or multiple rows, depending on the \texttt{id} column values and the values in the \texttt{RAND()} sequence.

The effects of nondeterminism are not limited to \texttt{SELECT} statements. This \texttt{UPDATE} statement uses a nondeterministic function to select rows to be modified:

\begin{verbatim}
UPDATE t SET col_a = \texttt{some_expr} WHERE id = FLOOR(1 + RAND() * 49);
\end{verbatim}

Presumably the intent is to update at most a single row for which the primary key matches the expression. However, it might update zero, one, or multiple rows, depending on the \texttt{id} column values and the values in the \texttt{RAND()} sequence.

The behavior just described has implications for performance and replication:

- Because a nondeterministic function does not produce a constant value, the optimizer cannot use strategies that might otherwise be applicable, such as index lookups. The result may be a table scan.

- \texttt{InnoDB} might escalate to a range-key lock rather than taking a single row lock for one matching row.

- Updates that do not execute deterministically are unsafe for replication.

The difficulties stem from the fact that the \texttt{RAND()} function is evaluated once for every row of the table. To avoid multiple function evaluations, use one of these techniques:

- Move the expression containing the nondeterministic function to a separate statement, saving the value in a variable. In the original statement, replace the expression with a reference to the variable, which the optimizer can treat as a constant value:

\begin{verbatim}
SET @keyval = FLOOR(1 + RAND() * 49);
UPDATE t SET col_a = \texttt{some_expr} WHERE id = @keyval;
\end{verbatim}

- Assign the random value to a variable in a derived table. This technique causes the variable to be assigned a value, once, prior to its use in the comparison in the \texttt{WHERE} clause:
As mentioned previously, a nondeterministic expression in the `WHERE` clause might prevent optimizations and result in a table scan. However, it may be possible to partially optimize the `WHERE` clause if other expressions are deterministic. For example:

```sql
SELECT * FROM t WHERE partial_key=5 AND some_column=RAND();
```

If the optimizer can use `partial_key` to reduce the set of rows selected, `RAND()` is executed fewer times, which diminishes the effect of nondeterminism on optimization.

### 8.2.1.15 Row Constructor Expression Optimization

Row constructors permit simultaneous comparisons of multiple values. For example, these two statements are semantically equivalent:

```sql
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

In addition, the optimizer handles both expressions the same way.

The optimizer is less likely to use available indexes if the row constructor columns do not cover the prefix of an index. Consider the following table, which has a primary key on `(c1, c2, c3)`:  

```sql
CREATE TABLE t1 (
    c1 INT, c2 INT, c3 INT, c4 CHAR(100),
    PRIMARY KEY(c1,c2,c3)
);
```

In this query, the `WHERE` clause uses all columns in the index. However, the row constructor itself does not cover an index prefix, with the result that the optimizer uses only `c1` (key len=4, the size of `c1`):

```sql
mysql> EXPLAIN SELECT * FROM t1 WHERE c1=1 AND (c2,c3) > (1,1)
G
*************************** 1. row ***************************
  id: 1
  select_type: SIMPLE
  table: t1
  partitions: NULL
  type: ref
  possible_keys: PRIMARY
  key: PRIMARY
  key_len: 4
  ref: const
  rows: 3
  Extra: Using where
```

In such cases, rewriting the row constructor expression using an equivalent nonconstructor expression may result in more complete index use. For the given query, the row constructor and equivalent nonconstructor expressions are:

- `(c2,c3) > (1,1)`
- `c2 > 1 OR ((c2 = 1) AND (c3 > 1))`

Rewriting the query to use the nonconstructor expression results in the optimizer using all three columns in the index (key len=12):

```sql
mysql> EXPLAIN SELECT * FROM t1 WHERE c1 = 1 AND (c2 > 1 OR ((c2 = 1) AND (c3 > 1)))
G
*************************** 1. row ***************************
  id: 1
  select_type: SIMPLE
  table: t1
  partitions: NULL
  type: ref
  possible_keys: PRIMARY
  key: PRIMARY
  key_len: 13
  ref: const
  rows: 3
  Extra: Using where
```
Thus, for better results, avoid mixing row constructors with AND/OR expressions. Use one or the other.

8.2.1.16 Avoiding Full Table Scans

Frequently, a full table scan is a danger sign that a query can be speeded up significantly. For tables with more than a few rows, consider redesigning the query by adding an index for one or more of the columns tested in the WHERE clause. Put extra effort into avoiding table scans for queries that perform joins or reference foreign keys. If the nature of the data means there is no way to avoid reading all the rows, then it might not be practical to make the query faster, or making it faster might involve extensive restructuring of your tables that is beyond the scope of this section.

The output from EXPLAIN shows ALL in the type column when MySQL uses a table scan to resolve a query. This usually happens under the following conditions:

- The ON or WHERE clauses do not reference any indexed columns that the query can use. Consider adding an index, or refining those clauses to refer to an indexed column.

- The table is so small that it is faster to perform a table scan than to bother with a key lookup. This is common for tables with fewer than 10 rows and a short row length.

- You are comparing indexed columns with constant values and MySQL has calculated (based on the index tree) that the constants cover too large a part of the table and that a table scan would be faster. See Section 8.2.1.1, “WHERE Clause Optimization”. For example, to query census data only for males or only for females, MySQL must read most of the data blocks in the table, so locating the rows through the index would add unnecessary overhead. If these reports are frequent or truly time-critical, and the table is huge, you might partition, shard, or create dimension tables using the relevant column.

- You are using a key with low cardinality (many rows match the key value) through another column. In this case, MySQL assumes that by using the key it probably will do many key lookups and that a table scan would be faster.

For small tables, a table scan often is appropriate and the performance impact is negligible. For large tables, try the following techniques to avoid having the optimizer incorrectly choose a table scan:

- Minimize the OR keywords in your WHERE clauses. If there is no index that helps to locate the values on both sides of the OR, any row could potentially be part of the result set, so all rows must be tested, and that requires a full table scan. If you have one index that helps to optimize one side of an OR query, and a different index that helps to optimize the other side, use a UNION operator to run separate fast queries and merge the results afterward.

- With tables that use the MEMORY storage engine, if you run queries that examine ranges of values (using operators such as >, <=, or BETWEEN on the indexed columns), create the index with the USING BTREE clause. The default (USING HASH) is fast for retrieving individual rows with an equality operator (= or <=), but is much slower (requiring a full table scan) to examine a range of column values. A MEMORY table created with the USING BTREE clause is still fast for equality comparisons, so use that clause for your MEMORY tables that handle a variety of queries.
• Use `ANALYZE TABLE tbl_name` to update the key distributions for the scanned table. See Section 13.7.2.1, "ANALYZE TABLE Statement".

• Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

```
SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
WHERE t1.col_name=t2.col_name;
```

See Section 8.9.3, “Index Hints”.

• Start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.7, “Server System Variables”.

### 8.2.2 Subquery Optimization

Certain optimizations are applicable to comparisons that use the `IN` operator to test subquery results (or that use `=ANY`, which is equivalent). This section discusses these optimizations, particularly with regard to the challenges that `NULL` values present. The last part of the discussion suggests how you can help the optimizer.

Consider the following subquery comparison:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

MySQL evaluates queries “from outside to inside.” That is, it first obtains the value of the outer expression `outer_expr`, and then runs the subquery and captures the rows that it produces.

A very useful optimization is to “inform” the subquery that the only rows of interest are those where the inner expression `inner_expr` is equal to `outer_expr`. This is done by pushing down an appropriate equality into the subquery’s `WHERE` clause to make it more restrictive. The converted comparison looks like this:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)
```

After the conversion, MySQL can use the pushed-down equality to limit the number of rows it must examine to evaluate the subquery.

More generally, a comparison of \( N \) values to a subquery that returns \( N \)-value rows is subject to the same conversion. If `oe_i` and `ie_i` represent corresponding outer and inner expression values, this subquery comparison:

```
(oe_1, ..., oe_N) IN (SELECT ie_1, ..., ie_N FROM ... WHERE subquery_where)
```

Becomes:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND oe_1 = ie_1 AND ...
AND oe_N = ie_N)
```

For simplicity, the following discussion assumes a single pair of outer and inner expression values.

The conversion just described has its limitations. It is valid only if we ignore possible `NULL` values. That is, the “pushdown” strategy works as long as both of these conditions are true:

- `outer_expr` and `inner_expr` cannot be `NULL`.  

914
Subquery Optimization

- You need not distinguish `NULL` from `FALSE` subquery results. If the subquery is a part of an `OR` or `AND` expression in the `WHERE` clause, MySQL assumes that you do not care.

When either or both of those conditions do not hold, optimization is more complex.

Suppose that `outer_expr` is known to be a non-`NULL` value but the subquery does not produce a row such that `outer_expr = inner_expr`. Then `outer_expr IN (SELECT ...)` evaluates as follows:

- **NULL**, if the `SELECT` produces any row where `inner_expr` is `NULL`
- **FALSE**, if the `SELECT` produces only non-`NULL` values or produces nothing

In this situation, the approach of looking for rows with `outer_expr = inner_expr` is no longer valid. It is necessary to look for such rows, but if none are found, also look for rows where `inner_expr` is `NULL`. Roughly speaking, the subquery can be converted to something like this:

```sql
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND
(outter_expr=inner_expr OR inner_expr IS NULL))
```

The need to evaluate the extra `IS NULL` condition is why MySQL has the `ref_or_null` access method:

```sql
mysql> EXPLAIN
SELECT outer_expr IN (SELECT maybe_null_key FROM t2, t3 WHERE ...)
FROM t1;
```

```sql
<table>
<thead>
<tr>
<th>id</th>
<th>select_type</th>
<th>table</th>
<th>type</th>
<th>possible_keys</th>
<th>key</th>
<th>key_len</th>
<th>ref</th>
<th>rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PRIMARY</td>
<td>t1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Using where; Using index</td>
</tr>
<tr>
<td>2</td>
<td>DEPENDENT SUBQUERY</td>
<td>t2</td>
<td>ref_or_null</td>
<td>maybe_null_key</td>
<td>maybe_null_key</td>
<td>5</td>
<td>func</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
```

The `unique_subquery` and `index_subquery` subquery-specific access methods also have “or `NULL`” variants. However, they are not visible in `EXPLAIN` output, so you must use `EXPLAIN EXTENDED` followed by `SHOW WARNINGS` (note the checking `NULL` in the warning message):

```sql
mysql> EXPLAIN EXTENDED
SELECT outer_expr IN (SELECT maybe_null_key FROM t2) FROM t1\G
```

```sql
<table>
<thead>
<tr>
<th>id</th>
<th>select_type</th>
<th>table</th>
<th>type</th>
<th>possible_keys</th>
<th>key</th>
<th>key_len</th>
<th>ref</th>
<th>rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PRIMARY</td>
<td>t1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>DEPENDENT SUBQUERY</td>
<td>t2</td>
<td>index_subquery</td>
<td>maybe_null_key</td>
<td>maybe_null_key</td>
<td>5</td>
<td>func</td>
<td></td>
</tr>
</tbody>
</table>
```

**915**
The additional OR ... IS NULL condition makes query execution slightly more complicated (and some optimizations within the subquery become inapplicable), but generally this is tolerable.

The situation is much worse when outer_expr can be NULL. According to the SQL interpretation of NULL as “unknown value,” NULL IN (SELECT inner_expr ...) should evaluate to:

- NULL, if the SELECT produces any rows
- FALSE, if the SELECT produces no rows

For proper evaluation, it is necessary to be able to check whether the SELECT has produced any rows at all, so outer_expr = inner_expr cannot be pushed down into the subquery. This is a problem because many real world subqueries become very slow unless the equality can be pushed down.

Essentially, there must be different ways to execute the subquery depending on the value of outer_expr.

The optimizer chooses SQL compliance over speed, so it accounts for the possibility that outer_expr might be NULL:

- If outer_expr is NULL, to evaluate the following expression, it is necessary to execute the SELECT to determine whether it produces any rows:

  NULL IN (SELECT inner_expr FROM ... WHERE subquery_where)

  It is necessary to execute the original SELECT here, without any pushed-down equalities of the kind mentioned previously.

- On the other hand, when outer_expr is not NULL, it is absolutely essential that this comparison:

  outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)

  be converted to this expression that uses a pushed-down condition:

  EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)

  Without this conversion, subqueries will be slow.

To solve the dilemma of whether or not to push down conditions into the subquery, the conditions are wrapped within “trigger” functions. Thus, an expression of the following form:

outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)

is converted into:

EXISTS (SELECT 1 FROM ... WHERE subquery_where AND trigcond(outer_expr=inner_expr))

More generally, if the subquery comparison is based on several pairs of outer and inner expressions, the conversion takes this comparison:
Subquery Optimization

\[(\text{oe}_1, \ldots, \text{oe}_N) \text{ IN } (\text{SELECT } \text{ie}_1, \ldots, \text{ie}_N \text{ FROM } \ldots \text{ WHERE } \text{subquery\_where})\]

and converts it to this expression:

\[
\text{EXISTS } (\text{SELECT } 1 \text{ FROM } \ldots \text{ WHERE } \text{subquery\_where} \\
\quad \text{AND } \text{trigcond}(\text{oe}_1=\text{ie}_1) \\
\quad \text{AND } \ldots \\
\quad \text{AND } \text{trigcond}(\text{oe}_N=\text{ie}_N)\}
\]

Each \text{trigcond}(X) is a special function that evaluates to the following values:

- \(X\) when the “linked” outer expression \(\text{oe}_i\) is not \text{NULL}
- \text{TRUE} when the “linked” outer expression \(\text{oe}_i\) is \text{NULL}

\[\text{Note}\]

Trigger functions are \textit{not} triggers of the kind that you create with \text{CREATE TRIGGER}.

Equalities that are wrapped within \text{trigcond()} functions are not first class predicates for the query optimizer. Most optimizations cannot deal with predicates that may be turned on and off at query execution time, so they assume any \text{trigcond}(X) to be an unknown function and ignore it. Triggered equalities can be used by those optimizations:

- Reference optimizations: \text{trigcond}(X=Y \text{ OR } Y \text{ IS NULL}) can be used to construct \text{ref}, \text{eq\_ref}, or \text{ref\_or\_null} table accesses.
- Index lookup-based subquery execution engines: \text{trigcond}(X=Y) can be used to construct \text{unique\_subquery} or \text{index\_subquery} accesses.
- Table-condition generator: If the subquery is a join of several tables, the triggered condition is checked as soon as possible.

When the optimizer uses a triggered condition to create some kind of index lookup-based access (as for the first two items of the preceding list), it must have a fallback strategy for the case when the condition is turned off. This fallback strategy is always the same: Do a full table scan. In \text{EXPLAIN} output, the fallback shows up as \text{Full scan on NULL key} in the \text{Extra} column:

mysql> \text{EXPLAIN SELECT t1.col1,} \\
\text{t1.col1 IN (SELECT t2.key1 FROM t2 WHERE t2.col2=t1.col2) FROM t1} \G

```
*************************** 1. row ***************************
 id: 1
 select_type: PRIMARY
 table: t1
 ... 

*************************** 2. row ***************************
 id: 2
 select_type: DEPENDENT SUBQUERY
 table: t2
 type: index\_subquery
 possible_keys: key1
 key: key1
 key\_len: 5
 ref: func
 rows: 2
 Extra: Using where; Full scan on NULL key
```

If you run \text{EXPLAIN EXTENDED} followed by \text{SHOW WARNINGS}, you can see the triggered condition:
The use of triggered conditions has some performance implications. A NULL IN (SELECT ...) expression now may cause a full table scan (which is slow) when it previously did not. This is the price paid for correct results (the goal of the trigger-condition strategy is to improve compliance, not speed).

For multiple-table subqueries, execution of NULL IN (SELECT ...) is particularly slow because the join optimizer does not optimize for the case where the outer expression is NULL. It assumes that subquery evaluations with NULL on the left side are very rare, even if there are statistics that indicate otherwise. On the other hand, if the outer expression might be NULL but never actually is, there is no performance penalty.

To help the query optimizer better execute your queries, use these suggestions:

- Declare a column as NOT NULL if it really is. This also helps other aspects of the optimizer by simplifying condition testing for the column.

- If you need not distinguish a NULL from FALSE subquery result, you can easily avoid the slow execution path. Replace a comparison that looks like this:

  outer_expr IN (SELECT inner_expr FROM ...)

with this expression:

  (outer_expr IS NOT NULL) AND (outer_expr IN (SELECT inner_expr FROM ...))

Then NULL IN (SELECT ...) is never evaluated because MySQL stops evaluating AND parts as soon as the expression result is clear.

### 8.2.3 Optimizing INFORMATION_SCHEMA Queries

Applications that monitor databases may make frequent use of INFORMATION_SCHEMA tables. Certain types of queries for INFORMATION_SCHEMA tables can be optimized to execute more quickly. The goal is to minimize file operations (for example, scanning a directory or opening a table file) to collect the information that makes up these dynamic tables.

Note

Comparison behavior for database and table names in INFORMATION_SCHEMA queries might differ from what you expect. For details, see Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

1) Try to use constant lookup values for database and table names in the WHERE clause

You can take advantage of this principle as follows:

- To look up databases or tables, use expressions that evaluate to a constant, such as literal values, functions that return a constant, or scalar subqueries.
• Avoid queries that use a nonconstant database name lookup value (or no lookup value) because they require a scan of the data directory to find matching database directory names.

• Within a database, avoid queries that use a nonconstant table name lookup value (or no lookup value) because they require a scan of the database directory to find matching table files.

This principle applies to the INFORMATION_SCHEMA tables shown in the following table, which shows the columns for which a constant lookup value enables the server to avoid a directory scan. For example, if you are selecting from TABLES, using a constant lookup value for TABLE_SCHEMA in the WHERE clause enables a data directory scan to be avoided.

<table>
<thead>
<tr>
<th>Table</th>
<th>Column to specify to avoid data directory scan</th>
<th>Column to specify to avoid database directory scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLUMNS</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>KEY_COLUMN_USAGE</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>PARTITIONS</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>REFERENTIAL_CONSTRAINTS</td>
<td>CONSTRAINT_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>STATISTICS</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>TABLES</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>TABLE_CONSTRAINTS</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
<tr>
<td>TRIGGERS</td>
<td>EVENT_OBJECT_SCHEMA</td>
<td>EVENT_OBJECT_TABLE</td>
</tr>
<tr>
<td>VIEWS</td>
<td>TABLE_SCHEMA</td>
<td>TABLE_NAME</td>
</tr>
</tbody>
</table>

The benefit of a query that is limited to a specific constant database name is that checks need be made only for the named database directory. Example:

```sql
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

Use of the literal database name `test` enables the server to check only the `test` database directory, regardless of how many databases there might be. By contrast, the following query is less efficient because it requires a scan of the data directory to determine which database names match the pattern 'test%':

```sql
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA LIKE 'test%';
```

For a query that is limited to a specific constant table name, checks need be made only for the named table within the corresponding database directory. Example:

```sql
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 't1';
```

Use of the literal table name `t1` enables the server to check only the files for the `t1` table, regardless of how many tables there might be in the `test` database. By contrast, the following query requires a scan of the database directory to determine which table names match the pattern 't%':

```sql
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME LIKE 't%';
```

The following query requires a scan of the database directory to determine matching database names for the pattern 'test%', and for each matching database, it requires a scan of the database directory to determine matching table names for the pattern 't%':

```sql
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA LIKE 'test%';
```
2) Write queries that minimize the number of table files that must be opened

For queries that refer to certain INFORMATION_SCHEMA table columns, several optimizations are available that minimize the number of table files that must be opened. Example:

```
SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

In this case, after the server has scanned the database directory to determine the names of the tables in the database, those names become available with no further file system lookups. Thus, TABLE_NAME requires no files to be opened. The ENGINE (storage engine) value can be determined by opening the table’s .frm file, without touching other table files such as the .MYD or .MYI file.

Some values, such as INDEX_LENGTH for MyISAM tables, require opening the .MYD or .MYI file as well.

The file-opening optimization types are denoted thus:

- **SKIP_OPEN_TABLE**: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.
- **OPEN_FRM_ONLY**: Only the table’s .frm file need be opened.
- **OPEN_TRIGGER_ONLY**: Only the table’s .TRG file need be opened.
- **OPEN_FULL_TABLE**: The unoptimized information lookup. The .frm, .MYD, and .MYI files must be opened.

The following list indicates how the preceding optimization types apply to INFORMATION_SCHEMA table columns. For tables and columns not named, none of the optimizations apply.

- **COLUMNS**: OPEN_FRM_ONLY applies to all columns
- **KEY_COLUMN_USAGE**: OPEN_FULL_TABLE applies to all columns
- **PARTITIONS**: OPEN_FULL_TABLE applies to all columns
- **REFERENTIAL_CONSTRAINTS**: OPEN_FULL_TABLE applies to all columns
- **STATISTICS**:

<table>
<thead>
<tr>
<th>Column</th>
<th>Optimization type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE_CATALOG</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_SCHEMA</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_NAME</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>NON_UNIQUE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>INDEX_SCHEMA</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>INDEX_NAME</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>SEQ_IN_INDEX</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>COLUMN_NAME</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>COLLATION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
</tbody>
</table>
### Optimizing INFORMATION_SCHEMA Queries

<table>
<thead>
<tr>
<th>Column</th>
<th>Optimization type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARDINALITY</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>SUB_PART</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>PACKED</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>NULLABLE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>INDEX_TYPE</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>COMMENT</td>
<td>OPEN_FRM_ONLY</td>
</tr>
</tbody>
</table>

**TABLES:**

<table>
<thead>
<tr>
<th>Column</th>
<th>Optimization type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE_CATALOG</td>
<td>SKIP_OPEN_TABLE</td>
</tr>
<tr>
<td>TABLE_SCHEMA</td>
<td>SKIP_OPEN_TABLE</td>
</tr>
<tr>
<td>TABLE_NAME</td>
<td>SKIP_OPEN_TABLE</td>
</tr>
<tr>
<td>TABLE_TYPE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>ENGINE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>VERSION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>ROW_FORMAT</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_ROWS</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>AVG_ROW_LENGTH</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>DATA_LENGTH</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>MAX_DATA_LENGTH</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>INDEX_LENGTH</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>DATA_FREE</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>AUTO_INCREMENT</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>CREATE_TIME</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>UPDATE_TIME</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>CHECK_TIME</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>TABLE_COLLATION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>CHECKSUM</td>
<td>OPEN_FULL_TABLE</td>
</tr>
<tr>
<td>CREATE_OPTIONS</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_COMMENT</td>
<td>OPEN_FRM_ONLY</td>
</tr>
</tbody>
</table>

**TABLE_CONSTRAINTS:** OPEN_FULL_TABLE applies to all columns

**TRIGGERS:** OPEN_TRIGGER_ONLY applies to all columns

**VIEWS:**

<table>
<thead>
<tr>
<th>Column</th>
<th>Optimization type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE_CATALOG</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_SCHEMA</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>TABLE_NAME</td>
<td>OPEN_FRM_ONLY</td>
</tr>
</tbody>
</table>
### Optimizing INFORMATION_SCHEMA Queries

<table>
<thead>
<tr>
<th>Column</th>
<th>Optimization type</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIEW_DEFINITION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>CHECK_OPTION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>IS_UPDATABLE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>DEFINER</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>SECURITY_TYPE</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>CHARACTER_SET_CLIENT</td>
<td>OPEN_FRM_ONLY</td>
</tr>
<tr>
<td>COLLATION_CONNECTION</td>
<td>OPEN_FRM_ONLY</td>
</tr>
</tbody>
</table>

3) Use `EXPLAIN` to determine whether the server can use `INFORMATION_SCHEMA` optimizations for a query

This applies particularly for `INFORMATION_SCHEMA` queries that search for information from more than one database, which might take a long time and impact performance. The `Extra` value in `EXPLAIN` output indicates which, if any, of the optimizations described earlier the server can use to evaluate `INFORMATION_SCHEMA` queries. The following examples demonstrate the kinds of information you can expect to see in the `Extra` value.

```sql
mysql> EXPLAIN SELECT TABLE_NAME FROM INFORMATION_SCHEMA.VIEWS WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v1'\G
*************************** 1. row ***************************
id: 1
select_type: SIMPLE
table: VIEWS
type: ALL
possible_keys: NULL
key: TABLE_SCHEMA,TABLE_NAME
key_len: NULL
ref: NULL
rows: NULL
Extra: Using where; Open_frm_only; Scanned 0 databases
```

Use of constant database and table lookup values enables the server to avoid directory scans. For references to `VIEWS.TABLE_NAME`, only the `.frm` file need be opened.

```sql
mysql> EXPLAIN SELECT TABLE_NAME, ROW_FORMAT FROM INFORMATION_SCHEMA.TABLES\G
*************************** 1. row ***************************
id: 1
select_type: SIMPLE
table: TABLES
type: ALL
possible_keys: NULL
key: NULL
key_len: NULL
ref: NULL
rows: NULL
Extra: Open_full_table; Scanned all databases
```

No lookup values are provided (there is no `WHERE` clause), so the server must scan the data directory and each database directory. For each table thus identified, the table name and row format are selected. `TABLE_NAME` requires no further table files to be opened (the `SKIP_OPEN_TABLE` optimization applies). `ROW_FORMAT` requires all table files to be opened (`OPEN_FULL_TABLE` applies). `EXPLAIN` reports `OPEN_FULL_TABLE` because it is more expensive than `SKIP_OPEN_TABLE`.

```sql
mysql> EXPLAIN SELECT TABLE_NAME, TABLE_TYPE FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test'\G
*************************** 1. row ***************************
id: 1
```
Optimizing INFORMATION_SCHEMA Queries

No table name lookup value is provided, so the server must scan the test database directory. For the TABLE_NAME and TABLE_TYPE columns, the SKIP_OPEN_TABLE and OPEN_FRM_ONLY optimizations apply, respectively. EXPLAIN reports OPEN_FRM_ONLY because it is more expensive.

For the first EXPLAIN output row: Constant database and table lookup values enable the server to avoid directory scans for TABLES values. References to TABLES.TABLE_NAME require no further table files.

For the second EXPLAIN output row: All COLUMNS table values are OPEN_FRM_ONLY lookups, so COLUMNS.TABLE_NAME requires the .frm file to be opened.

In this case, no optimizations apply because COLLATIONS is not one of the INFORMATION_SCHEMA tables for which optimizations are available.
8.2.4 Optimizing Data Change Statements

This section explains how to speed up data change statements: **INSERT**, **UPDATE**, and **DELETE**. Traditional OLTP applications and modern web applications typically do many small data change operations, where concurrency is vital. Data analysis and reporting applications typically run data change operations that affect many rows at once, where the main considerations is the I/O to write large amounts of data and keep indexes up-to-date. For inserting and updating large volumes of data (known in the industry as ETL, for “extract-transform-load”), sometimes you use other SQL statements or external commands, that mimic the effects of **INSERT**, **UPDATE**, and **DELETE** statements.

8.2.4.1 Optimizing INSERT Statements

To optimize insert speed, combine many small operations into a single large operation. Ideally, you make a single connection, send the data for many new rows at once, and delay all index updates and consistency checking until the very end.

The time required for inserting a row is determined by the following factors, where the numbers indicate approximate proportions:

- Connecting: (3)
- Sending query to server: (2)
- Parsing query: (2)
- Inserting row: (1 x size of row)
- Inserting indexes: (1 x number of indexes)
- Closing: (1)

This does not take into consideration the initial overhead to open tables, which is done once for each concurrently running query.

The size of the table slows down the insertion of indexes by log \( N \), assuming B-tree indexes.

You can use the following methods to speed up inserts:

- If you are inserting many rows from the same client at the same time, use **INSERT** statements with multiple **VALUES** lists to insert several rows at a time. This is considerably faster (many times faster in some cases) than using separate single-row **INSERT** statements. If you are adding data to a nonempty table, you can tune the **bulk_insert_buffer_size** variable to make data insertion even faster. See Section 5.1.7, “Server System Variables”.

- When loading a table from a text file, use **LOAD DATA**. This is usually 20 times faster than using **INSERT** statements. See Section 13.2.6, “LOAD DATA Statement”.

- Take advantage of the fact that columns have default values. Insert values explicitly only when the value to be inserted differs from the default. This reduces the parsing that MySQL must do and improves the insert speed.

- See Section 8.5.4, “Bulk Data Loading for InnoDB Tables” for tips specific to **InnoDB** tables.

- See Section 8.6.2, “Bulk Data Loading for MyISAM Tables” for tips specific to **MyISAM** tables.

8.2.4.2 Optimizing UPDATE Statements
An update statement is optimized like a `SELECT` query with the additional overhead of a write. The speed of the write depends on the amount of data being updated and the number of indexes that are updated. Indexes that are not changed do not get updated.

Another way to get fast updates is to delay updates and then do many updates in a row later. Performing multiple updates together is much quicker than doing one at a time if you lock the table.

For a MyISAM table that uses dynamic row format, updating a row to a longer total length may split the row. If you do this often, it is very important to use `OPTIMIZE TABLE` occasionally. See Section 13.7.2.4, “OPTIMIZE TABLE Statement”.

### 8.2.4.3 Optimizing DELETE Statements

The time required to delete individual rows in a MyISAM table is exactly proportional to the number of indexes. To delete rows more quickly, you can increase the size of the key cache by increasing the `key_buffer_size` system variable. See Section 5.1.1, “Configuring the Server”.

To delete all rows from a MyISAM table, `TRUNCATE TABLE tbl_name` is faster than `DELETE FROM tbl_name`. Truncate operations are not transaction-safe; an error occurs when attempting one in the course of an active transaction or active table lock. See Section 13.1.33, “TRUNCATE TABLE Statement”.

### 8.2.5 Optimizing Database Privileges

The more complex your privilege setup, the more overhead applies to all SQL statements. Simplifying the privileges established by `GRANT` statements enables MySQL to reduce permission-checking overhead when clients execute statements. For example, if you do not grant any table-level or column-level privileges, the server need not ever check the contents of the `tables_priv` and `columns_priv` tables. Similarly, if you place no resource limits on any accounts, the server does not have to perform resource counting. If you have a very high statement-processing load, consider using a simplified grant structure to reduce permission-checking overhead.

### 8.2.6 Other Optimization Tips

This section lists a number of miscellaneous tips for improving query processing speed:

- If your application makes several database requests to perform related updates, combining the statements into a stored routine can help performance. Similarly, if your application computes a single result based on several column values or large volumes of data, combining the computation into a UDF (user-defined function) can help performance. The resulting fast database operations are then available to be reused by other queries, applications, and even code written in different programming languages. See Section 20.2, “Using Stored Routines” and Section 24.4, “Adding Functions to MySQL” for more information.

- To fix any compression issues that occur with `ARCHIVE` tables, use `OPTIMIZE TABLE`. See Section 15.6, “The ARCHIVE Storage Engine”.

- If possible, classify reports as “live” or as “statistical”, where data needed for statistical reports is created only from summary tables that are generated periodically from the live data.

- If you have data that does not conform well to a rows-and-columns table structure, you can pack and store data into a `BLOB` column. In this case, you must provide code in your application to pack and unpack information, but this might save I/O operations to read and write the sets of related values.

- With Web servers, store images and other binary assets as files, with the path name stored in the database rather than the file itself. Most Web servers are better at caching files than database contents,
so using files is generally faster. (Although you must handle backups and storage issues yourself in this case.)

- If you need really high speed, look at the low-level MySQL interfaces. For example, by accessing the MySQL InnoDB or MyISAM storage engine directly, you could get a substantial speed increase compared to using the SQL interface.

- Replication can provide a performance benefit for some operations. You can distribute client retrievals among replication servers to split up the load. To avoid slowing down the master while making backups, you can make backups using a slave server. See Chapter 17, Replication.

### 8.3 Optimization and Indexes

The best way to improve the performance of SELECT operations is to create indexes on one or more of the columns that are tested in the query. The index entries act like pointers to the table rows, allowing the query to quickly determine which rows match a condition in the WHERE clause, and retrieve the other column values for those rows. All MySQL data types can be indexed.

Although it can be tempting to create an indexes for every possible column used in a query, unnecessary indexes waste space and waste time for MySQL to determine which indexes to use. Indexes also add to the cost of inserts, updates, and deletes because each index must be updated. You must find the right balance to achieve fast queries using the optimal set of indexes.

#### 8.3.1 How MySQL Uses Indexes

Indexes are used to find rows with specific column values quickly. Without an index, MySQL must begin with the first row and then read through the entire table to find the relevant rows. The larger the table, the more this costs. If the table has an index for the columns in question, MySQL can quickly determine the position to seek to in the middle of the data file without having to look at all the data. This is much faster than reading every row sequentially.

Most MySQL indexes (PRIMARY KEY, UNIQUE, INDEX, and FULLTEXT) are stored in B-trees. Exceptions are that indexes on spatial data types use R-trees, and that MEMORY tables also support hash indexes.

In general, indexes are used as described in the following discussion. Characteristics specific to hash indexes (as used in MEMORY tables) are described in Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

MySQL uses indexes for these operations:

- To find the rows matching a WHERE clause quickly.

- To eliminate rows from consideration. If there is a choice between multiple indexes, MySQL normally uses the index that finds the smallest number of rows (the most selective index).

- If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on \((\text{col1, col2, col3})\), you have indexed search capabilities on \((\text{col1})\), \((\text{col1, col2})\), and \((\text{col1, col2, col3})\). For more information, see Section 8.3.5, “Multiple-Column Indexes”.

- To retrieve rows from other tables when performing joins. MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, VARCHAR and CHAR are considered the same if they are declared as the same size. For example, VARCHAR(10) and CHAR(10) are the same size, but VARCHAR(10) and CHAR(15) are not.
Primary Key Optimization

For comparisons between nonbinary string columns, both columns should use the same character set. For example, comparing a `utf8` column with a `latin1` column precludes use of an index.

Comparison of dissimilar columns (comparing a string column to a temporal or numeric column, for example) may prevent use of indexes if values cannot be compared directly without conversion. For a given value such as `1` in the numeric column, it might compare equal to any number of values in the string column such as `'1'`, `'1'`, `'00001'`, or `'01.e1'`. This rules out use of any indexes for the string column.

- To find the `MIN()` or `MAX()` value for a specific indexed column `key_col`. This is optimized by a preprocessor that checks whether you are using `WHERE key_part_N = constant` on all key parts that occur before `key_col` in the index. In this case, MySQL does a single key lookup for each `MIN()` or `MAX()` expression and replaces it with a constant. If all expressions are replaced with constants, the query returns at once. For example:

  ```sql
  SELECT MIN(key_part2), MAX(key_part2)
  FROM tbl_name WHERE key_part1=10;
  ```

- To sort or group a table if the sorting or grouping is done on a leftmost prefix of a usable index (for example, `ORDER BY key_part1, key_part2`). If all key parts are followed by `DESC`, the key is read in reverse order. See Section 8.2.1.10, “ORDER BY Optimization”, and Section 8.2.1.11, “GROUP BY Optimization”.

- In some cases, a query can be optimized to retrieve values without consulting the data rows. (An index that provides all the necessary results for a query is called a covering index.) If a query uses from a table only columns that are included in some index, the selected values can be retrieved from the index tree for greater speed:

  ```sql
  SELECT key_part3 FROM tbl_name
  WHERE key_part1=1
  ```

Indexes are less important for queries on small tables, or big tables where report queries process most or all of the rows. When a query needs to access most of the rows, reading sequentially is faster than working through an index. Sequential reads minimize disk seeks, even if not all the rows are needed for the query. See Section 8.2.1.16, “Avoiding Full Table Scans” for details.

### 8.3.2 Primary Key Optimization

The primary key for a table represents the column or set of columns that you use in your most vital queries. It has an associated index, for fast query performance. Query performance benefits from the `NOT NULL` optimization, because it cannot include any `NULL` values. With the InnoDB storage engine, the table data is physically organized to do ultra-fast lookups and sorts based on the primary key column or columns.

If your table is big and important, but does not have an obvious column or set of columns to use as a primary key, you might create a separate column with auto-increment values to use as the primary key. These unique IDs can serve as pointers to corresponding rows in other tables when you join tables using foreign keys.

### 8.3.3 Foreign Key Optimization

If a table has many columns, and you query many different combinations of columns, it might be efficient to split the less-frequently used data into separate tables with a few columns each, and relate them back to the main table by duplicating the numeric ID column from the main table. That way, each small table can have a primary key for fast lookups of its data, and you can query just the set of columns that you need using a join operation. Depending on how the data is distributed, the queries might perform less I/O and

927
Column Indexes

take up less cache memory because the relevant columns are packed together on disk. (To maximize performance, queries try to read as few data blocks as possible from disk; tables with only a few columns can fit more rows in each data block.)

8.3.4 Column Indexes

The most common type of index involves a single column, storing copies of the values from that column in a data structure, allowing fast lookups for the rows with the corresponding column values. The B-tree data structure lets the index quickly find a specific value, a set of values, or a range of values, corresponding to operators such as =, >, ≤, BETWEEN, IN, and so on, in a WHERE clause.

The maximum number of indexes per table and the maximum index length is defined per storage engine. See Chapter 14, The InnoDB Storage Engine, and Chapter 15, Alternative Storage Engines. All storage engines support at least 16 indexes per table and a total index length of at least 256 bytes. Most storage engines have higher limits.

For additional information about column indexes, see Section 13.1.13, “CREATE INDEX Statement”.

- Index Prefixes
- FULLTEXT Indexes
- Spatial Indexes
- Indexes in the MEMORY Storage Engine

Index Prefixes

With `col_name(N)` syntax in an index specification for a string column, you can create an index that uses only the first `N` characters of the column. Indexing only a prefix of column values in this way can make the index file much smaller. When you index a BLOB or TEXT column, you must specify a prefix length for the index. For example:

```
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
```

Prefixes can be up to 1000 bytes long (767 bytes for InnoDB tables, unless you have innodb_large_prefix set).

Note

Prefix limits are measured in bytes, whereas the prefix length in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements is interpreted as number of characters for nonbinary string types (CHAR, VARCHAR, TEXT) and number of bytes for binary string types (BINARY, VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

If a search term exceeds the index prefix length, the index is used to exclude non-matching rows, and the remaining rows are examined for possible matches.

For additional information about index prefixes, see Section 13.1.13, “CREATE INDEX Statement”.

FULLTEXT Indexes

FULLTEXT indexes are used for full-text searches. Only the MyISAM storage engine supports FULLTEXT indexes and only for CHAR, VARCHAR, and TEXT columns. Indexing always takes place over the entire
Multiple-Column Indexes

column and column prefix indexing is not supported. For details, see Section 12.9, “Full-Text Search Functions”.

For queries that contain full-text expressions, MySQL evaluates those expressions during the optimization phase of query execution. The optimizer does not just look at full-text expressions and make estimates, it actually evaluates them in the process of developing an execution plan.

An implication of this behavior is that \texttt{EXPLAIN} for full-text queries is typically slower than for non-full-text queries for which no expression evaluation occurs during the optimization phase.

\texttt{EXPLAIN} for full-text queries may show \texttt{Select tables optimized away} in the \texttt{Extra} column due to matching occurring during optimization; in this case, no table access need occur during later execution.

Spatial Indexes

You can create indexes on spatial data types. Only \texttt{MyISAM} supports R-tree indexes on spatial types. Other storage engines use B-trees for indexing spatial types (except for \texttt{ARCHIVE}, which does not support spatial type indexing).

Indexes in the MEMORY Storage Engine

The \texttt{MEMORY} storage engine uses \texttt{HASH} indexes by default, but also supports \texttt{BTREE} indexes.

8.3.5 Multiple-Column Indexes

MySQL can create composite indexes (that is, indexes on multiple columns). An index may consist of up to 16 columns. For certain data types, you can index a prefix of the column (see Section 8.3.4, “Column Indexes”).

MySQL can use multiple-column indexes for queries that test all the columns in the index, or queries that test just the first column, the first two columns, the first three columns, and so on. If you specify the columns in the right order in the index definition, a single composite index can speed up several kinds of queries on the same table.

A multiple-column index can be considered a sorted array, the rows of which contain values that are created by concatenating the values of the indexed columns.

\textbf{Note}

As an alternative to a composite index, you can introduce a column that is “hashed” based on information from other columns. If this column is short, reasonably unique, and indexed, it might be faster than a “wide” index on many columns. In MySQL, it is very easy to use this extra column:

```
SELECT * FROM tbl_name
WHERE hash_col=MD5(CONCAT(val1,val2))
AND col1=val1 AND col2=val2;
```

Suppose that a table has the following specification:

```
CREATE TABLE test (  
id INT NOT NULL,  
last_name CHAR(30) NOT NULL,  
first_name CHAR(30) NOT NULL,  
PRIMARY KEY (id),  
INDEX name (last_name,first_name)
```
The `name` index is an index over the `last_name` and `first_name` columns. The index can be used for lookups in queries that specify values in a known range for combinations of `last_name` and `first_name` values. It can also be used for queries that specify just a `last_name` value because that column is a leftmost prefix of the index (as described later in this section). Therefore, the `name` index is used for lookups in the following queries:

```sql
SELECT * FROM test WHERE last_name='Smith';
SELECT * FROM test
  WHERE last_name='Smith' AND first_name='John';
SELECT * FROM test
  WHERE last_name='Smith'
    AND (first_name='John' OR first_name='Jon');
SELECT * FROM test
  WHERE last_name='Smith'
    AND first_name >='M' AND first_name < 'N';
```

However, the `name` index is *not* used for lookups in the following queries:

```sql
SELECT * FROM test WHERE first_name='John';
SELECT * FROM test
  WHERE last_name='Smith' OR first_name='John';
```

Suppose that you issue the following `SELECT` statement:

```sql
SELECT * FROM `tbl_name`
  WHERE col1=val1 AND col2=val2;
```

If a multiple-column index exists on `col1` and `col2`, the appropriate rows can be fetched directly. If separate single-column indexes exist on `col1` and `col2`, the optimizer attempts to use the Index Merge optimization (see Section 8.2.1.3, “Index Merge Optimization”), or attempts to find the most restrictive index by deciding which index excludes more rows and using that index to fetch the rows.

If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on `(col1, col2, col3)`, you have indexed search capabilities on `(col1)`, `(col1, col2)`, and `(col1, col2, col3)`.

MySQL cannot use the index to perform lookups if the columns do not form a leftmost prefix of the index. Suppose that you have the `SELECT` statements shown here:

```sql
SELECT * FROM `tbl_name`
  WHERE col1=val1;
SELECT * FROM `tbl_name`
  WHERE col1=val1 AND col2=val2;
SELECT * FROM `tbl_name`
  WHERE col2=val2;
SELECT * FROM `tbl_name`
  WHERE col2=val2 AND col3=val3;
```

If an index exists on `(col1, col1, col3)`, only the first two queries use the index. The third and fourth queries do involve indexed columns, but do not use an index to perform lookups because `(col2)` and `(col2, col3)` are not leftmost prefixes of `(col1, col2, col3)`.

### 8.3.6 Verifying Index Usage

Always check whether all your queries really use the indexes that you have created in the tables. Use the `EXPLAIN` statement, as described in Section 8.8.1, “Optimizing Queries with `EXPLAIN`”. 
8.3.7 InnoDB and MyISAM Index Statistics Collection

Storage engines collect statistics about tables for use by the optimizer. Table statistics are based on value groups, where a value group is a set of rows with the same key prefix value. For optimizer purposes, an important statistic is the average value group size.

MySQL uses the average value group size in the following ways:

- To estimate how many rows must be read for each `ref` access
- To estimate how many rows a partial join will produce; that is, the number of rows that an operation of this form will produce:

  ```sql
  (...) JOIN tbl_name ON tbl_name.key = expr
  ```

As the average value group size for an index increases, the index is less useful for those two purposes because the average number of rows per lookup increases. For the index to be good for optimization purposes, it is best that each index value target a small number of rows in the table. When a given index value yields a large number of rows, the index is less useful and MySQL is less likely to use it.

The average value group size is related to table cardinality, which is the number of value groups. The `SHOW INDEX` statement displays a cardinality value based on \( N/S \), where \( N \) is the number of rows in the table and \( S \) is the average value group size. That ratio yields an approximate number of value groups in the table.

For a join based on the `<>` comparison operator, `NULL` is not treated differently from any other value: `NULL` is treated as identical (that is, they all form a single value group).

However, for a join based on the `=` operator, `NULL` is different from non-`NULL` values: `expr1 = expr2` is not true when `expr1` or `expr2` (or both) are `NULL`. This affects `ref` accesses for comparisons of the form `tbl_name.key = expr`: MySQL will not access the table if the current value of `expr` is `NULL`, because the comparison cannot be true.

For `=` comparisons, it does not matter how many `NULL` values are in the table. For optimization purposes, the relevant value is the average size of the non-`NULL` value groups. However, MySQL does not currently enable that average size to be collected or used.

For InnoDB and MyISAM tables, you have some control over collection of table statistics by means of the `innodb_stats_method` and `myisam_stats_method` system variables, respectively. These variables have three possible values, which differ as follows:

- When the variable is set to `nulls_equal`, all `NULL` values are treated as identical (that is, they all form a single value group).

  If the `NULL` value group size is much higher than the average non-`NULL` value group size, this method skews the average value group size upward. This makes index appear to the optimizer to be less useful than it really is for joins that look for non-`NULL` values. Consequently, the `nulls_equal` method may cause the optimizer not to use the index for `ref` accesses when it should.

- When the variable is set to `nulls_unequal`, `NULL` values are not considered the same. Instead, each `NULL` value forms a separate value group of size 1.

  If you have many `NULL` values, this method skews the average value group size downward. If the average non-`NULL` value group size is large, counting `NULL` values each as a group of size 1 causes the optimizer to overestimate the value of the index for joins that look for non-`NULL` values. Consequently, the `nulls_unequal` method may cause the optimizer to use this index for `ref` lookups when other methods may be better.
Comparison of B-Tree and Hash Indexes

• When the variable is set to `nulls_ignored`, NULL values are ignored.

If you tend to use many joins that use `<>` rather than `=`, NULL values are not special in comparisons and one NULL is equal to another. In this case, `nulls_equal` is the appropriate statistics method.

The `innodb_stats_method` system variable has a global value; the `myisam_stats_method` system variable has both global and session values. Setting the global value affects statistics collection for tables from the corresponding storage engine. Setting the session value affects statistics collection only for the current client connection. This means that you can force a table's statistics to be regenerated with a given method without affecting other clients by setting the session value of `myisam_stats_method`.

To regenerate MyISAM table statistics, you can use any of the following methods:

• Execute `myisamchk --stats_method=method_name --analyze`

• Change the table to cause its statistics to go out of date (for example, insert a row and then delete it), and then set `myisam_stats_method` and issue an ANALYZE TABLE statement

Some caveats regarding the use of `innodb_stats_method` and `myisam_stats_method`:

• You can force table statistics to be collected explicitly, as just described. However, MySQL may also collect statistics automatically. For example, if during the course of executing statements for a table, some of those statements modify the table, MySQL may collect statistics. (This may occur for bulk inserts or deletes, or some `ALTER TABLE` statements, for example.) If this happens, the statistics are collected using whatever value `innodb_stats_method` or `myisam_stats_method` has at the time. Thus, if you collect statistics using one method, but the system variable is set to the other method when a table's statistics are collected automatically later, the other method will be used.

• There is no way to tell which method was used to generate statistics for a given table.

• These variables apply only to InnoDB and MyISAM tables. Other storage engines have only one method for collecting table statistics. Usually it is closer to the `nulls_equal` method.

8.3.8 Comparison of B-Tree and Hash Indexes

Understanding the B-tree and hash data structures can help predict how different queries perform on different storage engines that use these data structures in their indexes, particularly for the MEMORY storage engine that lets you choose B-tree or hash indexes.

• B-Tree Index Characteristics
• Hash Index Characteristics

B-Tree Index Characteristics

A B-tree index can be used for column comparisons in expressions that use the `=`, `>`, `>=`, `<`, `<=`, or `BETWEEN` operators. The index also can be used for LIKE comparisons if the argument to LIKE is a constant string that does not start with a wildcard character. For example, the following SELECT statements use indexes:

```sql
SELECT * FROM tbl_name WHERE key_col LIKE 'Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE 'Pat%ck%';
```

In the first statement, only rows with 'Patrick' <= key_col < 'Patrick' are considered. In the second statement, only rows with 'Pat' <= key_col < 'Pau' are considered.

The following SELECT statements do not use indexes:
Comparison of B-Tree and Hash Indexes

```
SELECT * FROM tbl_name WHERE key_col LIKE '%Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE other_col;
```

In the first statement, the LIKE value begins with a wildcard character. In the second statement, the LIKE value is not a constant.

If you use ... LIKE '%string%' and string is longer than three characters, MySQL uses the Turbo Boyer-Moore algorithm to initialize the pattern for the string and then uses this pattern to perform the search more quickly.

A search using col_name IS NULL employs indexes if col_name is indexed.

Any index that does not span all AND levels in the WHERE clause is not used to optimize the query. In other words, to be able to use an index, a prefix of the index must be used in every AND group.

The following WHERE clauses use indexes:

```
... WHERE index_part1=1 AND index_part2=2 AND other_column=3
    /* index = 1 OR index = 2 */
... WHERE index=1 OR A=10 AND index=2
    /* optimized like "index_part1='hello'" */
... WHERE index_part1='hello' AND index_part3=5
    /* Can use index on index1 but not on index2 or index3 */
... WHERE index1=1 AND index2=2 OR index3=3 AND index3=3;
```

These WHERE clauses do not use indexes:

```
    /* index_part1 is not used */
... WHERE index_part2=1 AND index_part3=2
    /* Index is not used in both parts of the WHERE clause */
... WHERE index=1 OR A=10
    /* No index spans all rows */
... WHERE index_part1=1 OR index_part2=10
```

Sometimes MySQL does not use an index, even if one is available. One circumstance under which this occurs is when the optimizer estimates that using the index would require MySQL to access a very large percentage of the rows in the table. (In this case, a table scan is likely to be much faster because it requires fewer seeks.) However, if such a query uses LIMIT to retrieve only some of the rows, MySQL uses an index anyway, because it can much more quickly find the few rows to return in the result.

Hash Index Characteristics

Hash indexes have somewhat different characteristics from those just discussed:

- They are used only for equality comparisons that use the = or <=> operators (but are very fast). They are not used for comparison operators such as < that find a range of values. Systems that rely on this type of single-value lookup are known as “key-value stores”; to use MySQL for such applications, use hash indexes wherever possible.

- The optimizer cannot use a hash index to speed up ORDER BY operations. (This type of index cannot be used to search for the next entry in order.)

- MySQL cannot determine approximately how many rows there are between two values (this is used by the range optimizer to decide which index to use). This may affect some queries if you change a MyISAM or InnoDB table to a hash-indexed MEMORY table.
Indexed Lookups from TIMESTAMP Columns

• Only whole keys can be used to search for a row. (With a B-tree index, any leftmost prefix of the key can be used to find rows.)

8.3.9 Indexed Lookups from TIMESTAMP Columns

Temporal values are stored in TIMESTAMP columns as UTC values, and values inserted into and retrieved from TIMESTAMP columns are converted between the session time zone and UTC. (This is the same type of conversion performed by the CONVERT_TZ() function. If the session time zone is UTC, there is effectively no time zone conversion.)

Due to conventions for local time zone changes such as Daylight Saving Time (DST), conversions between UTC and non-UTC time zones are not one-to-one in both directions. UTC values that are distinct may not be distinct in another time zone. The following example shows distinct UTC values that become identical in a non-UTC time zone:

```
mysql> CREATE TABLE tstable (ts TIMESTAMP);
mysql> SET time_zone = 'UTC'; -- insert UTC values
mysql> INSERT INTO tstable VALUES
     ('2018-10-28 00:30:00'),
     ('2018-10-28 01:30:00');
mysql> SELECT ts FROM tstable;
+---------------------+
| ts                  |
+---------------------+
| 2018-10-28 00:30:00 |
| 2018-10-28 01:30:00 |
+---------------------+
mysql> SET time_zone = 'MET'; -- retrieve non-UTC values
mysql> SELECT ts FROM tstable;
+---------------------+
| ts                  |
+---------------------+
| 2018-10-28 02:30:00 |
| 2018-10-28 02:30:00 |
+---------------------+
```

Note

To use named time zones such as 'MET' or 'Europe/Amsterdam', the time zone tables must be properly set up. For instructions, see Section 5.1.12, “MySQL Server Time Zone Support”.

You can see that the two distinct UTC values are the same when converted to the 'MET' time zone. This phenomenon can lead to different results for a given TIMESTAMP column query, depending on whether the optimizer uses an index to execute the query.

Suppose that a query selects values from the table shown earlier using a WHERE clause to search the ts column for a single specific value such as a user-provided timestamp literal:

```
SELECT ts FROM tstable
WHERE ts = 'literal';
```

Suppose further that the query executes under these conditions:

• The session time zone is not UTC and has a DST shift. For example:

```
SET time_zone = 'MET';
```

• Unique UTC values stored in the TIMESTAMP column are not unique in the session time zone due to DST shifts. (The example shown earlier illustrates how this can occur.)
Indexed Lookups from TIMESTAMP Columns

- The query specifies a search value that is within the hour of entry into DST in the session time zone.

Under those conditions, the comparison in the WHERE clause occurs in different ways for nonindexed and indexed lookups and leads to different results:

- If there is no index or the optimizer cannot use it, comparisons occur in the session time zone. The optimizer performs a table scan in which it retrieves each ts column value, converts it from UTC to the session time zone, and compares it to the search value (also interpreted in the session time zone):

  ```
  mysql> SELECT ts FROM tstable
          WHERE ts = '2018-10-28 02:30:00';
  +---------------------+
  | ts                  |
  +---------------------+
  | 2018-10-28 02:30:00 |
  | 2018-10-28 02:30:00 |
  +---------------------+
  ```

  Because the stored ts values are converted to the session time zone, it is possible for the query to return two timestamp values that are distinct as UTC values but equal in the session time zone: One value that occurs before the DST shift when clocks are changed, and one value that was occurs after the DST shift.

- If there is a usable index, comparisons occur in UTC. The optimizer performs an index scan, first converting the search value from the session time zone to UTC, then comparing the result to the UTC index entries:

  ```
  mysql> ALTER TABLE tstable ADD INDEX (ts);
_mysql> SELECT ts FROM tstable
          WHERE ts = '2018-10-28 02:30:00';
  +---------------------+
  | ts                  |
  +---------------------+
  | 2018-10-28 02:30:00 |
  +---------------------+
  ```

  In this case, the (converted) search value is matched only to index entries, and because the index entries for the distinct stored UTC values are also distinct, the search value can match only one of them.

Due to different optimizer operation for nonindexed and indexed lookups, the query produces different results in each case. The result from the nonindexed lookup returns all values that match in the session time zone. The indexed lookup cannot do so:

- It is performed within the storage engine, which knows only about UTC values.
- For the two distinct session time zone values that map to the same UTC value, the indexed lookup matches only the corresponding UTC index entry and returns only a single row.

In the preceding discussion, the data set stored in tstable happens to consist of distinct UTC values. In such cases, all index-using queries of the form shown match at most one index entry.

If the index is not UNIQUE, it is possible for the table (and the index) to store multiple instances of a given UTC value. For example, the ts column might contain multiple instances of the UTC value '2018-10-28 00:30:00'. In this case, the index-using query would return each of them (converted to the MET value '2018-10-28 02:30:00' in the result set). It remains true that index-using queries match the converted search value to a single value in the UTC index entries, rather than matching multiple UTC values that convert to the search value in the session time zone.

If it is important to return all ts values that match in the session time zone, the workaround is to suppress use of the index with an IGNORE INDEX hint:
The same lack of one-to-one mapping for time zone conversions in both directions occurs in other contexts as well, such as conversions performed with the `FROM_UNIXTIME()` and `UNIX_TIMESTAMP()` functions. See Section 12.6, “Date and Time Functions”.

### 8.4 Optimizing Database Structure

In your role as a database designer, look for the most efficient way to organize your schemas, tables, and columns. As when tuning application code, you minimize I/O, keep related items together, and plan ahead so that performance stays high as the data volume increases. Starting with an efficient database design makes it easier for team members to write high-performing application code, and makes the database likely to endure as applications evolve and are rewritten.

#### 8.4.1 Optimizing Data Size

Design your tables to minimize their space on the disk. This can result in huge improvements by reducing the amount of data written to and read from disk. Smaller tables normally require less main memory while their contents are being actively processed during query execution. Any space reduction for table data also results in smaller indexes that can be processed faster.

MySQL supports many different storage engines (table types) and row formats. For each table, you can decide which storage and indexing method to use. Choosing the proper table format for your application can give you a big performance gain. See Chapter 14, *The InnoDB Storage Engine*, and Chapter 15, *Alternative Storage Engines*.

You can get better performance for a table and minimize storage space by using the techniques listed here:

- **Table Columns**
- **Row Format**
- **Indexes**
- **Joins**
- **Normalization**

**Table Columns**

- Use the most efficient (smallest) data types possible. MySQL has many specialized types that save disk space and memory. For example, use the smaller integer types if possible to get smaller tables. `MEDIUMINT` is often a better choice than `INT` because a `MEDIUMINT` column uses 25% less space.

- Declare columns to be **NOT NULL** if possible. It makes SQL operations faster, by enabling better use of indexes and eliminating overhead for testing whether each value is **NULL**. You also save some storage space, one bit per column. If you really need **NULL** values in your tables, use them. Just avoid the default setting that allows **NULL** values in every column.
Optimizing Data Size

Row Format

- In MySQL 5.5, InnoDB tables use the COMPACT row storage format (ROW_FORMAT=COMPACT) by default. Older versions of MySQL use the REDUNDANT row format (ROW_FORMAT=REDUNDANT).

The compact family of row formats, which includes COMPACT, DYNAMIC, and COMPRESSED, decreases row storage space at the cost of increasing CPU use for some operations. If your workload is typical one that is limited by cache hit rates and disk speed it is likely to be faster. If it is a rare case that is limited by CPU speed, it might be slower.

The compact family of row formats also optimizes CHAR column storage when using a variable-length character set such as utf8mb3 or utf8mb4. With ROW_FORMAT=REDUNDANT, CHAR(N) occupies N × the maximum byte length of the character set. Many languages can be written primarily using single-byte utf8 characters, so a fixed storage length often wastes space. With the compact family of rows formats, InnoDB allocates a variable amount of storage in the range of N to N × the maximum byte length of the character set for these columns by stripping trailing spaces. The minimum storage length is N bytes to facilitate in-place updates in typical cases. For more information, see Section 14.14, “InnoDB Row Formats”.

- To minimize space even further by storing table data in compressed form, specify ROW_FORMAT=COMPRESSED when creating InnoDB tables, or run the myisampack command on an existing MyISAM table. (InnoDB compressed tables are readable and writable, while MyISAM compressed tables are read-only.)

- For MyISAM tables, if you do not have any variable-length columns (VARCHAR, TEXT, or BLOB columns), a fixed-size row format is used. This is faster but may waste some space. See Section 15.3.3, “MyISAM Table Storage Formats”. You can hint that you want to have fixed length rows even if you have VARCHAR columns with the CREATE TABLE option ROW_FORMAT=FIXED.

Indexes

- The primary index of a table should be as short as possible. This makes identification of each row easy and efficient. For InnoDB tables, the primary key columns are duplicated in each secondary index entry, so a short primary key saves considerable space if you have many secondary indexes.

- Create only the indexes that you need to improve query performance. Indexes are good for retrieval, but slow down insert and update operations. If you access a table mostly by searching on a combination of columns, create a single composite index on them rather than a separate index for each column. The first part of the index should be the column most used. If you always use many columns when selecting from the table, the first column in the index should be the one with the most duplicates, to obtain better compression of the index.

- If it is very likely that a long string column has a unique prefix on the first number of characters, it is better to index only this prefix, using MySQL’s support for creating an index on the leftmost part of the column (see Section 13.1.13, “CREATE INDEX Statement”). Shorter indexes are faster, not only because they require less disk space, but because they also give you more hits in the index cache, and thus fewer disk seeks. See Section 5.1.1, “Configuring the Server”.

Joins

- In some circumstances, it can be beneficial to split into two a table that is scanned very often. This is especially true if it is a dynamic-format table and it is possible to use a smaller static format table that can be used to find the relevant rows when scanning the table.

- Declare columns with identical information in different tables with identical data types, to speed up joins based on the corresponding columns.
Optimizing MySQL Data Types

• Keep column names simple, so that you can use the same name across different tables and simplify join queries. For example, in a table named `customer`, use a column name of `name` instead of `customer_name`. To make your names portable to other SQL servers, consider keeping them shorter than 18 characters.

Normalization

• Normally, try to keep all data nonredundant (observing what is referred to in database theory as third normal form). Instead of repeating lengthy values such as names and addresses, assign them unique IDs, repeat these IDs as needed across multiple smaller tables, and join the tables in queries by referencing the IDs in the join clause.

• If speed is more important than disk space and the maintenance costs of keeping multiple copies of data, for example in a business intelligence scenario where you analyze all the data from large tables, you can relax the normalization rules, duplicating information or creating summary tables to gain more speed.

8.4.2 Optimizing MySQL Data Types

8.4.2.1 Optimizing for Numeric Data

• For unique IDs or other values that can be represented as either strings or numbers, prefer numeric columns to string columns. Since large numeric values can be stored in fewer bytes than the corresponding strings, it is faster and takes less memory to transfer and compare them.

• If you are using numeric data, it is faster in many cases to access information from a database (using a live connection) than to access a text file. Information in the database is likely to be stored in a more compact format than in the text file, so accessing it involves fewer disk accesses. You also save code in your application because you can avoid parsing the text file to find line and column boundaries.

8.4.2.2 Optimizing for Character and String Types

For character and string columns, follow these guidelines:

• Use binary collation order for fast comparison and sort operations, when you do not need language-specific collation features. You can use the `BINARY` operator to use binary collation within a particular query.

• When comparing values from different columns, declare those columns with the same character set and collation wherever possible, to avoid string conversions while running the query.

• For column values less than 8KB in size, use binary `VARCHAR` instead of `BLOB`. The `GROUP BY` and `ORDER BY` clauses can generate temporary tables, and these temporary tables can use the `MEMORY` storage engine if the original table does not contain any `BLOB` columns.

• If a table contains string columns such as name and address, but many queries do not retrieve those columns, consider splitting the string columns into a separate table and using join queries with a foreign key when necessary. When MySQL retrieves any value from a row, it reads a data block containing all the columns of that row (and possibly other adjacent rows). Keeping each row small, with only the most frequently used columns, allows more rows to fit in each data block. Such compact tables reduce disk I/O and memory usage for common queries.

• When you use a randomly generated value as a primary key in an `InnoDB` table, prefix it with an ascending value such as the current date and time if possible. When consecutive primary values are physically stored near each other, `InnoDB` can insert and retrieve them faster.
Optimizing for Many Tables

- See Section 8.4.2.1, “Optimizing for Numeric Data” for reasons why a numeric column is usually preferable to an equivalent string column.

### 8.4.2.3 Optimizing for BLOB Types

- When storing a large blob containing textual data, consider compressing it first. Do not use this technique when the entire table is compressed by InnoDB or MyISAM.

- For a table with several columns, to reduce memory requirements for queries that do not use the BLOB column, consider splitting the BLOB column into a separate table and referencing it with a join query when needed.

- Since the performance requirements to retrieve and display a BLOB value might be very different from other data types, you could put the BLOB-specific table on a different storage device or even a separate database instance. For example, to retrieve a BLOB might require a large sequential disk read that is better suited to a traditional hard drive than to an SSD device.

- See Section 8.4.2.2, “Optimizing for Character and String Types” for reasons why a binary VARCHAR column is sometimes preferable to an equivalent BLOB column.

- Rather than testing for equality against a very long text string, you can store a hash of the column value in a separate column, index that column, and test the hashed value in queries. (Use the MD5() or CRC32() function to produce the hash value.) Since hash functions can produce duplicate results for different inputs, you still include a clause AND blob_column = long_string_value in the query to guard against false matches; the performance benefit comes from the smaller, easily scanned index for the hashed values.

### 8.4.2.4 Using PROCEDURE ANALYSE

```
ANALYSE([max_elements[,max_memory]])
```

ANALYSE() examines the result from a query and returns an analysis of the results that suggests optimal data types for each column that may help reduce table sizes. To obtain this analysis, append PROCEDURE ANALYSE to the end of a SELECT statement:

```
SELECT ... FROM ... WHERE ... PROCEDURE ANALYSE([max_elements,[max_memory]])
```

For example:

```
SELECT col1, col2 FROM table1 PROCEDURE ANALYSE(10, 2000);
```

The results show some statistics for the values returned by the query, and propose an optimal data type for the columns. This can be helpful for checking your existing tables, or after importing new data. You may need to try different settings for the arguments so that PROCEDURE ANALYSE() does not suggest the ENUM data type when it is not appropriate.

The arguments are optional and are used as follows:

- **max_elements** (default 256) is the maximum number of distinct values that ANALYSE() notices per column. This is used by ANALYSE() to check whether the optimal data type should be of type ENUM; if there are more than max_elements distinct values, then ENUM is not a suggested type.

- **max_memory** (default 8192) is the maximum amount of memory that ANALYSE() should allocate per column while trying to find all distinct values.

A PROCEDURE clause is not permitted in a UNION statement.

### 8.4.3 Optimizing for Many Tables
Some techniques for keeping individual queries fast involve splitting data across many tables. When the number of tables runs into the thousands or even millions, the overhead of dealing with all these tables becomes a new performance consideration.

### 8.4.3.1 How MySQL Opens and Closes Tables

When you execute a `mysqladmin status` command, you should see something like this:

| Uptime: 426 Running threads: 1 Questions: 11082 Reloads: 1 Open tables: 12 |

The `Open tables` value of 12 can be somewhat puzzling if you have fewer than 12 tables.

MySQL is multithreaded, so there may be many clients issuing queries for a given table simultaneously. To minimize the problem with multiple client sessions having different states on the same table, the table is opened independently by each concurrent session. This uses additional memory but normally increases performance. With MyISAM tables, one extra file descriptor is required for the data file for each client that has the table open. (By contrast, the index file descriptor is shared between all sessions.)

The `table_open_cache` and `max_connections` system variables affect the maximum number of files the server keeps open. If you increase one or both of these values, you may run up against a limit imposed by your operating system on the per-process number of open file descriptors. Many operating systems permit you to increase the open-files limit, although the method varies widely from system to system. Consult your operating system documentation to determine whether it is possible to increase the limit and how to do so.

`table_open_cache` is related to `max_connections`. For example, for 200 concurrent running connections, specify a table cache size of at least $200 \times N$, where $N$ is the maximum number of tables per join in any of the queries which you execute. You must also reserve some extra file descriptors for temporary tables and files.

Make sure that your operating system can handle the number of open file descriptors implied by the `table_open_cache` setting. If `table_open_cache` is set too high, MySQL may run out of file descriptors and exhibit symptoms such as refusing connections or failing to perform queries.

Also take into account that the MyISAM storage engine needs two file descriptors for each unique open table. For a partitioned MyISAM table, two file descriptors are required for each partition of the opened table. (When MyISAM opens a partitioned table, it opens every partition of this table, whether or not a given partition is actually used. See MyISAM and partition file descriptor usage.) To increase the number of file descriptors available to MySQL, set the `open_files_limit` system variable. See Section B.4.2.18, “File Not Found and Similar Errors”.

The cache of open tables is kept at a level of `table_open_cache` entries. The default value is 400. To set the size explicitly, set the `table_open_cache` system variable at startup. MySQL may temporarily open more tables than this to execute queries, as described later in this section.

MySQL closes an unused table and removes it from the table cache under the following circumstances:

- When the cache is full and a thread tries to open a table that is not in the cache.
- When the cache contains more than `table_open_cache` entries and a table in the cache is no longer being used by any threads.
- When a table-flushing operation occurs. This happens when someone issues a `FLUSH TABLES` statement or executes a `mysqladmin flush-tables` or `mysqladmin refresh` command.
When the table cache fills up, the server uses the following procedure to locate a cache entry to use:

- Tables not currently in use are released, beginning with the table least recently used.

- If a new table must be opened, but the cache is full and no tables can be released, the cache is temporarily extended as necessary. When the cache is in a temporarily extended state and a table goes from a used to unused state, the table is closed and released from the cache.

A MyISAM table is opened for each concurrent access. This means the table needs to be opened twice if two threads access the same table or if a thread accesses the table twice in the same query (for example, by joining the table to itself). Each concurrent open requires an entry in the table cache. The first open of any MyISAM table takes two file descriptors: one for the data file and one for the index file. Each additional use of the table takes only one file descriptor for the data file. The index file descriptor is shared among all threads.

If you are opening a table with the HANDLER tbl_name OPEN statement, a dedicated table object is allocated for the thread. This table object is not shared by other threads and is not closed until the thread calls HANDLER tbl_name CLOSE or the thread terminates. When this happens, the table is put back in the table cache (if the cache is not full). See Section 13.2.4, “HANDLER Statement”.

To determine whether your table cache is too small, check theOpened_tables status variable, which indicates the number of table-opening operations since the server started:

```
mysql> SHOW GLOBAL STATUS LIKE 'Opened_tables';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Opened_tables | 2741  |
+---------------+-------+
```

If the value is very large or increases rapidly, even when you have not issued many FLUSH TABLES statements, increase the table_open_cache value at server startup.

### 8.4.3.2 Disadvantages of Creating Many Tables in the Same Database

If you have many MyISAM tables in the same database directory, open, close, and create operations are slow. If you execute SELECT statements on many different tables, there is a little overhead when the table cache is full, because for every table that has to be opened, another must be closed. You can reduce this overhead by increasing the number of entries permitted in the table cache.

### 8.4.4 Internal Temporary Table Use in MySQL

In some cases, the server creates internal temporary tables while processing statements. Users have no direct control over when this occurs.

The server creates temporary tables under conditions such as these:

- Evaluation of UNION statements.
- Evaluation of some views, such those that use the TEMPTABLE algorithm, UNION, or aggregation.
- Evaluation of statements that contain an ORDER BY clause and a different GROUP BY clause, or for which the ORDER BY or GROUP BY contains columns from tables other than the first table in the join queue.
- Evaluation of DISTINCT combined with ORDER BY may require a temporary table.
Internal Temporary Table Use in MySQL

- For queries that use the `SQL_SMALL_RESULT` modifier, MySQL uses an in-memory temporary table, unless the query also contains elements (described later) that require on-disk storage.

- To evaluate `INSERT ... SELECT` statements that select from and insert into the same table, MySQL creates an internal temporary table to hold the rows from the `SELECT`, then inserts those rows into the target table. See Section 13.2.5.1, “INSERT ... SELECT Statement”.

- Evaluation of multiple-table `UPDATE` statements.

- Evaluation of `GROUP_CONCAT()` or `COUNT(DISTINCT)` expressions.

To determine whether a statement requires a temporary table, use `EXPLAIN` and check the `Extra` column to see whether it says `Using temporary` (see Section 8.8.1, “Optimizing Queries with EXPLAIN”).

When the server creates an internal temporary table (either in memory or on disk), it increments the `Created_tmp_tables` status variable. If the server creates the table on disk (either initially or by converting an in-memory table) it increments the `Created_tmp_disk_tables` status variable.

Some query conditions prevent the use of an in-memory temporary table, in which case the server uses an on-disk table instead:

- Presence of a `BLOB` or `TEXT` column in the table. This includes user-defined variables having a string value because they are treated as `BLOB` or `TEXT` columns, depending on whether their value is a binary or nonbinary string, respectively.

- Presence of any string column in a `GROUP BY` or `DISTINCT` clause larger than 512 bytes.

- Presence of any string column with a maximum length larger than 512 (bytes for binary strings, characters for nonbinary strings) in the `SELECT` list, if `UNION` or `UNION ALL` is used.

- The `SHOW COLUMNS` and `DESCRIBE` statements use `BLOB` as the type for some columns, thus the temporary table used for the results is an on-disk table.

- **Internal Temporary Table Storage Engine**

- **Internal Temporary Table Storage Format**

**Internal Temporary Table Storage Engine**

An internal temporary table can be held in memory and processed by the `MEMORY` storage engine, or stored on disk and processed by the `MyISAM` storage engine.

If an internal temporary table is created as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is defined by the `tmp_table_size` or `max_heap_table_size` value, whichever is smaller. This differs from `MEMORY` tables explicitly created with `CREATE TABLE`. For such tables, only the `max_heap_table_size` variable determines how large a table can grow, and there is no conversion to on-disk format.

**Internal Temporary Table Storage Format**

In-memory temporary tables are managed by the `MEMORY` storage engine, which uses fixed-length row format. `VARCHAR` and `VARBINARY` column values are padded to the maximum column length, in effect storing them as `CHAR` and `BINARY` columns.

On-disk temporary tables are managed by the `MyISAM` storage engine using dynamic-width row format. Columns take only as much storage as needed, which reduces disk I/O and space requirements, and
processing time compared to on-disk tables that use fixed-length rows. The exception to dynamic-length row format is that on-disk temporary tables for derived tables are stored using fixed-length rows.

Prior to MySQL 5.5.47, on-disk temporary table storage uses fixed-length rows.

For statements that initially create an internal temporary table in memory, then convert it to an on-disk table, better performance might be achieved by skipping the conversion step and creating the table on disk to begin with. The big_tables variable can be used to force disk storage of internal temporary tables.

8.4.5 Limits on Number of Databases and Tables

MySQL has no limit on the number of databases. The underlying file system may have a limit on the number of directories.

MySQL has no limit on the number of tables. The underlying file system may have a limit on the number of files that represent tables. Individual storage engines may impose engine-specific constraints. InnoDB permits up to 4 billion tables.

8.4.6 Limits on Table Size

The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. For up-to-date information operating system file size limits, refer to the documentation specific to your operating system.

Windows users, please note that FAT and VFAT (FAT32) are not considered suitable for production use with MySQL. Use NTFS instead.

If you encounter a full-table error, there are several reasons why it might have occurred:

- The disk might be full.
- You are using InnoDB tables and have run out of room in an InnoDB tablespace file. The maximum tablespace size is four billion pages (64TB), which is also the maximum size for a table. See Section 14.24, “InnoDB Limits”.

Generally, partitioning of tables into multiple tablespace files is recommended for tables larger than 1TB in size.

- You have hit an operating system file size limit. For example, you are using MyISAM tables on an operating system that supports files only up to 2GB in size and you have hit this limit for the data file or index file.
- You are using a MyISAM table and the space required for the table exceeds what is permitted by the internal pointer size. MyISAM permits data and index files to grow up to 256TB by default, but this limit can be changed up to the maximum permissible size of 65,536TB (256^7 – 1 bytes).

If you need a MyISAM table that is larger than the default limit and your operating system supports large files, the CREATE TABLE statement supports AVG_ROW_LENGTH and MAX_ROWS options. See Section 13.1.17, “CREATE TABLE Statement”. The server uses these options to determine how large a table to permit.

If the pointer size is too small for an existing table, you can change the options with ALTER TABLE to increase a table's maximum permissible size. See Section 13.1.7, “ALTER TABLE Statement”.

```
ALTER TABLE tbl_name MAX_ROWS=1000000000 AVG_ROW_LENGTH=nnn;
```

You have to specify AVG_ROW_LENGTH only for tables with BLOB or TEXT columns; in this case, MySQL cannot optimize the space required based only on the number of rows.
Limits on Table Column Count and Row Size

To change the default size limit for MyISAM tables, set the `myisam_data_pointer_size`, which sets the number of bytes used for internal row pointers. The value is used to set the pointer size for new tables if you do not specify the `MAX_ROWS` option. The value of `myisam_data_pointer_size` can be from 2 to 7. A value of 4 permits tables up to 4GB; a value of 6 permits tables up to 256TB.

You can check the maximum data and index sizes by using this statement:

```
SHOW TABLE STATUS FROM db_name LIKE 'tbl_name';
```

You also can use `mysampack` to compress it. `mysampack` usually compresses a table by at least 50%, so you can have, in effect, much bigger tables. `mysampack` also can merge multiple tables into a single table. See Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables".

Other ways to work around file-size limits for MyISAM tables are as follows:

- If your large table is read only, you can use `mysampack` to compress it. `mysampack` usually compresses a table by at least 50%, so you can have, in effect, much bigger tables. `mysampack` also can merge multiple tables into a single table. See Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables".

- MySQL includes a `MERGE` library that enables you to handle a collection of MyISAM tables that have identical structure as a single `MERGE` table. See Section 15.8, "The MERGE Storage Engine".

- You are using the NDB storage engine, in which case you need to increase the values for the `DataMemory` and `IndexMemory` configuration parameters in your `config.ini` file. See Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”.

- You are using the MEMORY (HEAP) storage engine; in this case you need to increase the value of the `max_heap_table_size` system variable. See Section 5.1.7, "Server System Variables".

### 8.4.7 Limits on Table Column Count and Row Size

This section describes limits on the number of columns in tables and the size of individual rows.

- **Column Count Limits**
- **Row Size Limits**

#### Column Count Limits

MySQL has hard limit of 4096 columns per table, but the effective maximum may be less for a given table. The exact column limit depends on several factors:

- The maximum row size for a table constrains the number (and possibly size) of columns because the total length of all columns cannot exceed this size. See `Row Size Limits`.

- The storage requirements of individual columns constrain the number of columns that fit within a given maximum row size. Storage requirements for some data types depend on factors such as storage engine, storage format, and character set. See Section 11.6, "Data Type Storage Requirements".

- Storage engines may impose additional restrictions that limit table column count. For example, InnoDB has a limit of 1000 columns per table. See Section 14.24, “InnoDB Limits”. For information about other storage engines, see Chapter 15, Alternative Storage Engines.

- Each table has an `.frm` file that contains the table definition. The definition affects the content of this file in ways that may affect the number of columns permitted in the table. See Limits Imposed by `.frm` File Structure.
Row Size Limits

The maximum row size for a given table is determined by several factors:

- The internal representation of a MySQL table has a maximum row size limit of 65,535 bytes, even if the storage engine is capable of supporting larger rows. **BLOB** and **TEXT** columns only contribute 9 to 12 bytes toward the row size limit because their contents are stored separately from the rest of the row.

- The maximum row size for an **InnoDB** table, which applies to data stored locally within a database page, is slightly less than half a page. For example, the maximum row size is slightly less than 8KB for the default 16KB **InnoDB** page size. See Section 14.24, “InnoDB Limits”.

  If a row containing **variable-length columns** exceeds the **InnoDB** maximum row size, **InnoDB** selects variable-length columns for external off-page storage until the row fits within the **InnoDB** row size limit. The amount of data stored locally for variable-length columns that are stored off-page differs by row format. For more information, see Section 14.14, “InnoDB Row Formats”.

- Different storage formats use different amounts of page header and trailer data, which affects the amount of storage available for rows.

  - For information about **InnoDB** row formats, see Section 14.14, “InnoDB Row Formats”.
  
  - For information about **MyISAM** storage formats, see Section 15.3.3, “MyISAM Table Storage Formats”.

Row Size Limit Examples

- The MySQL maximum row size limit of 65,535 bytes is demonstrated in the following **InnoDB** and **MyISAM** examples. The limit is enforced regardless of storage engine, even though the storage engine may be capable of supporting larger rows.

  ```sql
  mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
  c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
  f VARCHAR(10000), g VARCHAR(6000)) ENGINE=InnoDB CHARACTER SET latin1;
  ERROR 1118 (42000): Row size too large. The maximum row size for the used
  table type, not counting BLOBs, is 65535. You have to change some columns
  to TEXT or BLOBs
  ```

  ```sql
  mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
  c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
  f VARCHAR(10000), g VARCHAR(6000)) ENGINE=MyISAM CHARACTER SET latin1;
  ERROR 1118 (42000): Row size too large. The maximum row size for the used
  table type, not counting BLOBs, is 65535. You have to change some columns
  to TEXT or BLOBs
  ```

  In the following **MyISAM** example, changing a column to **TEXT** avoids the 65,535-byte row size limit and permits the operation to succeed because **BLOB** and **TEXT** columns only contribute 9 to 12 bytes toward the row size.

  ```sql
  mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
  c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
  f VARCHAR(10000), g TEXT(6000)) ENGINE=MyISAM CHARACTER SET latin1;
  Query OK, 0 rows affected (0.02 sec)
  ```

  The operation succeeds for an **InnoDB** table because changing a column to **TEXT** avoids the MySQL 65,535-byte row size limit, and **InnoDB** off-page storage of variable-length columns avoids the **InnoDB** row size limit.

  ```sql
  mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
  c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
  f VARCHAR(10000), g TEXT(6000)) ENGINE=InnoDB CHARACTER SET latin1;
  ```
Limits on Table Column Count and Row Size

• Storage for variable-length columns includes length bytes, which are counted toward the row size. For example, a VARCHAR(255) CHARACTER SET utf8mb3 column takes two bytes to store the length of the value, so each value can take up to 767 bytes.

The statement to create table `t1` succeeds because the columns require 32,765 + 2 bytes and 32,766 + 2 bytes, which falls within the maximum row size of 65,535 bytes:

```sql
mysql> CREATE TABLE t1
    -> (c1 VARCHAR(32765) NOT NULL, c2 VARCHAR(32766) NOT NULL)
    -> ENGINE = InnoDB CHARACTER SET latin1;
Query OK, 0 rows affected (0.02 sec)
```

The statement to create table `t2` fails because, although the column length is within the maximum length of 65,535 bytes, two additional bytes are required to record the length, which causes the row size to exceed 65,535 bytes:

```sql
mysql> CREATE TABLE t2
    -> (c1 VARCHAR(65535) NOT NULL)
    -> ENGINE = InnoDB CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the used table type, not counting BLOBs, is 65535. You have to change some columns to TEXT or BLOBs
```

Reducing the column length to 65,533 or less permits the statement to succeed.

```sql
mysql> CREATE TABLE t2
    -> (c1 VARCHAR(65533) NOT NULL)
    -> ENGINE = InnoDB CHARACTER SET latin1;
Query OK, 0 rows affected (0.01 sec)
```

• For **MyISAM** tables, **NULL** columns require additional space in the row to record whether their values are **NULL**. Each **NULL** column takes one bit extra, rounded up to the nearest byte.

The statement to create table `t3` fails because **MyISAM** requires space for **NULL** columns in addition to the space required for variable-length column length bytes, causing the row size to exceed 65,535 bytes:

```sql
mysql> CREATE TABLE t3
    -> (c1 VARCHAR(32765) NULL, c2 VARCHAR(32766) NULL)
    -> ENGINE = MyISAM CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the used table type, not counting BLOBs, is 65535. You have to change some columns to TEXT or BLOBs
```

For information about **InnoDB** **NULL** column storage, see Section 14.14, “InnoDB Row Formats”.

• **InnoDB** restricts row size (for data stored locally within the database page) to slightly less than half a database page. For example, the maximum row size is slightly less than 8KB for the 16KB **InnoDB** page size.

The statement to create table `t4` fails because the defined columns exceed the row size limit for a 16KB **InnoDB** page.

```sql
mysql> CREATE TABLE t4
    -> (c1 VARCHAR(32765) NULL, c2 VARCHAR(32766) NULL)
    -> ENGINE = MyISAM CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the used table type, not counting BLOBs, is 65535. You have to change some columns to TEXT or BLOBs
```

For information about **InnoDB** **NULL** column storage, see Section 14.14, “InnoDB Row Formats”.

**Note**

`innodb_strict_mode` is enabled in the following example to ensure that **InnoDB** returns an error if the defined columns exceed the **InnoDB** row size limit. When `innodb_strict_mode` is disabled (the default), creating a table that uses **REDUNDANT** or **COMPACT** row format succeeds with a warning if the **InnoDB** row size limit is exceeded.
8.5 Optimizing for InnoDB Tables

InnoDB is the storage engine that MySQL customers typically use in production databases where reliability and concurrency are important. Because InnoDB is the default storage engine in MySQL 5.5 and higher, you can expect to see InnoDB tables more often than before. This section explains how to optimize database operations for InnoDB tables.

8.5.1 Optimizing Storage Layout for InnoDB Tables

- Once your data reaches a stable size, or a growing table has increased by tens or some hundreds of megabytes, consider using the OPTIMIZE TABLE statement to reorganize the table and compact any wasted space. The reorganized tables require less disk I/O to perform full table scans. This is a straightforward technique that can improve performance when other techniques such as improving index usage or tuning application code are not practical.

    OPTIMIZE TABLE copies the data part of the table and rebuilds the indexes. The benefits come from improved packing of data within indexes, and reduced fragmentation within the tablespaces and on disk. The benefits vary depending on the data in each table. You may find that there are significant gains for some and not for others, or that the gains decrease over time until you next optimize the table. This operation can be slow if the table is large or if the indexes being rebuilt do not fit into the buffer pool. The first run after adding a lot of data to a table is often much slower than later runs.

- In InnoDB, having a long PRIMARY KEY (either a single column with a lengthy value, or several columns that form a long composite value) wastes a lot of disk space. The primary key value for a row is duplicated in all the secondary index records that point to the same row. (See Section 14.9.2.1, “Clustered and Secondary Indexes”.) Create an AUTO_INCREMENT column as the primary key if your primary key is long, or index a prefix of a long VARCHAR column instead of the entire column.

- Use the VARCHAR data type instead of CHAR to store variable-length strings or for columns with many NULL values. A CHAR(N) column always takes N characters to store data, even if the string is shorter or its value is NULL. Smaller tables fit better in the buffer pool and reduce disk I/O.

    When using COMPACT row format (the default InnoDB format) and variable-length character sets, such as utf8 or sjis, CHAR(N) columns occupy a variable amount of space, but still at least N bytes.
• For tables that are big, or contain lots of repetitive text or numeric data, consider using COMPRESSED row format. Less disk I/O is required to bring data into the buffer pool, or to perform full table scans. Before making a permanent decision, measure the amount of compression you can achieve by using COMPRESSED versus COMPACT row format.

8.5.2 Optimizing InnoDB Transaction Management

To optimize InnoDB transaction processing, find the ideal balance between the performance overhead of transactional features and the workload of your server. For example, an application might encounter performance issues if it commits thousands of times per second, and different performance issues if it commits only every 2-3 hours.

• The default MySQL setting AUTOCOMMIT=1 can impose performance limitations on a busy database server. Where practical, wrap several related data change operations into a single transaction, by issuing SET AUTOCOMMIT=0 or a START TRANSACTION statement, followed by a COMMIT statement after making all the changes.

InnoDB must flush the log to disk at each transaction commit if that transaction made modifications to the database. When each change is followed by a commit (as with the default autocommit setting), the I/O throughput of the storage device puts a cap on the number of potential operations per second.

• Avoid performing rollbacks after inserting, updating, or deleting huge numbers of rows. If a big transaction is slowing down server performance, rolling it back can make the problem worse, potentially taking several times as long to perform as the original data change operations. Killing the database process does not help, because the rollback starts again on server startup.

To minimize the chance of this issue occurring:

• Increase the size of the buffer pool so that all the data change changes can be cached rather than immediately written to disk.

• Set innodb_change_buffering=all so that update and delete operations are buffered in addition to inserts.

• Consider issuing COMMIT statements periodically during the big data change operation, possibly breaking a single delete or update into multiple statements that operate on smaller numbers of rows.

To get rid of a runaway rollback once it occurs, increase the buffer pool so that the rollback becomes CPU-bound and runs fast, or kill the server and restart with innodb_force_recovery=3, as explained in Section 14.21.2, “InnoDB Recovery”.

This issue is expected to be infrequent with the default setting innodb_change_buffering=all, which allows update and delete operations to be cached in memory, making them faster to perform in the first place, and also faster to roll back if needed. Make sure to use this parameter setting on servers that process long-running transactions with many inserts, updates, or deletes.

• If you can afford the loss of some of the latest committed transactions if a crash occurs, you can set the innodb_flush_log_at_trx_commit parameter to 0. InnoDB tries to flush the log once per second anyway, although the flush is not guaranteed. Also, set the value of innodb_support_xa to 0, which will reduce the number of disk flushes due to synchronizing on disk data and the binary log.

• When rows are modified or deleted, the rows and associated undo logs are not physically removed immediately, or even immediately after the transaction commits. The old data is preserved until transactions that started earlier or concurrently are finished, so that those transactions can access the previous state of modified or deleted rows. Thus, a long-running transaction can prevent InnoDB from purging data that was changed by a different transaction.
8.5.3 Optimizing InnoDB Redo Logging

Consider the following guidelines for optimizing redo logging:

- Make your redo log files big, even as big as the buffer pool. When InnoDB has written the redo log files full, it must write the modified contents of the buffer pool to disk in a checkpoint. Small redo log files cause many unnecessary disk writes. Although historically big redo log files caused lengthy recovery times, recovery is now much faster and you can confidently use large redo log files.

The size and number of redo log files are configured using the `innodb_log_file_size` and `innodb_log_files_in_group` configuration options. For information about modifying an existing redo log file configuration, see Changing the Number or Size of InnoDB Redo Log Files.

- Consider increasing the size of the log buffer. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O. Log buffer size is configured using the `innodb_log_buffer_size` configuration option.

8.5.4 Bulk Data Loading for InnoDB Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.4.1, "Optimizing INSERT Statements".

- When importing data into InnoDB, turn off autocommit mode, because it performs a log flush to disk for every insert. To disable autocommit during your import operation, surround it with `SET autocommit` and `COMMIT` statements:

```
SET autocommit=0;... SQL import statements ...
COMMIT;
```

The `mysqldump` option `--opt` creates dump files that are fast to import into an InnoDB table, even without wrapping them with the `SET autocommit` and `COMMIT` statements.

- If you have `UNIQUE` constraints on secondary keys, you can speed up table imports by temporarily turning off the uniqueness checks during the import session:

```
SET unique_checks=0;... SQL import statements ...
SET unique_checks=1;
```

For big tables, this saves a lot of disk I/O because InnoDB can use its change buffer to write secondary index records in a batch. Be certain that the data contains no duplicate keys.

- If you have `FOREIGN KEY` constraints in your tables, you can speed up table imports by turning off the foreign key checks for the duration of the import session:

```
SET foreign_key_checks=0;... SQL import statements ...
SET foreign_key_checks=1;
```
For big tables, this can save a lot of disk I/O.

- Use the multiple-row `INSERT` syntax to reduce communication overhead between the client and the server if you need to insert many rows:

```
INSERT INTO yourtable VALUES (1,2), (5,5), ...;
```

This tip is valid for inserts into any table, not just InnoDB tables.

- When doing bulk inserts into tables with auto-increment columns, set `innodb_autoinc_lock_mode` to 2 instead of the default value 1. See Section 14.9.1.4, "AUTO_INCREMENT Handling in InnoDB" for details.

- When performing bulk inserts, it is faster to insert rows in PRIMARY KEY order. InnoDB tables use a clustered index, which makes it relatively fast to use data in the order of the PRIMARY KEY. Performing bulk inserts in PRIMARY KEY order is particularly important for tables that do not fit entirely within the buffer pool.

### 8.5.5 Optimizing InnoDB Queries

To tune queries for InnoDB tables, create an appropriate set of indexes on each table. See Section 8.3.1, "How MySQL Uses Indexes" for details. Follow these guidelines for InnoDB indexes:

- Because each InnoDB table has a primary key (whether you request one or not), specify a set of primary key columns for each table, columns that are used in the most important and time-critical queries.

- Do not specify too many or too long columns in the primary key, because these column values are duplicated in each secondary index. When an index contains unnecessary data, the I/O to read this data and memory to cache it reduce the performance and scalability of the server.

- Do not create a separate secondary index for each column, because each query can only make use of one index. Indexes on rarely tested columns or columns with only a few different values might not be helpful for any queries. If you have many queries for the same table, testing different combinations of columns, try to create a small number of concatenated indexes rather than a large number of single-column indexes. If an index contains all the columns needed for the result set (known as a covering index), the query might be able to avoid reading the table data at all.

- If an indexed column cannot contain any NULL values, declare it as `NOT NULL` when you create the table. The optimizer can better determine which index is most effective to use for a query, when it knows whether each column contains NULL values.

### 8.5.6 Optimizing InnoDB DDL Operations

- For DDL operations on tables and indexes (CREATE, ALTER, and DROP statements), the most significant aspect for InnoDB tables is that creating and dropping secondary indexes is much faster in MySQL 5.5 and higher, than in earlier versions. See Section 14.16, "InnoDB Fast Index Creation" for details.

- “Fast index creation” makes it faster in some cases to drop an index before loading data into a table, then re-create the index after loading the data.

- Use `TRUNCATE TABLE` to empty a table, not DELETE FROM `tbl_name`. Foreign key constraints can make a `TRUNCATE` statement work like a regular DELETE statement, in which case a sequence of commands like DROP TABLE and CREATE TABLE might be fastest.

- Because the primary key is integral to the storage layout of each InnoDB table, and changing the definition of the primary key involves reorganizing the whole table, always set up the primary key as part
of the `CREATE TABLE` statement, and plan ahead so that you do not need to `ALTER` or `DROP` the primary key afterward.

### 8.5.7 Optimizing InnoDB Disk I/O

If you follow best practices for database design and tuning techniques for SQL operations, but your database is still slow due to heavy disk I/O activity, consider these disk I/O optimizations. If the Unix `top` tool or the Windows Task Manager shows that the CPU usage percentage with your workload is less than 70%, your workload is probably disk-bound.

- **Increase buffer pool size**

  When table data is cached in the InnoDB buffer pool, it can be accessed repeatedly by queries without requiring any disk I/O. Specify the size of the buffer pool with the `innodb_buffer_pool_size` option. This memory area is important enough that it is typically recommended that `innodb_buffer_pool_size` is configured to 50 to 75 percent of system memory. For more information see, Section 8.12.4.1, “How MySQL Uses Memory”.

- **Adjust the flush method**

  In some versions of GNU/Linux and Unix, flushing files to disk with the Unix `fsync()` call (which InnoDB uses by default) and similar methods is surprisingly slow. If database write performance is an issue, conduct benchmarks with the `innodb_flush_method` parameter set to `O_DSYNC`.

- **Use a noop or deadline I/O scheduler with native AIO on Linux**

  InnoDB uses the asynchronous I/O subsystem (native AIO) on Linux to perform read-ahead and write requests for data file pages. This behavior is controlled by the `innodb_use_native_aio` configuration option, which is enabled by default. With native AIO, the type of I/O scheduler has greater influence on I/O performance. Generally, noop and deadline I/O schedulers are recommended. Conduct benchmarks to determine which I/O scheduler provides the best results for your workload and environment. For more information, see Section 14.11.6, “Using Asynchronous I/O on Linux”.

- **Use direct I/O on Solaris 10 for x86_64 architecture**

  When using the InnoDB storage engine on Solaris 10 for x86_64 architecture (AMD Opteron), use direct I/O for InnoDB-related files to avoid degradation of InnoDB performance. To use direct I/O for an entire UFS file system used for storing InnoDB-related files, mount it with the `forcedirectio` option; see `mount_ufs(1M)`. (The default on Solaris 10/x86_64 is not to use this option.) To apply direct I/O only to InnoDB file operations rather than the whole file system, set `innodb_flush_method = O_DIRECT`. With this setting, InnoDB calls `directio()` instead of `fcntl()` for I/O to data files (not for I/O to log files).

- **Use raw storage for data and log files with Solaris 2.6 or later**

  When using the InnoDB storage engine with a large `innodb_buffer_pool_size` value on any release of Solaris 2.6 and up and any platform (sparc/x86/x64/amd64), conduct benchmarks with InnoDB data files and log files on raw devices or on a separate direct I/O UFS file system, using the `forcedirectio` mount option as described previously. (It is necessary to use the mount option rather than setting `innodb_flush_method` if you want direct I/O for the log files.) Users of the Veritas file system VxFS should use the `convosync=direct` mount option.

  Do not place other MySQL data files, such as those for MyISAM tables, on a direct I/O file system. Executables or libraries must not be placed on a direct I/O file system.

- **Use additional storage devices**
Additional storage devices could be used to set up a RAID configuration. For related information, see Section 8.12.2, “Optimizing Disk I/O”.

Alternatively, InnoDB tablespace data files and log files can be placed on different physical disks. For more information, refer to the following sections:

• Section 14.11.1, “InnoDB Startup Configuration”
• Section 14.9.1.2, “Moving or Copying InnoDB Tables”

• Non-rotational storage generally provides better performance for random I/O operations; and rotational storage for sequential I/O operations. When distributing data and log files across rotational and non-rotational storage devices, consider the type of I/O operations that are predominantly performed on each file.

Random I/O-oriented files are typically file-per-table data files. Sequential I/O-oriented files include InnoDB system tablespace files (due to doublewrite buffering and change buffering) and log files such as binary log files and redo log files.

Review settings for the following configuration options when using non-rotational storage:

• `innodb_io_capacity`

  The default setting of 200 is generally sufficient for a lower-end non-rotational storage device. For higher-end, bus-attached devices, consider a higher setting such as 1000.

• `innodb_log_file_size`

  If redo logs are on non-rotational storage, configure this option to maximize caching and write combining.

Early-generation SSD devices often have a 4KB sector size, but some newer devices have a 16KB sector size. The default InnoDB page size is 16KB. Keeping the page size close to the storage device block size minimizes the amount of unchanged data that is rewritten to disk.

Ensure that TRIM support is enabled for your operating system. It is typically enabled by default.

• Increase I/O capacity to avoid backlogs

  If throughput drops periodically because of InnoDB checkpoint operations, consider increasing the value of the `innodb_io_capacity` configuration option. Higher values cause more frequent flushing, avoiding the backlog of work that can cause dips in throughput.

• Lower I/O capacity if flushing does not fall behind

  If the system is not falling behind with InnoDB flushing operations, consider lowering the value of the `innodb_io_capacity` configuration option. Typically, you keep this option value as low as practical, but not so low that it causes periodic drops in throughput as mentioned in the preceding bullet. In a typical scenario where you could lower the option value, you might see a combination like this in the output from `SHOW ENGINE INNODB STATUS`:

  • History list length low, below a few thousand.
  • Insert buffer merges close to rows inserted.
• Modified pages in buffer pool consistently well below `innodb_max_dirty_pages_pct` of the buffer pool. (Measure at a time when the server is not doing bulk inserts; it is normal during bulk inserts for the modified pages percentage to rise significantly.)

• Log sequence number – Last checkpoint is at less than 7/8 or ideally less than 6/8 of the total size of the InnoDB log files.

8.5.8 Optimizing InnoDB Configuration Variables

Different settings work best for servers with light, predictable loads, versus servers that are running near full capacity all the time, or that experience spikes of high activity.

Because the InnoDB storage engine performs many of its optimizations automatically, many performance-tuning tasks involve monitoring to ensure that the database is performing well, and changing configuration options when performance drops. See Section 14.19, “InnoDB Integration with MySQL Performance Schema” for information about detailed InnoDB performance monitoring.

For a list of the most important and most recent InnoDB performance features, see Section 1.4, “What Is New in MySQL 5.5”. Even if you have used InnoDB tables in prior versions, these features might be new to you, because they are from the “InnoDB Plugin”. The Plugin co-existed alongside the built-in InnoDB in MySQL 5.1, and becomes the default storage engine in MySQL 5.5 and higher.

The main configuration steps you can perform include:

• Enabling InnoDB to use high-performance memory allocators on systems that include them. See Section 14.11.3, “Configuring the Memory Allocator for InnoDB”.

• Controlling the types of data change operations for which InnoDB buffers the changed data, to avoid frequent small disk writes. See Configuring Change Buffering. Because the default is to buffer all types of data change operations, only change this setting if you need to reduce the amount of buffering.

• Turning the adaptive hash indexing feature on and off using the `innodb_adaptive_hash_index` option. See Section 14.8.3, “Adaptive Hash Index” for more information. You might change this setting during periods of unusual activity, then restore it to its original setting.

• Setting a limit on the number of concurrent threads that InnoDB processes, if context switching is a bottleneck. See Section 14.11.4, “Configuring Thread Concurrency for InnoDB”.

• Controlling the amount of prefetching that InnoDB does with its read-ahead operations. When the system has unused I/O capacity, more read-ahead can improve the performance of queries. Too much read-ahead can cause periodic drops in performance on a heavily loaded system. See Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

• Increasing the number of background threads for read or write operations, if you have a high-end I/O subsystem that is not fully utilized by the default values. See Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”.

• Controlling how much I/O InnoDB performs in the background. See Section 14.11.7, “Configuring InnoDB I/O Capacity”. You might scale back this setting if you observe periodic drops in performance.

• Controlling the algorithm that determines when InnoDB performs certain types of background writes. See Section 14.11.2.4, “Configuring Buffer Pool Flushing”. The algorithm works for some types of workloads but not others, so might turn off this setting if you observe periodic drops in performance.

• Taking advantage of multicore processors and their cache memory configuration, to minimize delays in context switching. See Section 14.11.8, “Configuring Spin Lock Polling”.
• Preventing one-time operations such as table scans from interfering with the frequently accessed data stored in the InnoDB buffer cache. See Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”.

• Adjusting log files to a size that makes sense for reliability and crash recovery. InnoDB log files have often been kept small to avoid long startup times after a crash. Optimizations introduced in MySQL 5.5 speed up certain steps of the crash recovery process. In particular, scanning the redo log and applying the redo log are faster due to improved algorithms for memory management. If you have kept your log files artificially small to avoid long startup times, you can now consider increasing log file size to reduce the I/O that occurs due recycling of redo log records.

• Configuring the size and number of instances for the InnoDB buffer pool, especially important for systems with multi-gigabyte buffer pools. See Section 14.11.2.1, “Configuring Multiple Buffer Pool Instances”.

• Increasing the maximum number of concurrent transactions, which dramatically improves scalability for the busiest databases. See Section 14.9.7, “Undo Logs”. Although this feature does not require any action during day-to-day operation, you must perform a slow shutdown during or after upgrading the database to MySQL 5.5 to enable the higher limit.

• Moving purge operations (a type of garbage collection) into a background thread. See Section 14.11.9, “Purge Configuration”. To effectively measure the results of this setting, tune the other I/O-related and thread-related configuration settings first.

• Reducing the amount of switching that InnoDB does between concurrent threads, so that SQL operations on a busy server do not queue up and form a “traffic jam”. Set a value for the innodb_thread_concurrency option, up to approximately 32 for a high-powered modern system. Increase the value for the innodb_concurrency_tickets option, typically to 5000 or so. This combination of options sets a cap on the number of threads that InnoDB processes at any one time, and allows each thread to do substantial work before being swapped out, so that the number of waiting threads stays low and operations can complete without excessive context switching.

8.5.9 Optimizing InnoDB for Systems with Many Tables

• InnoDB computes index cardinality values for a table the first time that table is accessed after startup, instead of storing such values in the table. This step can take significant time on systems that partition the data into many tables. Since this overhead only applies to the initial table open operation, to “warm up” a table for later use, access it immediately after startup by issuing a statement such as SELECT 1 FROM tbl_name LIMIT 1.

8.6 Optimizing for MyISAM Tables

The MyISAM storage engine performs best with read-mostly data or with low-concurrency operations, because table locks limit the ability to perform simultaneous updates. In MySQL 5.5, InnoDB is the default storage engine rather than MyISAM.

8.6.1 Optimizing MyISAM Queries

Some general tips for speeding up queries on MyISAM tables:

• To help MySQL better optimize queries, use ANALYZE TABLE or run myisamchk --analyze on a table after it has been loaded with data. This updates a value for each index part that indicates the average number of rows that have the same value. (For unique indexes, this is always 1.) MySQL uses this to decide which index to choose when you join two tables based on a nonconstant expression. You can check the result from the table analysis by using SHOW INDEX FROM tbl_name and examining the Cardinality value. myisamchk --description --verbose shows index distribution information.
To sort an index and data according to an index, use `myisamchk --sort-index --sort-records=1` (assuming that you want to sort on index 1). This is a good way to make queries faster if you have a unique index from which you want to read all rows in order according to the index. The first time you sort a large table this way, it may take a long time.

Try to avoid complex `SELECT` queries on `MyISAM` tables that are updated frequently, to avoid problems with table locking that occur due to contention between readers and writers.

`MyISAM` supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can `INSERT` new rows into it at the same time that other threads are reading from the table. If it is important to be able to do this, consider using the table in ways that avoid deleting rows. Another possibility is to run `OPTIMIZE TABLE` to defragment the table after you have deleted a lot of rows from it. This behavior is altered by setting the `concurrent_insert` variable. You can force new rows to be appended (and therefore permit concurrent inserts), even in tables that have deleted rows. See Section 8.11.3, “Concurrent Inserts”.

For `MyISAM` tables that change frequently, try to avoid all variable-length columns (`VARCHAR`, `BLOB`, and `TEXT`). The table uses dynamic row format if it includes even a single variable-length column. See Chapter 15, Alternative Storage Engines.

It is normally not useful to split a table into different tables just because the rows become large. In accessing a row, the biggest performance hit is the disk seek needed to find the first byte of the row. After finding the data, most modern disks can read the entire row fast enough for most applications. The only cases where splitting up a table makes an appreciable difference is if it is a `MyISAM` table using dynamic row format that you can change to a fixed row size, or if you very often need to scan the table but do not need most of the columns. See Chapter 15, Alternative Storage Engines.

Use `ALTER TABLE ... ORDER BY expr1, expr2, ...` if you usually retrieve rows in `expr1, expr2, ...` order. By using this option after extensive changes to the table, you may be able to get higher performance.

If you often need to calculate results such as counts based on information from a lot of rows, it may be preferable to introduce a new table and update the counter in real time. An update of the following form is very fast:

```sql
UPDATE tbl_name SET count_col=count_col+1 WHERE key_col=constant;
```

This is very important when you use a MySQL storage engine such as `MyISAM` that has only table-level locking (multiple readers with single writers). This also gives better performance with most database systems, because the row locking manager in this case has less to do.

Use `INSERT DELAYED` when you do not need to know when your data is written. This reduces the overall insertion impact because many rows can be written with a single disk write.

Use `INSERT LOW_PRIORITY` when you want to give `SELECT` statements higher priority than your inserts.

Use `SELECT HIGH_PRIORITY` to get retrievals that jump the queue. That is, the `SELECT` is executed even if there is another client waiting to do a write.

`LOW_PRIORITY` and `HIGH_PRIORITY` have an effect only for storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

Use `OPTIMIZE TABLE` periodically to avoid fragmentation with dynamic-format `MyISAM` tables. See Section 15.3.3, “MyISAM Table Storage Formats”.

Declaring a `MyISAM` table with the `DELAY_KEY_WRITE=1` table option makes index updates faster because they are not flushed to disk until the table is closed. The downside is that if something kills
the server while such a table is open, you must ensure that the table is okay by running the server with the
mysam_recover_options system variable set, or by running myisamchk before restarting
the server. (However, even in this case, you should not lose anything by using DELAY_KEY_WRITE,
because the key information can always be generated from the data rows.)

• Strings are automatically prefix- and end-space compressed in MyISAM indexes. See Section 13.1.13,
“CREATE INDEX Statement”.

• You can increase performance by caching queries or answers in your application and then executing
many inserts or updates together. Locking the table during this operation ensures that the index cache
is only flushed once after all updates. You can also take advantage of MySQL’s query cache to achieve
similar results; see Section 8.10.3, “The MySQL Query Cache”.

8.6.2 Bulk Data Loading for MyISAM Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.4.1, “Optimizing
INSERT Statements”.

• To improve performance when multiple clients insert a lot of rows, use the INSERT DELAYED statement.
See Section 13.2.5.3, "INSERT DELAYED Statement". This technique works for MyISAM and some
other storage engines, but not InnoDB.

• For a MyISAM table, you can use concurrent inserts to add rows at the same time that SELECT
statements are running, if there are no deleted rows in middle of the data file. See Section 8.11.3,
“Concurrent Inserts”.

• With some extra work, it is possible to make LOAD DATA run even faster for a MyISAM table when the
table has many indexes. Use the following procedure:

1. Execute a FLUSH TABLES statement or a mysqladmin flush-tables command.

2. Use myisamchk --keys-used=0 -rq /path/to/db/tbl_name to remove all use of indexes
for the table.

3. Insert data into the table with LOAD DATA. This does not update any indexes and therefore is very
fast.

4. If you intend only to read from the table in the future, use myisampack to compress it. See
Section 15.3.3.3, “Compressed Table Characteristics”.

5. Re-create the indexes with myisamchk -rq /path/to/db/tbl_name. This creates the index
tree in memory before writing it to disk, which is much faster than updating the index during LOAD
DATA because it avoids lots of disk seeks. The resulting index tree is also perfectly balanced.

6. Execute a FLUSH TABLES statement or a mysqladmin flush-tables command.

LOAD DATA performs the preceding optimization automatically if the MyISAM table into which you insert
data is empty. The main difference between automatic optimization and using the procedure explicitly
is that you can let myisamchk allocate much more temporary memory for the index creation than you
might want the server to allocate for index re-creation when it executes the LOAD DATA statement.

You can also disable or enable the nonunique indexes for a MyISAM table by using the following
statements rather than myisamchk. If you use these statements, you can skip the FLUSH TABLES
operations:

| ALTER TABLE tbl_name DISABLE KEYS; |
| ALTER TABLE tbl_name ENABLE KEYS; |
• To speed up INSERT operations that are performed with multiple statements for nontransactional tables, lock your tables:

```
LOCK TABLES a WRITE;
INSERT INTO a VALUES (1,23),(2,34),(4,33);
INSERT INTO a VALUES (8,26),(6,29);
...
UNLOCK TABLES;
```

This benefits performance because the index buffer is flushed to disk only once, after all INSERT statements have completed. Normally, there would be as many index buffer flushes as there are INSERT statements. Explicit locking statements are not needed if you can insert all rows with a single INSERT.

Locking also lowers the total time for multiple-connection tests, although the maximum wait time for individual connections might go up because they wait for locks. Suppose that five clients attempt to perform inserts simultaneously as follows:

• Connection 1 does 1000 inserts
• Connections 2, 3, and 4 do 1 insert
• Connection 5 does 1000 inserts

If you do not use locking, connections 2, 3, and 4 finish before 1 and 5. If you use locking, connections 2, 3, and 4 probably do not finish before 1 or 5, but the total time should be about 40% faster.

INSERT, UPDATE, and DELETE operations are very fast in MySQL, but you can obtain better overall performance by adding locks around everything that does more than about five successive inserts or updates. If you do very many successive inserts, you could do a LOCK TABLES followed by an UNLOCK TABLES once in a while (each 1,000 rows or so) to permit other threads to access table. This would still result in a nice performance gain.

INSERT is still much slower for loading data than LOAD DATA, even when using the strategies just outlined.

• To increase performance for MyISAM tables, for both LOAD DATA and INSERT, enlarge the key cache by increasing the key_buffer_size system variable. See Section 5.1.1, “Configuring the Server”.

8.6.3 Optimizing REPAIR TABLE Statements

REPAIR TABLE for MyISAM tables is similar to using myisamchk for repair operations, and some of the same performance optimizations apply:

• myisamchk has variables that control memory allocation. You may be able to improve performance by setting these variables, as described in Section 4.6.3.6, “myisamchk Memory Usage”.

• For REPAIR TABLE, the same principle applies, but because the repair is done by the server, you set server system variables instead of myisamchk variables. Also, in addition to setting memory-allocation variables, increasing the myisam_max_sort_file_size system variable increases the likelihood that the repair will use the faster filesort method and avoid the slower repair by key cache method. Set the variable to the maximum file size for your system, after checking to be sure that there is enough free space to hold a copy of the table files. The free space must be available in the file system containing the original table files.

Suppose that a myisamchk table-repair operation is done using the following options to set its memory-allocation variables:

```
--key_buffer_size=128M --myisam_sort_buffer_size=256M
```
Optimizing for MEMORY Tables

--read_buffer_size=64M --write_buffer_size=64M

Some of those `myisamchk` variables correspond to server system variables:

<table>
<thead>
<tr>
<th><code>myisamchk</code> Variable</th>
<th>System Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>key_buffer_size</code></td>
<td><code>key_buffer_size</code></td>
</tr>
<tr>
<td><code>myisam_sort_buffer_size</code></td>
<td><code>myisam_sort_buffer_size</code></td>
</tr>
<tr>
<td><code>read_buffer_size</code></td>
<td><code>read_buffer_size</code></td>
</tr>
<tr>
<td><code>write_buffer_size</code></td>
<td><code>none</code></td>
</tr>
</tbody>
</table>

Each of the server system variables can be set at runtime, and some of them (`myisam_sort_buffer_size, read_buffer_size`) have a session value in addition to a global value. Setting a session value limits the effect of the change to your current session and does not affect other users. Changing a global-only variable (`key_buffer_size, myisam_max_sort_file_size`) affects other users as well. For `key_buffer_size`, you must take into account that the buffer is shared with those users. For example, if you set the `myisamchk key_buffer_size` variable to 128MB, you could set the corresponding `key_buffer_size` system variable larger than that (if it is not already set larger), to permit key buffer use by activity in other sessions. However, changing the global key buffer size invalidates the buffer, causing increased disk I/O and slowdown for other sessions. An alternative that avoids this problem is to use a separate key cache, assign to it the indexes from the table to be repaired, and deallocate it when the repair is complete. See Section 8.10.2.2, “Multiple Key Caches”.

Based on the preceding remarks, a `REPAIR TABLE` operation can be done as follows to use settings similar to the `myisamchk` command. Here a separate 128MB key buffer is allocated and the file system is assumed to permit a file size of at least 100GB.

```
SET SESSION myisam_sort_buffer_size = 256*1024*1024;
SET SESSION read_buffer_size = 64*1024*1024;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
SET GLOBAL repair_cache.key_buffer_size = 128*1024*1024;
CACHE INDEX `tbl_name` IN repair_cache;
LOAD INDEX INTO CACHE `tbl_name`;
REPAIR TABLE `tbl_name`;
SET GLOBAL repair_cache.key_buffer_size = 0;
```

If you intend to change a global variable but want to do so only for the duration of a `REPAIR TABLE` operation to minimally affect other users, save its value in a user variable and restore it afterward. For example:

```
SET @old_myisam_sort_buffer_size = @@GLOBAL.myisam_max_sort_file_size;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
REPAIR TABLE `tbl_name`;
SET GLOBAL myisam_max_sort_file_size = @old_myisam_max_sort_file_size;
```

The system variables that affect `REPAIR TABLE` can be set globally at server startup if you want the values to be in effect by default. For example, add these lines to the server `my.cnf` file:

```
[mysqld]
myisam_sort_buffer_size=256M
key_buffer_size=1G
myisam_max_sort_file_size=100G
```

These settings do not include `read_buffer_size`. Setting `read_buffer_size` globally to a large value does so for all sessions and can cause performance to suffer due to excessive memory allocation for a server with many simultaneous sessions.

8.7 Optimizing for MEMORY Tables
Consider using MEMORY tables for noncritical data that is accessed often, and is read-only or rarely updated. Benchmark your application against equivalent InnoDB or MyISAM tables under a realistic workload, to confirm that any additional performance is worth the risk of losing data, or the overhead of copying data from a disk-based table at application start.

For best performance with MEMORY tables, examine the kinds of queries against each table, and specify the type to use for each associated index, either a B-tree index or a hash index. On the CREATE INDEX statement, use the clause USING BTREE or USING HASH. B-tree indexes are fast for queries that do greater-than or less-than comparisons through operators such as > or BETWEEN. Hash indexes are only fast for queries that look up single values through the = operator, or a restricted set of values through the IN operator. For why USING BTREE is often a better choice than the default USING HASH, see Section 8.2.1.16, “Avoiding Full Table Scans”. For implementation details of the different types of MEMORY indexes, see Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

8.8 Understanding the Query Execution Plan

Depending on the details of your tables, columns, indexes, and the conditions in your WHERE clause, the MySQL optimizer considers many techniques to efficiently perform the lookups involved in an SQL query. A query on a huge table can be performed without reading all the rows; a join involving several tables can be performed without comparing every combination of rows. The set of operations that the optimizer chooses to perform the most efficient query is called the “query execution plan”, also known as the EXPLAIN plan. Your goals are to recognize the aspects of the EXPLAIN plan that indicate a query is optimized well, and to learn the SQL syntax and indexing techniques to improve the plan if you see some inefficient operations.

8.8.1 Optimizing Queries with EXPLAIN

The EXPLAIN statement provides information about how MySQL executes statements:

• When you precede a SELECT statement with the keyword EXPLAIN, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using EXPLAIN to obtain execution plan information, see Section 8.8.2, “EXPLAIN Output Format”.

• EXPLAIN EXTENDED produces additional execution plan information that can be displayed using SHOW WARNINGS. See Section 8.8.3, “Extended EXPLAIN Output Format”.

• EXPLAIN PARTITIONS is useful for examining queries involving partitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

With the help of EXPLAIN, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use EXPLAIN to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a SELECT statement, begin the statement with SELECT STRAIGHT_JOIN rather than just SELECT. (See Section 13.2.9, “SELECT Statement”.)

If you have a problem with indexes not being used when you believe that they should be, run ANALYZE TABLE to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, “ANALYZE TABLE Statement”.

Note

EXPLAIN can also be used to obtain information about the columns in a table. EXPLAIN tbl_name is synonymous with DESCRIBE tbl_name and SHOW COLUMNS FROM tbl_name. For more information, see Section 13.8.1, “DESCRIBE Statement”, and Section 13.7.5.6, “SHOW COLUMNS Statement”.

959
8.8.2 EXPLAIN Output Format

The `EXPLAIN` statement provides information about the execution plan for a `SELECT` statement.

`EXPLAIN` returns a row of information for each table used in the `SELECT` statement. It lists the tables in the output in the order that MySQL would read them while processing the statement. MySQL resolves all joins using a nested-loop join method. This means that MySQL reads a row from the first table, and then finds a matching row in the second table, the third table, and so on. When all tables are processed, MySQL outputs the selected columns and backtracks through the table list until a table is found for which there are more matching rows. The next row is read from this table and the process continues with the next table.

When the `EXTENDED` keyword is used, `EXPLAIN` produces extra information that can be viewed by issuing a `SHOW WARNINGS` statement following the `EXPLAIN` statement. `EXPLAIN EXTENDED` also displays the `filtered` column. See Section 8.8.3, "Extended EXPLAIN Output Format".

**Note**
You cannot use the `EXTENDED` and `PARTITIONS` keywords together in the same `EXPLAIN` statement.

**Note**
MySQL Workbench has a Visual Explain capability that provides a visual representation of `EXPLAIN` output. See Tutorial: Using Explain to Improve Query Performance.

- EXPLAIN Output Columns
- EXPLAIN Join Types
- EXPLAIN Extra Information
- EXPLAIN Output Interpretation

### EXPLAIN Output Columns

This section describes the output columns produced by `EXPLAIN`. Later sections provide additional information about the `type` and `Extra` columns.

Each output row from `EXPLAIN` provides information about one table. Each row contains the values summarized in Table 8.1, "EXPLAIN Output Columns", and described in more detail following the table.

<table>
<thead>
<tr>
<th>Column</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>The <code>SELECT</code> identifier</td>
</tr>
<tr>
<td><code>select_type</code></td>
<td>The <code>SELECT</code> type</td>
</tr>
<tr>
<td>table</td>
<td>The table for the output row</td>
</tr>
<tr>
<td>partitions</td>
<td>The matching partitions</td>
</tr>
<tr>
<td>type</td>
<td>The join type</td>
</tr>
<tr>
<td>possible_keys</td>
<td>The possible indexes to choose</td>
</tr>
<tr>
<td>key</td>
<td>The index actually chosen</td>
</tr>
<tr>
<td>key_len</td>
<td>The length of the chosen key</td>
</tr>
</tbody>
</table>
EXPLAIN Output Format

<table>
<thead>
<tr>
<th>Column</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ref</td>
<td>The columns compared to the index</td>
</tr>
<tr>
<td>rows</td>
<td>Estimate of rows to be examined</td>
</tr>
<tr>
<td>filtered</td>
<td>Percentage of rows filtered by table condition</td>
</tr>
<tr>
<td>Extra</td>
<td>Additional information</td>
</tr>
</tbody>
</table>

- **id**

The SELECT identifier. This is the sequential number of the SELECT within the query. The value can be NULL if the row refers to the union result of other rows. In this case, the table column shows a value like \(<\text{union}M,N>\) to indicate that the row refers to the union of the rows with id values of \(M\) and \(N\).

- **select_type**

The type of SELECT, which can be any of those shown in the following table.

<table>
<thead>
<tr>
<th>select_type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPLE</td>
<td>Simple SELECT (not using UNION or subqueries)</td>
</tr>
<tr>
<td>PRIMARY</td>
<td>Outermost SELECT</td>
</tr>
<tr>
<td>UNION</td>
<td>Second or later SELECT statement in a UNION</td>
</tr>
<tr>
<td>DEPENDENT UNION</td>
<td>Second or later SELECT statement in a UNION, dependent on outer query</td>
</tr>
<tr>
<td>UNION RESULT</td>
<td>Result of a UNION.</td>
</tr>
<tr>
<td>SUBQUERY</td>
<td>First SELECT in subquery</td>
</tr>
<tr>
<td>DEPENDENT SUBQUERY</td>
<td>First SELECT in subquery, dependent on outer query</td>
</tr>
<tr>
<td>DERIVED</td>
<td>Derived table</td>
</tr>
<tr>
<td>UNCACHEABLE SUBQUERY</td>
<td>A subquery for which the result cannot be cached and must be re-evaluated for each row of the outer query</td>
</tr>
<tr>
<td>UNCACHEABLE UNION</td>
<td>The second or later select in a UNION that belongs to an uncacheable subquery (see UNCACHEABLE SUBQUERY)</td>
</tr>
</tbody>
</table>

DEPENDENT typically signifies the use of a correlated subquery. See Section 13.2.10.7, "Correlated Subqueries".

DEPENDENT SUBQUERY evaluation differs from UNCACHEABLE SUBQUERY evaluation. For DEPENDENT SUBQUERY, the subquery is re-evaluated only once for each set of different values of the variables from its outer context. For UNCACHEABLE SUBQUERY, the subquery is re-evaluated for each row of the outer context.

Cacheability of subqueries differs from caching of query results in the query cache (which is described in Section 8.10.3.1, "How the Query Cache Operates"). Subquery caching occurs during query execution, whereas the query cache is used to store results only after query execution finishes.

- **table**

The name of the table to which the row of output refers. This can also be one of the following values:

- \(<\text{union}M,N>\): The row refers to the union of the rows with id values of \(M\) and \(N\).
- \(<\text{derived}N>\): The row refers to the derived table result for the row with an id value of \(N\). A derived table may result, for example, from a subquery in the FROM clause.
EXPLAIN Output Format

- **partitions**
  The partitions from which records would be matched by the query. This column is displayed only if the `PARTITIONS` keyword is used. The value is `NULL` for nonpartitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

- **type**
  The join type. For descriptions of the different types, see EXPLAIN Join Types.

- **possible_keys**
  The `possible_keys` column indicates the indexes from which MySQL can choose to find the rows in this table. Note that this column is totally independent of the order of the tables as displayed in the output from EXPLAIN. That means that some of the keys in `possible_keys` might not be usable in practice with the generated table order.

  If this column is `NULL`, there are no relevant indexes. In this case, you may be able to improve the performance of your query by examining the `WHERE` clause to check whether it refers to some column or columns that would be suitable for indexing. If so, create an appropriate index and check the query with EXPLAIN again. See Section 13.1.7, “ALTER TABLE Statement”.

  To see what indexes a table has, use `SHOW INDEX FROM tbl_name`.

- **key**
  The `key` column indicates the key (index) that MySQL actually decided to use. If MySQL decides to use one of the `possible_keys` indexes to look up rows, that index is listed as the key value.

  It is possible that `key` will name an index that is not present in the `possible_keys` value. This can happen if none of the `possible_keys` indexes are suitable for looking up rows, but all the columns selected by the query are columns of some other index. That is, the named index covers the selected columns, so although it is not used to determine which rows to retrieve, an index scan is more efficient than a data row scan.

  For InnoDB, a secondary index might cover the selected columns even if the query also selects the primary key because InnoDB stores the primary key value with each secondary index. If `key` is `NULL`, MySQL found no index to use for executing the query more efficiently.

  To force MySQL to use or ignore an index listed in the `possible_keys` column, use `FORCE INDEX`, `USE INDEX`, or `IGNORE INDEX` in your query. See Section 8.9.3, “Index Hints”.

  For MyISAM and NDB tables, running `ANALYZE TABLE` helps the optimizer choose better indexes. For NDB tables, this also improves performance of distributed pushed-down joins. For MyISAM tables, `myisamchk --analyze` does the same as `ANALYZE TABLE`. See Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

- **key_len**
  The `key_len` column indicates the length of the key that MySQL decided to use. The value of `key_len` enables you to determine how many parts of a multiple-part key MySQL actually uses. If the `key` column says `NULL`, the `len_len` column also says `NULL`.

  Due to the key storage format, the key length is one greater for a column that can be `NULL` than for a NOT NULL column.

- **ref**
EXPLAIN Output Format

The **ref** column shows which columns or constants are compared to the index named in the **key** column to select rows from the table.

• **rows**

The **rows** column indicates the number of rows MySQL believes it must examine to execute the query.

For InnoDB tables, this number is an estimate, and may not always be exact.

• **filtered**

The **filtered** column indicates an estimated percentage of table rows that will be filtered by the table condition. The maximum value is 100, which means no filtering of rows occurred. Values decreasing from 100 indicate increasing amounts of filtering. **rows** shows the estimated number of rows examined and **rows × filtered** shows the number of rows that will be joined with the following table. For example, if **rows** is 1000 and **filtered** is 50.00 (50%), the number of rows to be joined with the following table is 1000 × 50% = 500. This column is displayed if you use **EXPLAIN EXTENDED**.

• **Extra**

This column contains additional information about how MySQL resolves the query. For descriptions of the different values, see **EXPLAIN Extra Information**.

EXPLAIN Join Types

The **type** column of **EXPLAIN** output describes how tables are joined. The following list describes the join types, ordered from the best type to the worst:

• **system**

The table has only one row (= system table). This is a special case of the **const** join type.

• **const**

The table has at most one matching row, which is read at the start of the query. Because there is only one row, values from the column in this row can be regarded as constants by the rest of the optimizer. **const** tables are very fast because they are read only once.

**const** is used when you compare all parts of a **PRIMARY KEY** or **UNIQUE** index to constant values. In the following queries, **tbl_name** can be used as a **const** table:

```
SELECT * FROM tbl_name WHERE primary_key=1;
SELECT * FROM tbl_name WHERE primary_key_part1=1 AND primary_key_part2=2;
```

• **eq_ref**

One row is read from this table for each combination of rows from the previous tables. Other than the **system** and **const** types, this is the best possible join type. It is used when all parts of an index are used by the join and the index is a **PRIMARY KEY** or **UNIQUE NOT NULL** index.

**eq_ref** can be used for indexed columns that are compared using the **=** operator. The comparison value can be a constant or an expression that uses columns from tables that are read before this table. In the following examples, MySQL can use an **eq_ref** join to process **ref_table**:

```
SELECT * FROM ref_table,other_table
```
WHERE ref_table.key_column = other_table.column;

SELECT * FROM ref_table, other_table
WHERE ref_table.key_column_part1 = other_table.column
AND ref_table.key_column_part2 = 1;

• **ref**

All rows with matching index values are read from this table for each combination of rows from the previous tables. **ref** is used if the join uses only a leftmost prefix of the key or if the key is not a **PRIMARY KEY** or **UNIQUE** index (in other words, if the join cannot select a single row based on the key value). If the key that is used matches only a few rows, this is a good join type.

**ref** can be used for indexed columns that are compared using the = or <=> operator. In the following examples, MySQL can use a **ref** join to process **ref_table**:

```sql
SELECT * FROM ref_table WHERE key_column = expr;
SELECT * FROM ref_table, other_table
WHERE ref_table.key_column = other_table.column;
SELECT * FROM ref_table, other_table
WHERE ref_table.key_column_part1 = other_table.column
AND ref_table.key_column_part2 = 1;
```

• **fulltext**

The join is performed using a **FULLTEXT** index.

• **ref_or_null**

This join type is like **ref**, but with the addition that MySQL does an extra search for rows that contain NULL values. This join type optimization is used most often in resolving subqueries. In the following examples, MySQL can use a **ref_or_null** join to process **ref_table**:

```sql
SELECT * FROM ref_table WHERE key_column = expr OR key_column IS NULL;
```

See Section 8.2.1.9, “IS NULL Optimization”.

• **index_merge**

This join type indicates that the Index Merge optimization is used. In this case, the **key** column in the output row contains a list of indexes used, and **key_len** contains a list of the longest key parts for the indexes used. For more information, see Section 8.2.1.3, “Index Merge Optimization”.

• **unique_subquery**

This type replaces **eq_ref** for some **IN** subqueries of the following form:

```
value IN (SELECT primary_key FROM single_table WHERE some_expr)
```

**unique_subquery** is just an index lookup function that replaces the subquery completely for better efficiency.

• **index_subquery**

This join type is similar to **unique_subquery**. It replaces **IN** subqueries, but it works for nonunique indexes in subqueries of the following form:

```
value IN (SELECT key_column FROM single_table WHERE some_expr)
```


**EXPLAIN Output Format**

- **range**

  Only rows that are in a given range are retrieved, using an index to select the rows. The `key` column in the output row indicates which index is used. The `key_len` contains the longest key part that was used. The `ref` column is **NULL** for this type.

  `range` can be used when a key column is compared to a constant using any of the `=, <>, >, >=, <, <=, IS NULL, <=>, BETWEEN, LIKE, or IN()` operators:

  ```sql
  SELECT * FROM tbl_name
  WHERE key_column = 10;
  
  SELECT * FROM tbl_name
  WHERE key_column BETWEEN 10 and 20;
  
  SELECT * FROM tbl_name
  WHERE key_column IN (10,20,30);
  
  SELECT * FROM tbl_name
  WHERE key_part1 = 10 AND key_part2 IN (10,20,30);
  ```

- **index**

  The `index` join type is the same as **ALL**, except that the index tree is scanned. This occurs two ways:

  - If the index is a covering index for the queries and can be used to satisfy all data required from the table, only the index tree is scanned. In this case, the `Extra` column says `Using index`. An index-only scan usually is faster than **ALL** because the size of the index usually is smaller than the table data.

  - A full table scan is performed using reads from the index to look up data rows in index order. `Uses index` does not appear in the `Extra` column.

  MySQL can use this join type when the query uses only columns that are part of a single index.

- **ALL**

  A full table scan is done for each combination of rows from the previous tables. This is normally not good if the table is the first table not marked `const`, and usually very bad in all other cases. Normally, you can avoid **ALL** by adding indexes that enable row retrieval from the table based on constant values or column values from earlier tables.

**EXPLAIN Extra Information**

The `Extra` column of **EXPLAIN** output contains additional information about how MySQL resolves the query. The following list explains the values that can appear in this column. If you want to make your queries as fast as possible, look out for `Extra` values of `Using filesort` and `Using temporary`.

- **Child of 'table' pushed join@1**

  This table is referenced as the child of `table` in a join that can be pushed down to the NDB kernel. Applies only in MySQL NDB Cluster 7.2 and later, when pushed-down joins are enabled. See the description of the `ndb_join_pushdown` server system variable for more information and examples.

- **const row not found**

  For a query such as `SELECT ... FROM tbl_name`, the table was empty.

- **Distinct**
MySQL is looking for distinct values, so it stops searching for more rows for the current row combination after it has found the first matching row.

- **Full scan on NULL key**

  This occurs for subquery optimization as a fallback strategy when the optimizer cannot use an index-lookup access method.

- **Impossible HAVING**

  The `HAVING` clause is always false and cannot select any rows.

- **Impossible WHERE**

  The `WHERE` clause is always false and cannot select any rows.

- **Impossible WHERE noticed after reading const tables**

  MySQL has read all `const` (and `system`) tables and notice that the `WHERE` clause is always false.

- **No matching min/max row**

  No row satisfies the condition for a query such as `SELECT MIN(...) FROM ... WHERE condition`.

- **No matching row in const table**

  For a query with a join, there was an empty table or a table with no rows satisfying a unique index condition.

- **No tables used**

  The query has no `FROM` clause, or has a `FROM DUAL` clause.

- **Not exists**

  MySQL was able to do a `LEFT JOIN` optimization on the query and does not examine more rows in this table for the previous row combination after it finds one row that matches the `LEFT JOIN` criteria. Here is an example of the type of query that can be optimized this way:

  ```sql
  SELECT * FROM t1 LEFT JOIN t2 ON t1.id=t2.id
  WHERE t2.id IS NULL;
  ```

  Assume that `t2.id` is defined as `NOT NULL`. In this case, MySQL scans `t1` and looks up the rows in `t2` using the values of `t1.id`. If MySQL finds a matching row in `t2`, it knows that `t2.id` can never be `NULL`, and does not scan through the rest of the rows in `t2` that have the same `id` value. In other words, for each row in `t1`, MySQL needs to do only a single lookup in `t2`, regardless of how many rows actually match in `t2`.

- **Range checked for each record (index map: N)**

  MySQL found no good index to use, but found that some of indexes might be used after column values from preceding tables are known. For each row combination in the preceding tables, MySQL checks whether it is possible to use a `range` or `index_merge` access method to retrieve rows. This is not very fast, but is faster than performing a join with no index at all. The applicability criteria are as described
in Section 8.2.1.2, “Range Optimization”, and Section 8.2.1.3, “Index Merge Optimization”, with the exception that all column values for the preceding table are known and considered to be constants.

Indexes are numbered beginning with 1, in the same order as shown by \texttt{SHOW INDEX} for the table. The index map value $N$ is a bitmask value that indicates which indexes are candidates. For example, a value of \texttt{0x19} (binary 11001) means that indexes 1, 4, and 5 will be considered.

- **Scanned $N$ databases**

  This indicates how many directory scans the server performs when processing a query for \texttt{INFORMATION_SCHEMA} tables, as described in Section 8.2.3, “Optimizing \texttt{INFORMATION_SCHEMA} Queries”. The value of $N$ can be 0, 1, or \texttt{all}.

- **Select tables optimized away**

  The optimizer determined 1) that at most one row should be returned, and 2) that to produce this row, a deterministic set of rows must be read. When the rows to be read can be read during the optimization phase (for example, by reading index rows), there is no need to read any tables during query execution.

  The first condition is fulfilled when the query is implicitly grouped (contains an aggregate function but no \texttt{GROUP BY} clause). The second condition is fulfilled when one row lookup is performed per index used. The number of indexes read determines the number of rows to read.

  Consider the following implicitly grouped query:

  \begin{verbatim}
  SELECT MIN(c1), MIN(c2) FROM t1;
  \end{verbatim}

  Suppose that \texttt{MIN(c1)} can be retrieved by reading one index row and \texttt{MIN(c2)} can be retrieved by reading one row from a different index. That is, for each column \texttt{c1} and \texttt{c2}, there exists an index where the column is the first column of the index. In this case, one row is returned, produced by reading two deterministic rows.

  This \texttt{Extra} value does not occur if the rows to read are not deterministic. Consider this query:

  \begin{verbatim}
  SELECT MIN(c2) FROM t1 WHERE c1 <= 10;
  \end{verbatim}

  Suppose that \texttt{(c1, c2)} is a covering index. Using this index, all rows with \texttt{c1 <= 10} must be scanned to find the minimum \texttt{c2} value. By contrast, consider this query:

  \begin{verbatim}
  SELECT MIN(c2) FROM t1 WHERE c1 = 10;
  \end{verbatim}

  In this case, the first index row with \texttt{c1 = 10} contains the minimum \texttt{c2} value. Only one row must be read to produce the returned row.

  For storage engines that maintain an exact row count per table (such as \texttt{MyISAM}, but not \texttt{InnoDB}), this \texttt{Extra} value can occur for \texttt{COUNT(*)} queries for which the \texttt{WHERE} clause is missing or always true and there is no \texttt{GROUP BY} clause. (This is an instance of an implicitly grouped query where the storage engine influences whether a deterministic number of rows can be read.)

- **Skip\_open\_table, Open\_frm\_only, Open\_full\_table**

  These values indicate file-opening optimizations that apply to queries for \texttt{INFORMATION_SCHEMA} tables, as described in Section 8.2.3, “Optimizing \texttt{INFORMATION_SCHEMA} Queries”.

  - **Skip\_open\_table**: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.

  - **Open\_frm\_only**: Only the table’s \texttt{.frm} file need be opened.
**EXPLAIN Output Format**

- **Open_full_table**: The unoptimized information lookup. The .frm, .MYD, and .MYI files must be opened.

- **unique row not found**
  For a query such as `SELECT ... FROM tbl_name`, no rows satisfy the condition for a UNIQUE index or PRIMARY KEY on the table.

- **Using filesort**
  MySQL must do an extra pass to find out how to retrieve the rows in sorted order. The sort is done by going through all rows according to the join type and storing the sort key and pointer to the row for all rows that match the WHERE clause. The keys then are sorted and the rows are retrieved in sorted order. See Section 8.2.1.10, “ORDER BY Optimization”.

- **Using index**
  The column information is retrieved from the table using only information in the index tree without having to do an additional seek to read the actual row. This strategy can be used when the query uses only columns that are part of a single index.

  For InnoDB tables that have a user-defined clustered index, that index can be used even when Using index is absent from the Extra column. This is the case if type is index and key is PRIMARY.

- **Using index for group-by**
  Similar to the Using index table access method, Using index for group-by indicates that MySQL found an index that can be used to retrieve all columns of a GROUP BY or DISTINCT query without any extra disk access to the actual table. Additionally, the index is used in the most efficient way so that for each group, only a few index entries are read. For details, see Section 8.2.1.11, “GROUP BY Optimization”.

- **Using join buffer**
  Tables from earlier joins are read in portions into the join buffer, and then their rows are used from the buffer to perform the join with the current table.

- **Using sort_union(...), Using union(...), Using intersect(...)**
  These indicate the particular algorithm showing how index scans are merged for the index_merge join type. See Section 8.2.1.3, “Index Merge Optimization”.

- **Using temporary**
  To resolve the query, MySQL needs to create a temporary table to hold the result. This typically happens if the query contains GROUP BY and ORDER BY clauses that list columns differently.

- **Using where**
  A WHERE clause is used to restrict which rows to match against the next table or send to the client. Unless you specifically intend to fetch or examine all rows from the table, you may have something wrong in your query if the Extra value is not Using where and the table join type is ALL or index. Even if you are using an index for all parts of a WHERE clause, you may see Using where if the column can be NULL.
EXPLAIN Output Format

- **Using where with pushed condition**

  This item applies to NDB tables only. It means that NDB Cluster is using the Condition Pushdown optimization to improve the efficiency of a direct comparison between a nonindexed column and a constant. In such cases, the condition is "pushed down" to the cluster's data nodes and is evaluated on all data nodes simultaneously. This eliminates the need to send nonmatching rows over the network, and can speed up such queries by a factor of 5 to 10 times over cases where Condition Pushdown could be but is not used. For more information, see Section 8.2.1.4, “Engine Condition Pushdown Optimization”.

EXPLAIN Output Interpretation

You can get a good indication of how good a join is by taking the product of the values in the rows column of the EXPLAIN output. This should tell you roughly how many rows MySQL must examine to execute the query. If you restrict queries with the max_join_size system variable, this row product also is used to determine which multiple-table SELECT statements to execute and which to abort. See Section 5.1.1, “Configuring the Server”.

The following example shows how a multiple-table join can be optimized progressively based on the information provided by EXPLAIN.

Suppose that you have the SELECT statement shown here and that you plan to examine it using EXPLAIN:

```sql
EXPLAIN SELECT tt.TicketNumber, tt.TimeIn,
    tt.ProjectReference, tt.EstimatedShipDate,
    tt.ActualShipDate, tt.ClientID,
    tt.ServiceCodes, tt.RepetitiveID,
    tt.CurrentProcess, tt.CurrentDPPerson,
    tt.RecordVolume, tt.DPPrinted, et.COUNTRY,
    et_1.COUNTRY, do.CUSTNAME
FROM tt, et, et AS et_1, do
WHERE tt.SubmitTime IS NULL
    AND tt.ActualPC = et.EMPLOYID
    AND tt.AssignedPC = et_1.EMPLOYID
    AND tt.ClientID = do.CUSTNMBR;
```

For this example, make the following assumptions:
- The columns being compared have been declared as follows.

<table>
<thead>
<tr>
<th>Table</th>
<th>Column</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>tt</td>
<td>ActualPC</td>
<td>CHAR(10)</td>
</tr>
<tr>
<td>tt</td>
<td>AssignedPC</td>
<td>CHAR(10)</td>
</tr>
<tr>
<td>tt</td>
<td>ClientID</td>
<td>CHAR(10)</td>
</tr>
<tr>
<td>et</td>
<td>EMPLOYID</td>
<td>CHAR(15)</td>
</tr>
<tr>
<td>do</td>
<td>CUSTNMBR</td>
<td>CHAR(15)</td>
</tr>
</tbody>
</table>

- The tables have the following indexes.

<table>
<thead>
<tr>
<th>Table</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>tt</td>
<td>ActualPC</td>
</tr>
<tr>
<td>tt</td>
<td>AssignedPC</td>
</tr>
<tr>
<td>tt</td>
<td>ClientID</td>
</tr>
<tr>
<td>et</td>
<td>EMPLOYID (primary key)</td>
</tr>
<tr>
<td>do</td>
<td>CUSTNMBR (primary key)</td>
</tr>
</tbody>
</table>
• The \texttt{ActualPC} values are not evenly distributed.

Initially, before any optimizations have been performed, the \texttt{EXPLAIN} statement produces the following information:

<table>
<thead>
<tr>
<th>table type</th>
<th>possible_keys</th>
<th>key</th>
<th>key_len</th>
<th>ref</th>
<th>rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>et</td>
<td>ALL PRIMARY</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>do</td>
<td>ALL PRIMARY</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>2135</td>
<td></td>
</tr>
<tr>
<td>et_1</td>
<td>ALL PRIMARY</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>tt</td>
<td>ALL AssignedPC, ClientID, ActualPC</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>3872</td>
<td>Range checked for each record (index map: 0x23)</td>
</tr>
</tbody>
</table>

Because \texttt{type} is \texttt{ALL} for each table, this output indicates that MySQL is generating a Cartesian product of all the tables; that is, every combination of rows. This takes quite a long time, because the product of the number of rows in each table must be examined. For the case at hand, this product is $74 \times 2135 \times 74 \times 3872 = 45,268,558,720$ rows. If the tables were bigger, you can only imagine how long it would take.

One problem here is that MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, \texttt{VARCHAR} and \texttt{CHAR} are considered the same if they are declared as the same size. \texttt{ActualPC} is declared as \texttt{CHAR(10)} and \texttt{EMPLOYID} is \texttt{CHAR(15)}, so there is a length mismatch.

To fix this disparity between column lengths, use \texttt{ALTER TABLE} to lengthen \texttt{ActualPC} from 10 characters to 15 characters:

```
mysql> ALTER TABLE tt MODIFY ActualPC VARCHAR(15);
```

Now \texttt{ActualPC} and \texttt{EMPLOYID} are both \texttt{VARCHAR(15)}. Executing the \texttt{EXPLAIN} statement again produces this result:

<table>
<thead>
<tr>
<th>table type</th>
<th>possible_keys</th>
<th>key</th>
<th>key_len</th>
<th>ref</th>
<th>rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>et</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>do</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>2135</td>
<td></td>
</tr>
<tr>
<td>et_1</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>tt</td>
<td>AssignedPC, ClientID, ActualPC</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>3872</td>
<td>Range checked for each record (index map: 0x1)</td>
</tr>
</tbody>
</table>

This is not perfect, but is much better: The product of the \texttt{rows} values is less by a factor of 74. This version executes in a couple of seconds.

A second alteration can be made to eliminate the column length mismatches for the \texttt{AssignedPC = EMPLOYID} and \texttt{ClientID = CUSTNMBR} comparisons:

```
mysql> ALTER TABLE tt MODIFY AssignedPC VARCHAR(15),
       MODIFY ClientID VARCHAR(15);
```

After that modification, \texttt{EXPLAIN} produces the output shown here:
At this point, the query is optimized almost as well as possible. The remaining problem is that, by default, MySQL assumes that values in the `tt.ActualPC` column are evenly distributed, and that is not the case for the `tt` table. Fortunately, it is easy to tell MySQL to analyze the key distribution:

```sql
mysql> ANALYZE TABLE tt;
```

With the additional index information, the join is perfect and `EXPLAIN` produces this result:

<table>
<thead>
<tr>
<th>table</th>
<th>type</th>
<th>possible_keys</th>
<th>key</th>
<th>key_len</th>
<th>ref</th>
<th>rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>tt</td>
<td>ALL</td>
<td>AssignedPC</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>3872</td>
<td>Using ClientID, where ActualPC</td>
</tr>
<tr>
<td>et</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>tt.ActualPC</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>et_1</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>tt.AssignedPC</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>do</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>15</td>
<td>tt.ClientID</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The `rows` column in the output from `EXPLAIN` is an educated guess from the MySQL join optimizer. Check whether the numbers are even close to the truth by comparing the `rows` product with the actual number of rows that the query returns. If the numbers are quite different, you might get better performance by using `STRAIGHT_JOIN` in your `SELECT` statement and trying to list the tables in a different order in the `FROM` clause.

It is possible in some cases to execute statements that modify data when `EXPLAIN SELECT` is used with a subquery; for more information, see Section 13.2.10.8, “Derived Tables”.

### 8.8.3 Extended EXPLAIN Output Format

When `EXPLAIN` is used with the `EXTENDED` keyword, the output includes a `filtered` column not otherwise displayed. This column indicates the estimated percentage of table rows that will be filtered by the table condition.

In addition, the statement produces extra (“extended”) information that is not part of `EXPLAIN` output but can be viewed by issuing a `SHOW WARNINGS` statement following `EXPLAIN`. The `Message` value in `SHOW WARNINGS` output displays how the optimizer qualifies table and column names in the `SELECT` statement, what the `SELECT` looks like after the application of rewriting and optimization rules, and possibly other notes about the optimization process.

Here is an example of extended `EXPLAIN` output:

```sql
mysql> EXPLAIN EXTENDED
    
    SELECT t1.a, t1.a IN (SELECT t2.a FROM t2) FROM t1
```

```
*************************** 1. row ***************************
<table>
<thead>
<tr>
<th>id: 1</th>
<th>select_type: PRIMARY</th>
<th>table: t1</th>
<th>type: index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>possible_keys: NULL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>key: PRIMARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>key_len: 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ref: NULL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rows: 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>filtered: 100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extra: Using index</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*************************** 2. row ***************************
<table>
<thead>
<tr>
<th>id: 2</th>
<th>select_type: DEPENDENT SUBQUERY</th>
<th>table: t2</th>
<th>type: index_subquery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>possible_keys: a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>key: a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>key_len: 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ref: func</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
Because the statement displayed by `SHOW WARNINGS` may contain special markers to provide information about query rewriting or optimizer actions, the statement is not necessarily valid SQL and is not intended to be executed. The output may also include rows with `Message` values that provide additional non-SQL explanatory notes about actions taken by the optimizer.

The following list describes special markers that can appear in the extended output displayed by `SHOW WARNINGS`:

- `<cache>(expr)`
  The expression (such as a scalar subquery) is executed once and the resulting value is saved in memory for later use.

- `<exists>(query fragment)`
  The subquery predicate is converted to an `EXISTS` predicate and the subquery is transformed so that it can be used together with the `EXISTS` predicate.

- `<in_optimizer>(query fragment)`
  This is an internal optimizer object with no user significance.

- `<index_lookup>(query fragment)`
  The query fragment is processed using an index lookup to find qualifying rows.

- `<is_not_null_test>(expr)`
  A test to verify that the expression does not evaluate to `NULL`.

- `<primary_index_lookup>(query fragment)`
  The query fragment is processed using a primary key lookup to find qualifying rows.

- `<ref_null_helper>(expr)`
  This is an internal optimizer object with no user significance.

When some tables are of `const` or `system` type, expressions involving columns from these tables are evaluated early by the optimizer and are not part of the displayed statement. However, with `FORMAT=JSON`, some `const` table accesses are displayed as a `ref` access that uses a `const` value.

### 8.8.4 Estimating Query Performance
In most cases, you can estimate query performance by counting disk seeks. For small tables, you can usually find a row in one disk seek (because the index is probably cached). For bigger tables, you can estimate that, using B-tree indexes, you need this many seeks to find a row:

$$\log(\frac{\text{row} \times \text{count}}{\log(\frac{\text{index} \times \text{block} \times \text{length}}{\text{3 } \times \text{2}})} + 1)$$

In MySQL, an index block is usually 1,024 bytes and the data pointer is usually four bytes. For a 500,000-row table with a key value length of three bytes (the size of MEDIUMINT), the formula indicates

$$\log(500,000)/\log(1024/3*2/(3+4)) + 1 = 4$$

seeks.

This index would require storage of about 500,000 * 7 * 3/2 = 5.2MB (assuming a typical index buffer fill ratio of 2/3), so you probably have much of the index in memory and so need only one or two calls to read data to find the row.

For writes, however, you need four seek requests to find where to place a new index value and normally two seeks to update the index and write the row.

The preceding discussion does not mean that your application performance slowly degenerates by log N. As long as everything is cached by the OS or the MySQL server, things become only marginally slower as the table gets bigger. After the data gets too big to be cached, things start to go much slower until your applications are bound only by disk seeks (which increase by log N). To avoid this, increase the key cache size as the data grows. For MyISAM tables, the key cache size is controlled by the key_buffer_size system variable. See Section 5.1.1, “Configuring the Server”.

### 8.9 Controlling the Query Optimizer

MySQL provides optimizer control through system variables that affect how query plans are evaluated, switchable optimizations, and index hints.

#### 8.9.1 Controlling Query Plan Evaluation

The task of the query optimizer is to find an optimal plan for executing an SQL query. Because the difference in performance between “good” and “bad” plans can be orders of magnitude (that is, seconds versus hours or even days), most query optimizers, including that of MySQL, perform a more or less exhaustive search for an optimal plan among all possible query evaluation plans. For join queries, the number of possible plans investigated by the MySQL optimizer grows exponentially with the number of tables referenced in a query. For small numbers of tables (typically less than 7 to 10) this is not a problem. However, when larger queries are submitted, the time spent in query optimization may easily become the major bottleneck in the server's performance.

A more flexible method for query optimization enables the user to control how exhaustive the optimizer is in its search for an optimal query evaluation plan. The general idea is that the fewer plans that are investigated by the optimizer, the less time it spends in compiling a query. On the other hand, because the optimizer skips some plans, it may miss finding an optimal plan.

The behavior of the optimizer with respect to the number of plans it evaluates can be controlled using two system variables:

- The optimizer_prune_level variable tells the optimizer to skip certain plans based on estimates of the number of rows accessed for each table. Our experience shows that this kind of “educated guess” rarely misses optimal plans, and may dramatically reduce query compilation times. That is why this option is on (optimizer_prune_level=1) by default. However, if you believe that the optimizer missed a better query plan, this option can be switched off (optimizer_prune_level=0) with the risk that query compilation may take much longer. Note that, even with the use of this heuristic, the optimizer still explores a roughly exponential number of plans.
• The `optimizer_search_depth` variable tells how far into the “future” of each incomplete plan the optimizer should look to evaluate whether it should be expanded further. Smaller values of `optimizer_search_depth` may result in orders of magnitude smaller query compilation times. For example, queries with 12, 13, or more tables may easily require hours and even days to compile if `optimizer_search_depth` is close to the number of tables in the query. At the same time, if compiled with `optimizer_search_depth` equal to 3 or 4, the optimizer may compile in less than a minute for the same query. If you are unsure of what a reasonable value is for `optimizer_search_depth`, this variable can be set to 0 to tell the optimizer to determine the value automatically.

8.9.2 Switchable Optimizations

The `optimizer_switch` system variable enables control over optimizer behavior. Its value is a set of flags, each of which has a value of `on` or `off` to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch
+---------------------------+
| @@optimizer_switch: index_merge=on,index_merge_union=on,         |
| index_merge_sort_union=on,                                       |
| index_merge_intersection=on,                                     |
| engine_condition_pushdown=on                                      |
+---------------------------+
```

To change the value of `optimizer_switch`, assign a value consisting of a comma-separated list of one or more commands:

```
SET [GLOBAL|SESSION] optimizer_switch='command[,command]...';
```

Each `command` value should have one of the forms shown in the following table.

<table>
<thead>
<tr>
<th>Command Syntax</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>default</td>
<td>Reset every optimization to its default value</td>
</tr>
<tr>
<td>opt_name=default</td>
<td>Set the named optimization to its default value</td>
</tr>
<tr>
<td>opt_name=off</td>
<td>Disable the named optimization</td>
</tr>
<tr>
<td>opt_name=on</td>
<td>Enable the named optimization</td>
</tr>
</tbody>
</table>

The order of the commands in the value does not matter, although the `default` command is executed first if present. Setting an `opt_name` flag to `default` sets it to whichever of `on` or `off` is its default value. Specifying any given `opt_name` more than once in the value is not permitted and causes an error. Any errors in the value cause the assignment to fail with an error, leaving the value of `optimizer_switch` unchanged.

The following list describes the permissible `opt_name` flag names, grouped by optimization strategy:

• Engine Condition Pushdown Flags
  • `engine_condition_pushdown` (default `on`)
    Controls engine condition pushdown.

  For more information, see Section 8.2.1.4, “Engine Condition Pushdown Optimization”.

• Index Merge Flags
**Index Hints**

- **index_merge** *(default on)*
  Controls all Index Merge optimizations.

- **index_merge_intersection** *(default on)*
  Controls the Index Merge Intersection Access optimization.

- **index_merge_sort_union** *(default on)*
  Controls the Index Merge Sort-Union Access optimization.

- **index_merge_union** *(default on)*
  Controls the Index Merge Union Access optimization.

For more information, see Section 8.2.1.3, “Index Merge Optimization”.

When you assign a value to `optimizer_switch`, flags that are not mentioned keep their current values. This makes it possible to enable or disable specific optimizer behaviors in a single statement without affecting other behaviors. The statement does not depend on what other optimizer flags exist and what their values are. Suppose that all Index Merge optimizations are enabled:

```
mysql> SELECT @@optimizer_switch
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                   index_merge_sort_union=on,
                   index_merge_intersection=on,
                   engine_condition_pushdown=on
```

If the server is using the Index Merge Union or Index Merge Sort-Union access methods for certain queries and you want to check whether the optimizer will perform better without them, set the variable value like this:

```
mysql> SET optimizer_switch='index_merge_union=off,index_merge_sort_union=off';

mysql> SELECT @@optimizer_switch
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=off,
                   index_merge_sort_union=off,
                   index_merge_intersection=on,
                   engine_condition_pushdown=on
```

### 8.9.3 Index Hints

Index hints give the optimizer information about how to choose indexes during query processing. Index hints apply only to `SELECT` and `UPDATE` statements.

Index hints are specified following a table name. (For the general syntax for specifying tables in a `SELECT` statement, see Section 13.2.9.2, “JOIN Clause”.) The syntax for referring to an individual table, including index hints, looks like this:

```
tbl_name [[AS] alias] [index_hint_list]

index_hint_list:
  index_hint [index_hint] ...

index_hint:
  USE {INDEX|KEY}
  [FOR {JOIN|ORDER BY|GROUP BY}] {{index_list}}
```
Index Hints

The **USE INDEX** `(index_list)` hint tells MySQL to use only one of the named indexes to find rows in the table. The alternative syntax **IGNORE INDEX** `(index_list)` tells MySQL to not use some particular index or indexes. These hints are useful if **EXPLAIN** shows that MySQL is using the wrong index from the list of possible indexes.

The **FORCE INDEX** hint acts like **USE INDEX** `(index_list)`, with the addition that a table scan is assumed to be very expensive. In other words, a table scan is used only if there is no way to use one of the named indexes to find rows in the table.

Each hint requires index names, not column names. To refer to a primary key, use the name **PRIMARY**. To see the index names for a table, use the **SHOW INDEX** statement or the **INFORMATION_SCHEMA.STATISTICS** table.

An **index_name** value need not be a full index name. It can be an unambiguous prefix of an index name. If a prefix is ambiguous, an error occurs.

Examples:

```sql
SELECT * FROM table1 USE INDEX (col1_index,col2_index) WHERE col1=1 AND col2=2 AND col3=3;
SELECT * FROM table1 IGNORE INDEX (col3_index) WHERE col1=1 AND col2=2 AND col3=3;
```

The syntax for index hints has the following characteristics:

- It is syntactically valid to omit `index_list` for **USE INDEX**, which means “use no indexes.” Omitting `index_list` for **FORCE INDEX** or **IGNORE INDEX** is a syntax error.

- You can specify the scope of an index hint by adding a **FOR** clause to the hint. This provides more fine-grained control over optimizer selection of an execution plan for various phases of query processing. To affect only the indexes used when MySQL decides how to find rows in the table and how to process joins, use **FOR JOIN**. To influence index usage for sorting or grouping rows, use **FOR ORDER BY** or **FOR GROUP BY**.

- You can specify multiple index hints:

  ```sql
  SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX FOR ORDER BY (i2) ORDER BY a;
  ```

  It is not an error to name the same index in several hints (even within the same hint):

  ```sql
  SELECT * FROM t1 USE INDEX (i1) USE INDEX (i1,i1);
  ```

  However, it is an error to mix **USE INDEX** and **FORCE INDEX** for the same table:

  ```sql
  SELECT * FROM t1 USE INDEX FOR JOIN (i1) FORCE INDEX FOR JOIN (i2);
  ```

If an index hint includes no **FOR** clause, the scope of the hint is to apply to all parts of the statement. For example, this hint:

```sql
IGNORE INDEX (i1)
```

is equivalent to this combination of hints:

```sql
IGNORE INDEX FOR JOIN (i1)
```
In MySQL 5.0, hint scope with no `FOR` clause was to apply only to row retrieval. To cause the server to use this older behavior when no `FOR` clause is present, enable the `old` system variable at server startup. Take care about enabling this variable in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

When index hints are processed, they are collected in a single list by type (`USE`, `FORCE`, `IGNORE`) and by scope (`FOR JOIN`, `FOR ORDER BY`, `FOR GROUP BY`). For example:

```sql
SELECT * FROM t1
  USE INDEX () IGNORE INDEX (i2) USE INDEX (i1) USE INDEX (i2);
```

is equivalent to:

```sql
SELECT * FROM t1
  USE INDEX (i1,i2) IGNORE INDEX (i2);
```

The index hints then are applied for each scope in the following order:

1. `USE|FORCE INDEX` is applied if present. (If not, the optimizer-determined set of indexes is used.)
2. `IGNORE INDEX` is applied over the result of the previous step. For example, the following two queries are equivalent:

```sql
SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX (i2) USE INDEX (i2);
SELECT * FROM t1 USE INDEX (i1);
```

For `FULLTEXT` searches, index hints work as follows:

- For natural language mode searches, index hints are silently ignored. For example, `IGNORE INDEX(i1)` is ignored with no warning and the index is still used.

- For boolean mode searches, index hints with `FOR ORDER BY` or `FOR GROUP BY` are silently ignored. Index hints with `FOR JOIN` or no `FOR` modifier are honored. In contrast to how hints apply for non-`FULLTEXT` searches, the hint is used for all phases of query execution (finding rows and retrieval, grouping, and ordering). This is true even if the hint is given for a non-`FULLTEXT` index.

For example, the following two queries are equivalent:

```sql
SELECT * FROM t
  USE INDEX (index1)
  IGNORE INDEX (index1) FOR ORDER BY
  IGNORE INDEX (index1) FOR GROUP BY
  WHERE ... IN BOOLEAN MODE ...

SELECT * FROM t
  USE INDEX (index1)
  WHERE ... IN BOOLEAN MODE ...
```

### 8.10 Buffering and Caching

MySQL uses several strategies that cache information in memory buffers to increase performance. Depending on your database architecture, you balance the size and layout of these areas, to provide the most performance benefit without wasting memory or exceeding available memory. When you set up or resize these memory areas, test the resulting performance using the techniques from Section 8.13, "Measuring Performance (Benchmarking)".
8.10.1 InnoDB Buffer Pool Optimization

InnoDB maintains a storage area called the buffer pool for caching data and indexes in memory. Knowing how the InnoDB buffer pool works, and taking advantage of it to keep frequently accessed data in memory, is an important aspect of MySQL tuning.

For an explanation of the inner workings of the InnoDB buffer pool, an overview of its LRU replacement algorithm, and general configuration information, see Section 14.8.1, "Buffer Pool".

For additional InnoDB buffer pool configuration and tuning information, see these sections:

- Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
- Section 14.11.2.4, “Configuring Buffer Pool Flushing”
- Section 14.11.2.2, "Making the Buffer Pool Scan Resistant"
- Section 14.11.2.1, "Configuring Multiple Buffer Pool Instances"

8.10.2 The MyISAM Key Cache

To minimize disk I/O, the MyISAM storage engine exploits a strategy that is used by many database management systems. It employs a cache mechanism to keep the most frequently accessed table pages in memory:

- For index blocks, a special structure called the key cache (or key buffer) is maintained. The structure contains a number of block buffers where the most-used index blocks are placed.
- For data blocks, MySQL uses no special cache. Instead it relies on the native operating system file system cache.

This section first describes the basic operation of the MyISAM key cache. Then it discusses features that improve key cache performance and that enable you to better control cache operation:

- Multiple sessions can access the cache concurrently.
- You can set up multiple key caches and assign table indexes to specific caches.

To control the size of the key cache, use the key_buffer_size system variable. If this variable is set equal to zero, no key cache is used. The key cache also is not used if the key_buffer_size value is too small to allocate the minimal number of block buffers (8).

When the key cache is not operational, index files are accessed using only the native file system buffering provided by the operating system. (In other words, table index blocks are accessed using the same strategy as that employed for table data blocks.)

An index block is a contiguous unit of access to the MyISAM index files. Usually the size of an index block is equal to the size of nodes of the index B-tree. (Indexes are represented on disk using a B-tree data structure. Nodes at the bottom of the tree are leaf nodes. Nodes above the leaf nodes are nonleaf nodes.)

All block buffers in a key cache structure are the same size. This size can be equal to, greater than, or less than the size of a table index block. Usually one these two values is a multiple of the other.

When data from any table index block must be accessed, the server first checks whether it is available in some block buffer of the key cache. If it is, the server accesses data in the key cache rather than on disk. That is, it reads from the cache or writes into it rather than reading from or writing to disk. Otherwise, the server chooses a cache block buffer containing a different table index block (or blocks) and replaces the
data there by a copy of required table index block. As soon as the new index block is in the cache, the index data can be accessed.

If it happens that a block selected for replacement has been modified, the block is considered “dirty.” In this case, prior to being replaced, its contents are flushed to the table index from which it came.

Usually the server follows an *LRU (Least Recently Used)* strategy: When choosing a block for replacement, it selects the least recently used index block. To make this choice easier, the key cache module maintains all used blocks in a special list (*LRU chain*) ordered by time of use. When a block is accessed, it is the most recently used and is placed at the end of the list. When blocks need to be replaced, blocks at the beginning of the list are the least recently used and become the first candidates for eviction.

The *InnoDB* storage engine also uses an LRU algorithm, to manage its buffer pool. See Section 14.8.1, “Buffer Pool”.

### 8.10.2.1 Shared Key Cache Access

Threads can access key cache buffers simultaneously, subject to the following conditions:

- A buffer that is not being updated can be accessed by multiple sessions.
- A buffer that is being updated causes sessions that need to use it to wait until the update is complete.
- Multiple sessions can initiate requests that result in cache block replacements, as long as they do not interfere with each other (that is, as long as they need different index blocks, and thus cause different cache blocks to be replaced).

Shared access to the key cache enables the server to improve throughput significantly.

### 8.10.2.2 Multiple Key Caches

Shared access to the key cache improves performance but does not eliminate contention among sessions entirely. They still compete for control structures that manage access to the key cache buffers. To reduce key cache access contention further, MySQL also provides multiple key caches. This feature enables you to assign different table indexes to different key caches.

Where there are multiple key caches, the server must know which cache to use when processing queries for a given *MyISAM* table. By default, all *MyISAM* table indexes are cached in the default key cache. To assign table indexes to a specific key cache, use the *CACHE INDEX* statement (see Section 13.7.6.2, “CACHE INDEX Statement”). For example, the following statement assigns indexes from the tables `t1`, `t2`, and `t3` to the key cache named `hot_cache`:

```
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
```

<table>
<thead>
<tr>
<th>Table</th>
<th>Op</th>
<th>Msg_type</th>
<th>Msg_text</th>
</tr>
</thead>
<tbody>
<tr>
<td>test.t1</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
<tr>
<td>test.t2</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
<tr>
<td>test.t3</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
</tbody>
</table>

The key cache referred to in a *CACHE INDEX* statement can be created by setting its size with a *SET GLOBAL* parameter setting statement or by using server startup options. For example:

```
mysql> SET GLOBAL keycache1.key_buffer_size=128*1024;
```

To destroy a key cache, set its size to zero:
The MyISAM Key Cache

You cannot destroy the default key cache. Any attempt to do this is ignored:

```sql
mysql> SET GLOBAL keycache1.key_buffer_size=0;
You cannot destroy the default key cache. Any attempt to do this is ignored:
mysql> SET GLOBAL key_buffer_size = 0;
mysql> SHOW VARIABLES LIKE 'key_buffer_size';
+-----------------+---------+
| Variable_name   | Value   |
|-----------------+---------+
| key_buffer_size | 8384512 |
+-----------------+---------+
```

Key cache variables are structured system variables that have a name and components. For `keycache1.key_buffer_size`, `keycache1` is the cache variable name and `key_buffer_size` is the cache component. See Section 5.1.8.3, “Structured System Variables”, for a description of the syntax used for referring to structured key cache system variables.

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it are reassigned to the default key cache.

For a busy server, you can use a strategy that involves three key caches:

- A “hot” key cache that takes up 20% of the space allocated for all key caches. Use this for tables that are heavily used for searches but that are not updated.
- A “cold” key cache that takes up 20% of the space allocated for all key caches. Use this cache for medium-sized, intensively modified tables, such as temporary tables.
- A “warm” key cache that takes up 60% of the key cache space. Employ this as the default key cache, to be used by default for all other tables.

One reason the use of three key caches is beneficial is that access to one key cache structure does not block access to the others. Statements that access tables assigned to one cache do not compete with statements that access tables assigned to another cache. Performance gains occur for other reasons as well:

- The hot cache is used only for retrieval queries, so its contents are never modified. Consequently, whenever an index block needs to be pulled in from disk, the contents of the cache block chosen for replacement need not be flushed first.
- For an index assigned to the hot cache, if there are no queries requiring an index scan, there is a high probability that the index blocks corresponding to nonleaf nodes of the index B-tree remain in the cache.
- An update operation most frequently executed for temporary tables is performed much faster when the updated node is in the cache and need not be read from disk first. If the size of the indexes of the temporary tables are comparable with the size of cold key cache, the probability is very high that the updated node is in the cache.

The `CACHE INDEX` statement sets up an association between a table and a key cache, but the association is lost each time the server restarts. If you want the association to take effect each time the server starts, one way to accomplish this is to use an option file: Include variable settings that configure your key caches, and an `init_file` system variable that names a file containing `CACHE INDEX` statements to be executed. For example:

```
key_buffer_size = 4G
hot_cache.key_buffer_size = 2G
cold_cache.key_buffer_size = 2G
init_file=/path/to/data-directory/mysqld_init.sql
```
The statements in `mysqld_init.sql` are executed each time the server starts. The file should contain one SQL statement per line. The following example assigns several tables each to `hot_cache` and `cold_cache`:

```
CACHE INDEX db1.t1, db1.t2, db2.t3 IN hot_cache
CACHE INDEX db1.t4, db2.t5, db2.t6 IN cold_cache
```

### 8.10.2.3 Midpoint Insertion Strategy

By default, the key cache management system uses a simple LRU strategy for choosing key cache blocks to be evicted, but it also supports a more sophisticated method called the **midpoint insertion strategy**.

When using the midpoint insertion strategy, the LRU chain is divided into two parts: a hot sublist and a warm sublist. The division point between two parts is not fixed, but the key cache management system takes care that the warm part is not "too short," always containing at least `key_cache_division_limit` percent of the key cache blocks. `key_cache_division_limit` is a component of structured key cache variables, so its value is a parameter that can be set per cache.

When an index block is read from a table into the key cache, it is placed at the end of the warm sublist. After a certain number of hits (accesses of the block), it is promoted to the hot sublist. At present, the number of hits required to promote a block (3) is the same for all index blocks.

A block promoted into the hot sublist is placed at the end of the list. The block then circulates within this sublist. If the block stays at the beginning of the sublist for a long enough time, it is demoted to the warm sublist. This time is determined by the value of the `key_cache_age_threshold` component of the key cache.

The threshold value prescribes that, for a key cache containing $N$ blocks, the block at the beginning of the hot sublist not accessed within the last $N \times \text{key_cache_age_threshold} / 100$ hits is to be moved to the beginning of the warm sublist. It then becomes the first candidate for eviction, because blocks for replacement always are taken from the beginning of the warm sublist.

The midpoint insertion strategy enables you to keep more-valued blocks always in the cache. If you prefer to use the plain LRU strategy, leave the `key_cache_division_limit` value set to its default of 100.

The midpoint insertion strategy helps to improve performance when execution of a query that requires an index scan effectively pushes out of the cache all the index blocks corresponding to valuable high-level B-tree nodes. To avoid this, you must use a midpoint insertion strategy with the `key_cache_division_limit` set to much less than 100. Then valuable frequently hit nodes are preserved in the hot sublist during an index scan operation as well.

### 8.10.2.4 Index Preloading

If there are enough blocks in a key cache to hold blocks of an entire index, or at least the blocks corresponding to its nonleaf nodes, it makes sense to preload the key cache with index blocks before starting to use it. Preloading enables you to put the table index blocks into a key cache buffer in the most efficient way: by reading the index blocks from disk sequentially.

Without preloading, the blocks are still placed into the key cache as needed by queries. Although the blocks will stay in the cache, because there are enough buffers for all of them, they are fetched from disk in random order, and not sequentially.

To preload an index into a cache, use the `LOAD INDEX INTO CACHE` statement. For example, the following statement preloads nodes (index blocks) of indexes of the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
+---------+--------------+----------+----------+
| Table   | Op           | Msg_type | Msg_text |
```

981
The MySQL Query Cache

<table>
<thead>
<tr>
<th>test.t1</th>
<th>preload_keys</th>
<th>status</th>
<th>OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>test.t2</td>
<td>preload_keys</td>
<td>status</td>
<td>OK</td>
</tr>
</tbody>
</table>

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded. Thus, the statement shown preloads all index blocks from `t1`, but only blocks for the nonleaf nodes from `t2`.

If an index has been assigned to a key cache using a `CACHE INDEX` statement, preloading places index blocks into that cache. Otherwise, the index is loaded into the default key cache.

### 8.10.2.5 Key Cache Block Size

It is possible to specify the size of the block buffers for an individual key cache using the `key_cache_block_size` variable. This permits tuning of the performance of I/O operations for index files.

The best performance for I/O operations is achieved when the size of read buffers is equal to the size of the native operating system I/O buffers. But setting the size of key nodes equal to the size of the I/O buffer does not always ensure the best overall performance. When reading the big leaf nodes, the server pulls in a lot of unnecessary data, effectively preventing reading other leaf nodes.

To control the size of blocks in the `.MYI` index file of `MyISAM` tables, use the `--myisam-block-size` option at server startup.

### 8.10.2.6 Restructuring a Key Cache

A key cache can be restructured at any time by updating its parameter values. For example:

```sql
mysql> SET GLOBAL cold_cache.key_buffer_size=4*1024*1024;
```

If you assign to either the `key_buffer_size` or `key_cache_block_size` key cache component a value that differs from the component's current value, the server destroys the cache's old structure and creates a new one based on the new values. If the cache contains any dirty blocks, the server saves them to disk before destroying and re-creating the cache. Restructuring does not occur if you change other key cache parameters.

When restructuring a key cache, the server first flushes the contents of any dirty buffers to disk. After that, the cache contents become unavailable. However, restructuring does not block queries that need to use indexes assigned to the cache. Instead, the server directly accesses the table indexes using native file system caching. File system caching is not as efficient as using a key cache, so although queries execute, a slowdown can be anticipated. After the cache has been restructured, it becomes available again for caching indexes assigned to it, and the use of file system caching for the indexes ceases.

### 8.10.3 The MySQL Query Cache

The query cache stores the text of a `SELECT` statement together with the corresponding result that was sent to the client. If an identical statement is received later, the server retrieves the results from the query cache rather than parsing and executing the statement again. The query cache is shared among sessions, so a result set generated by one client can be sent in response to the same query issued by another client.

The query cache can be useful in an environment where you have tables that do not change very often and for which the server receives many identical queries. This is a typical situation for many Web servers that generate many dynamic pages based on database content. For example, when an order form queries a table to display the lists of all US states or all countries in the world, those values can be retrieved from the query cache. Although the values would probably be retrieved from memory in any case (from the InnoDB
buffer pool or MyISAM key cache), using the query cache avoids the overhead of processing the query, deciding whether to use a table scan, and locating the data block for each row.

The query cache always contains current and reliable data. Any insert, update, delete, or other modification to a table causes any relevant entries in the query cache to be flushed.

**Note**
The query cache does not work in an environment where you have multiple mysqld servers updating the same MyISAM tables.

The query cache is used for prepared statements under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.

**Note**
As of MySQL 5.5.23, the query cache is not supported for partitioned tables, and is automatically disabled for queries involving partitioned tables. The query cache cannot be enabled for such queries. (Bug #53775)

Some performance data for the query cache follows. These results were generated by running the MySQL benchmark suite on a Linux Alpha 2×500MHz system with 2GB RAM and a 64MB query cache.

- If all the queries you are performing are simple (such as selecting a row from a table with one row), but still differ so that the queries cannot be cached, the overhead for having the query cache active is 13%. This could be regarded as the worst case scenario. In real life, queries tend to be much more complicated, so the overhead normally is significantly lower.

- Searches for a single row in a single-row table are 238% faster with the query cache than without it. This can be regarded as close to the minimum speedup to be expected for a query that is cached.

To disable the query cache at server startup, set the `query_cache_size` system variable to 0. By disabling the query cache code, there is no noticeable overhead.

The query cache offers the potential for substantial performance improvement, but do not assume that it will do so under all circumstances. With some query cache configurations or server workloads, you might actually see a performance decrease:

- Be cautious about sizing the query cache excessively large, which increases the overhead required to maintain the cache, possibly beyond the benefit of enabling it. Sizes in tens of megabytes are usually beneficial. Sizes in the hundreds of megabytes might not be.

- Server workload has a significant effect on query cache efficiency. A query mix consisting almost entirely of a fixed set of `SELECT` statements is much more likely to benefit from enabling the cache than a mix in which frequent `INSERT` statements cause continual invalidation of results in the cache. In some cases, a workaround is to use the `SQL_NO_CACHE` option to prevent results from even entering the cache for `SELECT` statements that use frequently modified tables. (See Section 8.10.3.2, “Query Cache SELECT Options”.)

To verify that enabling the query cache is beneficial, test the operation of your MySQL server with the cache enabled and disabled. Then retest periodically because query cache efficiency may change as server workload changes.

### 8.10.3.1 How the Query Cache Operates

This section describes how the query cache works when it is operational. Section 8.10.3.3, “Query Cache Configuration”, describes how to control whether it is operational.
Incoming queries are compared to those in the query cache before parsing, so the following two queries are regarded as different by the query cache:

```
SELECT * FROM tbl_name
Select * from tbl_name
```

Queries must be exactly the same (byte for byte) to be seen as identical. In addition, query strings that are identical may be treated as different for other reasons. Queries that use different databases, different protocol versions, or different default character sets are considered different queries and are cached separately.

The cache is not used for queries of the following types:

- Queries that are a subquery of an outer query
- Queries executed within the body of a stored function, trigger, or event

Before a query result is fetched from the query cache, MySQL checks whether the user has `SELECT` privilege for all databases and tables involved. If this is not the case, the cached result is not used.

If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, “Query Cache Status and Maintenance”.

If a table changes, all cached queries that use the table become invalid and are removed from the cache. This includes queries that use `MERGE` tables that map to the changed table. A table can be changed by many types of statements, such as `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, `ALTER TABLE`, `DROP TABLE`, or `DROP DATABASE`.

The query cache also works within transactions when using `InnoDB` tables.

The result from a `SELECT` query on a view is cached.

The query cache works for `SELECT SQL_CALC_FOUND_ROWS ...` queries and stores a value that is returned by a following `SELECT FOUND_ROWS()` query. `FOUND_ROWS()` returns the correct value even if the preceding query was fetched from the cache because the number of found rows is also stored in the cache. The `SELECT FOUND_ROWS()` query itself cannot be cached.

Prepared statements that are issued using the binary protocol using `mysql_stmt_prepare()` and `mysql_stmt_execute()` (see Section 23.7.7, “C API Prepared Statements”), are subject to limitations on caching. Comparison with statements in the query cache is based on the text of the statement after expansion of `?` parameter markers. The statement is compared only with other cached statements that were executed using the binary protocol. That is, for query cache purposes, prepared statements issued using the binary protocol are distinct from prepared statements issued using the text protocol (see Section 13.5, “Prepared Statements”).

A query cannot be cached if it uses any of the following functions:

- `BENCHMARK()`
- `CONNECTION_ID()`
- `CONVERT_TZ()`
- `CURDATE()`
- `CURRENT_DATE()`
- `CURRENT_TIME()`
• CURRENT_TIMESTAMP()
• CURRENT_USER()
• CURTIME()
• DATABASE()
• ENCRYPT() with one parameter
• FOUND_ROWS()
• GET_LOCK()
• IS_FREE_LOCK()
• IS_USED_LOCK()
• LAST_INSERT_ID()
• LOAD_FILE()
• MASTER_POS_WAIT()
• NOW()
• RAND()
• RELEASE_ALL_LOCKS()
• RELEASE_LOCK()
• SLEEP()
• SYSDATE()
• UNIX_TIMESTAMP() with no parameters
• USER()
• UUID()
• UUID_SHORT()

A query also is not cached under these conditions:
• It refers to user-defined functions (UDFs) or stored functions.
• It refers to user variables or local stored program variables.
• It refers to tables in the mysql, INFORMATION_SCHEMA, or performance_schema database.
• (MySQL 5.5.23 and later) It refers to any partitioned tables.
• It is of any of the following forms:

  SELECT ... LOCK IN SHARE MODE
  SELECT ... FOR UPDATE
  SELECT ... INTO OUTFILE ...
  SELECT ... INTO DUMPFILE ...
  SELECT * FROM ... WHERE autoincrement_col IS NULL
The MySQL Query Cache

The last form is not cached because it is used as the ODBC workaround for obtaining the last insert ID value. See the Connector/ODBC section of Chapter 23, Connectors and APIs.

Statements within transactions that use SERIALIZE isolation level also cannot be cached because they use LOCK IN SHARE MODE locking.

- It uses TEMPORARY tables.
- It does not use any tables.
- It generates warnings.
- The user has a column-level privilege for any of the involved tables.

8.10.3.2 Query Cache SELECT Options

Two query cache-related options may be specified in SELECT statements:

- **SQL_CACHE**
  The query result is cached if it is cacheable and the value of the `query_cache_type` system variable is ON or DEMAND.

- **SQL_NO_CACHE**
  The server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the `SQL_NO_CACHE` keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

Examples:

```
SELECT SQL_CACHE id, name FROM customer;
SELECT SQL_NO_CACHE id, name FROM customer;
```

8.10.3.3 Query Cache Configuration

The `have_query_cache` server system variable indicates whether the query cache is available:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>have_query_cache</td>
<td>YES</td>
</tr>
</tbody>
</table>
+------------------+-------+
```

When using a standard MySQL binary, this value is always YES, even if query caching is disabled.

Several other system variables control query cache operation. These can be set in an option file or on the command line when starting `mysqld`. The query cache system variables all have names that begin with `query_cache_`. They are described briefly in Section 5.1.7, "Server System Variables", with additional configuration information given here.

To set the size of the query cache, set the `query_cache_size` system variable. Setting it to 0 disables the query cache. The default size is 0, so the query cache is disabled by default.

To reduce overhead significantly, start the server with `query_cache_type=0` if you will not be using the query cache.
The MySQL Query Cache

Note

When using the Windows Configuration Wizard to install or configure MySQL, the default value for `query_cache_size` will be configured automatically for you based on the different configuration types available. When using the Windows Configuration Wizard, the query cache may be enabled (that is, set to a nonzero value) due to the selected configuration. The query cache is also controlled by the setting of the `query_cache_type` variable. Check the values of these variables as set in your `my.ini` file after configuration has taken place.

When you set `query_cache_size` to a nonzero value, keep in mind that the query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value too small, you'll get a warning, as in this example:

```
mysql> SET GLOBAL query_cache_size = 40000;
Query OK, 0 rows affected, 1 warning (0.00 sec)
```

```
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
    Level: Warning
    Code: 1282
Message: Query cache failed to set size 39936;
         new query cache size is 0
```

```
mysql> SET GLOBAL query_cache_size = 41984;
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SHOW VARIABLES LIKE 'query_cache_size';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| query_cache_size | 41984 |
+------------------+-------+
```

For the query cache to actually be able to hold any query results, its size must be set larger:

```
mysql> SET GLOBAL query_cache_size = 1000000;
Query OK, 0 rows affected (0.04 sec)
```

```
mysql> SHOW VARIABLES LIKE 'query_cache_size';
+------------------+--------+
| Variable_name    | Value  |
+------------------+--------+
| query_cache_size | 999424 |
+------------------+--------+
```

The `query_cache_size` value is aligned to the nearest 1024 byte block. The value reported may therefore be different from the value that you assign.

If the query cache size is greater than 0, the `query_cache_type` variable influences how it works. This variable can be set to the following values:

- A value of `0` or `OFF` prevents caching or retrieval of cached results.
- A value of `1` or `ON` enables caching except of those statements that begin with `SELECT SQL_NO_CACHE`.
- A value of `2` or `DEMAND` causes caching of only those statements that begin with `SELECT SQL_CACHE`.

If `query_cache_size` is 0, you should also set `query_cache_type` variable to 0. In this case, the server does not acquire the query cache mutex at all, which means that the query cache cannot be enabled at runtime and there is reduced overhead in query execution.
Setting the `GLOBAL query_cache_type` value determines query cache behavior for all clients that connect after the change is made. Individual clients can control cache behavior for their own connection by setting the `SESSION query_cache_type` value. For example, a client can disable use of the query cache for its own queries like this:

```sql
mysql> SET SESSION query_cache_type = OFF;
```

If you set `query_cache_type` at server startup (rather than at runtime with a `SET` statement), only the numeric values are permitted.

To control the maximum size of individual query results that can be cached, set the `query_cache_limit` system variable. The default value is 1MB.

Be careful not to set the size of the cache too large. Due to the need for threads to lock the cache during updates, you may see lock contention issues with a very large cache.

```
Note
You can set the maximum size that can be specified for the query cache at runtime with the `SET` statement by using the `--maximum-query_cache_size=32M` option on the command line or in the configuration file.
```

When a query is to be cached, its result (the data sent to the client) is stored in the query cache during result retrieval. Therefore the data usually is not handled in one big chunk. The query cache allocates blocks for storing this data on demand, so when one block is filled, a new block is allocated. Because memory allocation operation is costly (timewise), the query cache allocates blocks with a minimum size given by the `query_cache_min_res_unit` system variable. When a query is executed, the last result block is trimmed to the actual data size so that unused memory is freed. Depending on the types of queries your server executes, you might find it helpful to tune the value of `query_cache_min_res_unit`:

- The default value of `query_cache_min_res_unit` is 4KB. This should be adequate for most cases.
- If you have a lot of queries with small results, the default block size may lead to memory fragmentation, as indicated by a large number of free blocks. Fragmentation can force the query cache to prune (delete) queries from the cache due to lack of memory. In this case, decrease the value of `query_cache_min_res_unit`. The number of free blocks and queries removed due to pruning are given by the values of the `Qcache_free_blocks` and `Qcache_lowmem_prunes` status variables.
- If most of your queries have large results (check the `Qcache_total_blocks` and `Qcache_queries_in_cache` status variables), you can increase performance by increasing `query_cache_min_res_unit`. However, be careful to not make it too large (see the previous item).

### 8.10.3.4 Query Cache Status and Maintenance

To check whether the query cache is present in your MySQL server, use the following statement:

```sql
mysql> SHOW VARIABLES LIKE 'have_query_cache';
```

```plaintext
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
```

You can defragment the query cache to better utilize its memory with the `FLUSH QUERY CACHE` statement. The statement does not remove any queries from the cache.

The `RESET QUERY CACHE` statement removes all query results from the query cache. The `FLUSH TABLES` statement also does this.
To monitor query cache performance, use `SHOW STATUS` to view the cache status variables:

```sql
mysql> SHOW STATUS LIKE 'Qcache%';
+-------------------------+--------+
| Variable_name           | Value  |
+-------------------------+--------+
| Qcache_free_blocks      | 36     |
| Qcache_free_memory      | 138488 |
| Qcache_hits             | 79570  |
| Qcache_inserts          | 27087  |
| Qcache_lowmem_prunes    | 3114   |
| Qcache_not_cached       | 22989  |
| Qcache_queries_in_cache | 415    |
| Qcache_total_blocks     | 912    |
+-------------------------+--------+
```

Descriptions of each of these variables are given in Section 5.1.9, “Server Status Variables”. Some uses for them are described here.

The total number of `SELECT` queries is given by this formula:

```sql
Com_select + Qcache_hits + queries with errors found by parser
```

The `Com_select` value is given by this formula:

```sql
Qcache_inserts + Qcache_not_cached + queries with errors found during the column-privileges check
```

The query cache uses variable-length blocks, so `Qcache_total_blocks` and `Qcache_free_blocks` may indicate query cache memory fragmentation. After `FLUSH QUERY CACHE`, only a single free block remains.

Every cached query requires a minimum of two blocks (one for the query text and one or more for the query results). Also, every table that is used by a query requires one block. However, if two or more queries use the same table, only one table block needs to be allocated.

The information provided by the `Qcache_lowmem_prunes` status variable can help you tune the query cache size. It counts the number of queries that have been removed from the cache to free up memory for caching new queries. The query cache uses a least recently used (LRU) strategy to decide which queries to remove from the cache. Tuning information is given in Section 8.10.3.3, “Query Cache Configuration”.

### 8.11 Optimizing Locking Operations

When your database is busy with multiple sessions reading and writing data, the mechanism that controls access to data files and memory areas can become a consideration for performance tuning. Otherwise, sessions can spend time waiting for access to resources when they could be running concurrently.

MySQL manages contention for table contents using locking:

- Internal locking is performed within the MySQL server itself to manage contention for table contents by multiple threads. This type of locking is internal because it is performed entirely by the server and involves no other programs. See Section 8.11.1, “Internal Locking Methods”.

- External locking occurs when the server and other programs lock `MyISAM` table files to coordinate among themselves which program can access the tables at which time. See Section 8.11.5, “External Locking”.  

989
8.11.1 Internal Locking Methods

This section discusses internal locking; that is, locking performed within the MySQL server itself to manage contention for table contents by multiple sessions. This type of locking is internal because it is performed entirely by the server and involves no other programs. For locking performed on MySQL files by other programs, see Section 8.11.5, “External Locking”.

- Row-Level Locking
- Table-Level Locking
- Choosing the Type of Locking

Row-Level Locking

MySQL uses row-level locking for InnoDB tables to support simultaneous write access by multiple sessions, making them suitable for multi-user, highly concurrent, and OLTP applications.

To avoid deadlocks when performing multiple concurrent write operations on a single InnoDB table, acquire necessary locks at the start of the transaction by issuing a `SELECT ... FOR UPDATE` statement for each group of rows expected to be modified, even if the data change statements come later in the transaction. If transactions modify or lock more than one table, issue the applicable statements in the same order within each transaction. Deadlocks affect performance rather than representing a serious error, because InnoDB automatically detects deadlock conditions and rolls back one of the affected transactions.

Advantages of row-level locking:

- Fewer lock conflicts when different sessions access different rows.
- Fewer changes for rollbacks.
- Possible to lock a single row for a long time.

Table-Level Locking

MySQL uses table-level locking for MyISAM, MEMORY, and MERGE tables, permitting only one session to update those tables at a time. This locking level makes these storage engines more suitable for read-only, read-mostly, or single-user applications.

These storage engines avoid deadlocks by always requesting all needed locks at once at the beginning of a query and always locking the tables in the same order. The tradeoff is that this strategy reduces concurrency; other sessions that want to modify the table must wait until the current data change statement finishes.

Advantages of table-level locking:

- Relatively little memory required (row locking requires memory per row or group of rows locked)
- Fast when used on a large part of the table because only a single lock is involved.
- Fast if you often do `GROUP BY` operations on a large part of the data or must scan the entire table frequently.

MySQL grants table write locks as follows:

1. If there are no locks on the table, put a write lock on it.
2. Otherwise, put the lock request in the write lock queue.
MySQL grants table read locks as follows:

1. If there are no write locks on the table, put a read lock on it.
2. Otherwise, put the lock request in the read lock queue.

Table updates are given higher priority than table retrievals. Therefore, when a lock is released, the lock is made available to the requests in the write lock queue and then to the requests in the read lock queue. This ensures that updates to a table are not “starved” even when there is heavy SELECT activity for the table. However, if there are many updates for a table, SELECT statements wait until there are no more updates.

For information on altering the priority of reads and writes, see Section 8.11.2, “Table Locking Issues”.

You can analyze the table lock contention on your system by checking the Table_locks_immediate and Table_locks_waited status variables, which indicate the number of times that requests for table locks could be granted immediately and the number that had to wait, respectively:

```
mysql> SHOW STATUS LIKE 'Table%';
+-----------------------+---------+
| Variable_name         | Value   |
+-----------------------+---------+
| Table_locks_immediate | 1151552 |
| Table_locks_waited    | 15324   |
+-----------------------+---------+
```

The MyISAM storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a MyISAM table has no free blocks in the middle of the data file, rows are always inserted at the end of the data file. In this case, you can freely mix concurrent INSERT and SELECT statements for a MyISAM table without locks. That is, you can insert rows into a MyISAM table at the same time other clients are reading from it. Holes can result from rows having been deleted from or updated in the middle of the table. If there are holes, concurrent inserts are disabled but are enabled again automatically when all holes have been filled with new data. To control this behavior, use the concurrent_insert system variable. See Section 8.11.3, “Concurrent Inserts”.

If you acquire a table lock explicitly with LOCK TABLES, you can request a READ LOCAL lock rather than a READ lock to enable other sessions to perform concurrent inserts while you have the table locked.

To perform many INSERT and SELECT operations on a table `t1` when concurrent inserts are not possible, you can insert rows into a temporary table `temp_t1` and update the real table with the rows from the temporary table:

```
mysql> LOCK TABLES t1 WRITE, temp_t1 WRITE;
mysql> INSERT INTO t1 SELECT * FROM temp_t1;
mysql> DELETE FROM temp_t1;
mysql> UNLOCK TABLES;
```

**Choosing the Type of Locking**

Generally, table locks are superior to row-level locks in the following cases:

- Most statements for the table are reads.
- Statements for the table are a mix of reads and writes, where writes are updates or deletes for a single row that can be fetched with one key read:

```
UPDATE tbl_name SET column=value WHERE unique_key_col=key_value;
DELETE FROM tbl_name WHERE unique_key_col=key_value;
```
Table Locking Issues

- **SELECT** combined with concurrent **INSERT** statements, and very few **UPDATE** or **DELETE** statements.
- Many scans or **GROUP BY** operations on the entire table without any writers.

With higher-level locks, you can more easily tune applications by supporting locks of different types, because the lock overhead is less than for row-level locks.

Options other than row-level locking:

- Versioning (such as that used in MySQL for concurrent inserts) where it is possible to have one writer at the same time as many readers. This means that the database or table supports different views for the data depending on when access begins. Other common terms for this are “time travel,” “copy on write,” or “copy on demand.”

- Copy on demand is in many cases superior to row-level locking. However, in the worst case, it can use much more memory than using normal locks.

- Instead of using row-level locks, you can employ application-level locks, such as those provided by **GET_LOCK()** and **RELEASE_LOCK()** in MySQL. These are advisory locks, so they work only with applications that cooperate with each other. See Section 12.14, “Locking Functions”.

8.11.2 Table Locking Issues

**InnoDB** tables use row-level locking so that multiple sessions and applications can read from and write to the same table simultaneously, without making each other wait or producing inconsistent results. For this storage engine, avoid using the **LOCK TABLES** statement, because it does not offer any extra protection, but instead reduces concurrency. The automatic row-level locking makes these tables suitable for your busiest databases with your most important data, while also simplifying application logic since you do not need to lock and unlock tables. Consequently, the **InnoDB** storage engine is the default in MySQL 5.5 and higher.

MySQL uses table locking (instead of page, row, or column locking) for all storage engines except **InnoDB** and **NDB**. The locking operations themselves do not have much overhead. But because only one session can write to a table at any one time, for best performance with these other storage engines, use them primarily for tables that are queried often and rarely inserted into or updated.

- **Performance Considerations Favoring InnoDB**

- **Workarounds for Locking Performance Issues**

**Performance Considerations Favoring InnoDB**

When choosing whether to create a table using **InnoDB** or a different storage engine, keep in mind the following disadvantages of table locking:

- Table locking enables many sessions to read from a table at the same time, but if a session wants to write to a table, it must first get exclusive access, meaning it might have to wait for other sessions to finish with the table first. During the update, all other sessions that want to access this particular table must wait until the update is done.

- Table locking causes problems when a session is waiting because the disk is full and free space needs to become available before the session can proceed. In this case, all sessions that want to access the problem table are also put in a waiting state until more disk space is made available.

- A **SELECT** statement that takes a long time to run prevents other sessions from updating the table in the meantime, making the other sessions appear slow or unresponsive. While a session is waiting to get
exclusive access to the table for updates, other sessions that issue `SELECT` statements will queue up behind it, reducing concurrency even for read-only sessions.

**Workarounds for Locking Performance Issues**

The following items describe some ways to avoid or reduce contention caused by table locking:

- Consider switching the table to the InnoDB storage engine, either using `CREATE TABLE ... ENGINE=INNODB` during setup, or using `ALTER TABLE ... ENGINE=INNODB` for an existing table. See Chapter 14, *The InnoDB Storage Engine* for more details about this storage engine.

- Optimize `SELECT` statements to run faster so that they lock tables for a shorter time. You might have to create some summary tables to do this.

- Start `mysqld` with `--low-priority-updates`. For storage engines that use only table-level locking (such as MyISAM, MEMORY, and MERGE), this gives all statements that update (modify) a table lower priority than `SELECT` statements. In this case, the second `SELECT` statement in the preceding scenario would execute before the `UPDATE` statement, and would not wait for the first `SELECT` to finish.

- To specify that all updates issued in a specific connection should be done with low priority, set the `low_priority_updates` server system variable equal to 1.

- To give a specific `INSERT`, `UPDATE`, or `DELETE` statement lower priority, use the `LOW_PRIORITY` attribute.

- To give a specific `SELECT` statement higher priority, use the `HIGH_PRIORITY` attribute. See Section 13.2.9, “SELECT Statement”.

- Start `mysqld` with a low value for the `max_write_lock_count` system variable to force MySQL to temporarily elevate the priority of all `SELECT` statements that are waiting for a table after a specific number of inserts to the table occur. This permits `READ` locks after a certain number of `WRITE` locks.

- If you have problems with `INSERT` combined with `SELECT`, consider switching to MyISAM tables, which support concurrent `SELECT` and `INSERT` statements. (See Section 8.11.3, “Concurrent Inserts”.)

- If you mix inserts and deletes on the same table, `INSERT DELAYED` may be of great help. See Section 13.2.5.3, “INSERT DELAYED Statement”.

- If you have problems with mixed `SELECT` and `DELETE` statements, the `LIMIT` option to `DELETE` may help. See Section 13.2.2, “DELETE Statement”.

- Using `SQL_BUFFER_RESULT` with `SELECT` statements can help to make the duration of table locks shorter. See Section 13.2.9, “SELECT Statement”.

- Splitting table contents into separate tables may help, by allowing queries to run against columns in one table, while updates are confined to columns in a different table.

- You could change the locking code in `mysys/thr_lock.c` to use a single queue. In this case, write locks and read locks would have the same priority, which might help some applications.

### 8.11.3 Concurrent Inserts

The MyISAM storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a MyISAM table has no holes in the data file (deleted rows in the middle), an `INSERT` statement can be executed to add rows to the end of the table at the same time that `SELECT` statements are reading rows from the table. If there are multiple `INSERT` statements, they are queued and performed
in sequence, concurrently with the \texttt{SELECT} statements. The results of a concurrent \texttt{INSERT} may not be visible immediately.

The \texttt{concurrent_insert} system variable can be set to modify the concurrent-insert processing. By default, the variable is set to \texttt{AUTO} (or 1) and concurrent inserts are handled as just described. If \texttt{concurrent_insert} is set to \texttt{NEVER} (or 0), concurrent inserts are disabled. If the variable is set to \texttt{ALWAYS} (or 2), concurrent inserts at the end of the table are permitted even for tables that have deleted rows. See also the description of the \texttt{concurrent_insert} system variable.

Under circumstances where concurrent inserts can be used, there is seldom any need to use the \texttt{DELAYED} modifier for \texttt{INSERT} statements. See Section 13.2.5.3, “INSERT DELAYED Statement”.

If you are using the binary log, concurrent inserts are converted to normal inserts for \texttt{CREATE \ldots SELECT} or \texttt{INSERT \ldots SELECT} statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. See Section 5.4.4, “The Binary Log”. In addition, for those statements a read lock is placed on the selected-from table such that inserts into that table are blocked. The effect is that concurrent inserts for that table must wait as well.

With \texttt{LOAD DATA}, if you specify \texttt{CONCURRENT} with a \texttt{MyISAM} table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other sessions can retrieve data from the table while \texttt{LOAD DATA} is executing. Use of the \texttt{CONCURRENT} option affects the performance of \texttt{LOAD DATA} a bit, even if no other session is using the table at the same time.

If you specify \texttt{HIGH_PRIORITY}, it overrides the effect of the \texttt{--low-priority-updates} option if the server was started with that option. It also causes concurrent inserts not to be used.

For \texttt{LOCK TABLE}, the difference between \texttt{READ LOCAL} and \texttt{READ} is that \texttt{READ LOCAL} permits nonconflicting \texttt{INSERT} statements (concurrent inserts) to execute while the lock is held. However, this cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock.

### 8.11.4 Metadata Locking

MySQL uses metadata locking to manage concurrent access to database objects and to ensure data consistency. Metadata locking applies not just to tables, but also to schemas and stored programs (procedures, functions, triggers, and scheduled events).

Metadata locking does involve some overhead, which increases as query volume increases. Metadata contention increases the more that multiple queries attempt to access the same objects.

Metadata locking is not a replacement for the table definition cache, and its mutexes and locks differ from the \texttt{LOCK_open} mutex. The following discussion provides some information about how metadata locking works.

- \texttt{Metadata Lock Acquisition}
- \texttt{Metadata Lock Release}

#### Metadata Lock Acquisition

If there are multiple waiters for a given lock, the highest-priority lock request is satisfied first, with an exception related to the \texttt{max_write_lock_count} system variable. Write lock requests have higher priority than read lock requests. However, if \texttt{max_write_lock_count} is set to some low value (say, 10), read lock requests may be preferred over pending write lock requests if the read lock requests have already been passed over in favor of 10 write lock requests. Normally this behavior does not occur because \texttt{max_write_lock_count} by default has a very large value.
Metadata Locking

Statements acquire metadata locks one by one, not simultaneously, and perform deadlock detection in the process.

DML statements normally acquire locks in the order in which tables are mentioned in the statement.

DDL statements, \texttt{LOCK TABLES}, and other similar statements try to reduce the number of possible deadlocks between concurrent DDL statements by acquiring locks on explicitly named tables in name order. Locks might be acquired in a different order for implicitly used tables (such as tables in foreign key relationships that also must be locked).

For example, \texttt{RENAME TABLE} is a DDL statement that acquires locks in name order:

- This \texttt{RENAME TABLE} statement renames \texttt{tbla} to something else, and renames \texttt{tblc} to \texttt{tbla}:

\begin{verbatim}
RENAME TABLE tbla TO tbld, tblc TO tbla;
\end{verbatim}

The statement acquires metadata locks, in order, on \texttt{tbla}, \texttt{tblc}, and \texttt{tbld} (because \texttt{tbld} follows \texttt{tblc} in name order):

- This slightly different statement also renames \texttt{tbla} to something else, and renames \texttt{tblc} to \texttt{tbla}:

\begin{verbatim}
RENAME TABLE tbla TO tblb, tblc TO tbla;
\end{verbatim}

In this case, the statement acquires metadata locks, in order, on \texttt{tbla}, \texttt{tblb}, and \texttt{tblc} (because \texttt{tblb} precedes \texttt{tblc} in name order):

Both statements acquire locks on \texttt{tbla} and \texttt{tblc}, in that order, but differ in whether the lock on the remaining table name is acquired before or after \texttt{tblc}.

Metadata lock acquisition order can make a difference in operation outcome when multiple transactions execute concurrently, as the following example illustrates.

Begin with two tables \texttt{x} and \texttt{x\_new} that have identical structure. Three clients issue statements that involve these tables:

Client 1:

\begin{verbatim}
LOCK TABLE x WRITE, x\_new WRITE;
\end{verbatim}

The statement requests and acquires write locks in name order on \texttt{x} and \texttt{x\_new}.

Client 2:

\begin{verbatim}
INSERT INTO x VALUES(1);
\end{verbatim}

The statement requests and blocks waiting for a write lock on \texttt{x}.

Client 3:

\begin{verbatim}
RENAME TABLE x TO x\_old, x\_new TO x;
\end{verbatim}

The statement requests exclusive locks in name order on \texttt{x}, \texttt{x\_new}, and \texttt{x\_old}, but blocks waiting for the lock on \texttt{x}.

Client 1:

\begin{verbatim}
UNLOCK TABLES;
\end{verbatim}

The statement releases the write locks on \texttt{x} and \texttt{x\_new}. The exclusive lock request for \texttt{x} by Client 3 has higher priority than the write lock request by Client 2, so Client 3 acquires its lock on \texttt{x}, then also on \texttt{x\_new}.
and \texttt{x\_old}, performs the renaming, and releases its locks. Client 2 then acquires its lock on \texttt{x}, performs the insert, and releases its lock.

Lock acquisition order results in the \texttt{RENAME TABLE} executing before the \texttt{INSERT}. The \texttt{x} into which the insert occurs is the table that was named \texttt{x\_new} when Client 2 issued the insert and was renamed to \texttt{x} by Client 3:

\begin{verbatim}
mysql> SELECT * FROM x;
+-----+
| i   |
+-----+
mysql> SELECT * FROM x_old;
Empty set (0.01 sec)
\end{verbatim}

Now begin instead with tables named \texttt{x} and \texttt{new\_x} that have identical structure. Again, three clients issue statements that involve these tables:

Client 1:

\begin{verbatim}
LOCK TABLE x WRITE, new_x WRITE;
\end{verbatim}

The statement requests and acquires write locks in name order on \texttt{new\_x} and \texttt{x}.

Client 2:

\begin{verbatim}
INSERT INTO x VALUES(1);
\end{verbatim}

The statement requests and blocks waiting for a write lock on \texttt{x}.

Client 3:

\begin{verbatim}
RENAME TABLE x TO old_x, new_x TO x;
\end{verbatim}

The statement requests exclusive locks in name order on \texttt{new\_x}, \texttt{old\_x}, and \texttt{x}, but blocks waiting for the lock on \texttt{new\_x}.

Client 1:

\begin{verbatim}
UNLOCK TABLES;
\end{verbatim}

The statement releases the write locks on \texttt{x} and \texttt{new\_x}. For \texttt{x}, the only pending request is by Client 2, so Client 2 acquires its lock, performs the insert, and releases the lock. For \texttt{new\_x}, the only pending request is by Client 3, which is permitted to acquire that lock (and also the lock on \texttt{old\_x}). The rename operation still blocks for the lock on \texttt{x} until the Client 2 insert finishes and releases its lock. Then Client 3 acquires the lock on \texttt{x}, performs the rename, and releases its lock.

In this case, lock acquisition order results in the \texttt{INSERT} executing before the \texttt{RENAME TABLE}. The \texttt{x} into which the insert occurs is the original \texttt{x}, now renamed to \texttt{old\_x} by the rename operation:

\begin{verbatim}
mysql> SELECT * FROM x;
Empty set (0.01 sec)
mysql> SELECT * FROM old_x;
+-----+
| i   |
+-----+
mysql> SELECT * FROM old_x;
\end{verbatim}
External Locking

If order of lock acquisition in concurrent statements makes a difference to an application in operation outcome, as in the preceding example, you may be able to adjust the table names to affect the order of lock acquisition.

Metadata Lock Release

To ensure transaction serializability, the server must not permit one session to perform a data definition language (DDL) statement on a table that is used in an uncompleted explicitly or implicitly started transaction in another session. The server achieves this by acquiring metadata locks on tables used within a transaction and deferring release of those locks until the transaction ends. A metadata lock on a table prevents changes to the table’s structure. This locking approach has the implication that a table that is being used by a transaction within one session cannot be used in DDL statements by other sessions until the transaction ends.

This principle applies not only to transactional tables, but also to nontransactional tables. Suppose that a session begins a transaction that uses transactional table \( t \) and nontransactional table \( nt \) as follows:

```sql
START TRANSACTION;
SELECT * FROM t;
SELECT * FROM nt;
```

The server holds metadata locks on both \( t \) and \( nt \) until the transaction ends. If another session attempts a DDL or write lock operation on either table, it blocks until metadata lock release at transaction end. For example, a second session blocks if it attempts any of these operations:

```sql
DROP TABLE t;
ALTER TABLE t ...;
DROP TABLE nt;
ALTER TABLE nt ...;
LOCK TABLE t ... WRITE;
```

If the server acquires metadata locks for a statement that is syntactically valid but fails during execution, it does not release the locks early. Lock release is still deferred to the end of the transaction because the failed statement is written to the binary log and the locks protect log consistency.

In autocommit mode, each statement is in effect a complete transaction, so metadata locks acquired for the statement are held only to the end of the statement.

Metadata locks acquired during a `PREPARE` statement are released once the statement has been prepared, even if preparation occurs within a multiple-statement transaction.

8.11.5 External Locking

External locking is the use of file system locking to manage contention for `MyISAM` database tables by multiple processes. External locking is used in situations where a single process such as the MySQL server cannot be assumed to be the only process that requires access to tables. Here are some examples:

- If you run multiple servers that use the same database directory (not recommended), each server must have external locking enabled.

- If you use `myisamchk` to perform table maintenance operations on `MyISAM` tables, you must either ensure that the server is not running, or that the server has external locking enabled so that it locks table files as necessary to coordinate with `myisamchk` for access to the tables. The same is true for use of `myisampack` to pack `MyISAM` tables.

If the server is run with external locking enabled, you can use `myisamchk` at any time for read operations such a checking tables. In this case, if the server tries to update a table that `myisamchk` is using, the server will wait for `myisamchk` to finish before it continues.
If you use `myisamchk` for write operations such as repairing or optimizing tables, or if you use `mysampack` to pack tables, you **must** always ensure that the `mysqld` server is not using the table. If you do not stop `mysqld`, at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables **may become corrupted** if the server and `myisamchk` access the tables simultaneously.

With external locking in effect, each process that requires access to a table acquires a file system lock for the table files before proceeding to access the table. If all necessary locks cannot be acquired, the process is blocked from accessing the table until the locks can be obtained (after the process that currently holds the locks releases them).

External locking affects server performance because the server must sometimes wait for other processes before it can access tables.

External locking is unnecessary if you run a single server to access a given data directory (which is the usual case) and if no other programs such as `myisamchk` need to modify tables while the server is running. If you only read tables with other programs, external locking is not required, although `myisamchk` might report warnings if the server changes tables while `myisamchk` is reading them.

With external locking disabled, to use `myisamchk`, you must either stop the server while `myisamchk` executes or else lock and flush the tables before running `myisamchk`. (See Section 8.12.1, “System Factors”.) To avoid this requirement, use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair MyISAM tables.

For `mysqld`, external locking is controlled by the value of the `skip_external_locking` system variable. When this variable is enabled, external locking is disabled, and vice versa. External locking is disabled by default.

Use of external locking can be controlled at server startup by using the `--external-locking` or `--skip-external-locking` option.

If you do use external locking option to enable updates to MyISAM tables from many MySQL processes, you must ensure that the following conditions are satisfied:

- Do not use the query cache for queries that use tables that are updated by another process.

- Do not start the server with the `delay_key_write` system variable set to `ALL` or use the `DELAY_KEY_WRITE=1` table option for any shared tables. Otherwise, index corruption can occur.

The easiest way to satisfy these conditions is to always use `--external-locking` together with `--delay-key-write=OFF` and `--query-cache-size=0`. (This is not done by default because in many setups it is useful to have a mixture of the preceding options.)

# 8.12 Optimizing the MySQL Server

This section discusses optimization techniques for the database server, primarily dealing with system configuration rather than tuning SQL statements. The information in this section is appropriate for DBAs who want to ensure performance and scalability across the servers they manage; for developers constructing installation scripts that include setting up the database; and people running MySQL themselves for development, testing, and so on who want to maximize their own productivity.

## 8.12.1 System Factors

Some system-level factors can affect performance in a major way:

- If you have enough RAM, you could remove all swap devices. Some operating systems use a swap device in some contexts even if you have free memory.
Optimizing Disk I/O

• Avoid external locking for MyISAM tables. The default is for external locking to be disabled. The --external-locking and --skip-external-locking options explicitly enable and disable external locking.

Disabling external locking does not affect MySQL's functionality as long as you run only one server. Just remember to take down the server (or lock and flush the relevant tables) before you run myisamchk. On some systems it is mandatory to disable external locking because it does not work, anyway.

The only case in which you cannot disable external locking is when you run multiple MySQL servers (not clients) on the same data, or if you run myisamchk to check (not repair) a table without telling the server to flush and lock the tables first. Note that using multiple MySQL servers to access the same data concurrently is generally not recommended, except when using NDB Cluster.

The LOCK TABLES and UNLOCK TABLES statements use internal locking, so you can use them even if external locking is disabled.

8.12.2 Optimizing Disk I/O

This section describes ways to configure storage devices when you can devote more and faster storage hardware to the database server. For information about optimizing an InnoDB configuration to improve I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

• Disk seeks are a huge performance bottleneck. This problem becomes more apparent when the amount of data starts to grow so large that effective caching becomes impossible. For large databases where you access data more or less randomly, you can be sure that you need at least one disk seek to read and a couple of disk seeks to write things. To minimize this problem, use disks with low seek times.

• Increase the number of available disk spindles (and thereby reduce the seek overhead) by either symlinking files to different disks or striping the disks:

• Using symbolic links

This means that, for MyISAM tables, you symlink the index file and data files from their usual location in the data directory to another disk (that may also be striped). This makes both the seek and read times better, assuming that the disk is not used for other purposes as well. See Section 8.12.3, “Using Symbolic Links”.

Symbolic links are not supported for use with InnoDB tables. However, it is possible to place InnoDB data and log files on different physical disks. For more information, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

• Stripping

Striping means that you have many disks and put the first block on the first disk, the second block on the second disk, and the N-th block on the (N MOD number_of_disks) disk, and so on. This means if your normal data size is less than the stripe size (or perfectly aligned), you get much better performance. Striping is very dependent on the operating system and the stripe size, so benchmark your application with different stripe sizes. See Section 8.13.3, “Using Your Own Benchmarks”.

The speed difference for striping is very dependent on the parameters. Depending on how you set the striping parameters and number of disks, you may get differences measured in orders of magnitude. You have to choose to optimize for random or sequential access.

• For reliability, you may want to use RAID 0+1 (striping plus mirroring), but in this case, you need 2 × N drives to hold N drives of data. This is probably the best option if you have the money for it. However, you may also have to invest in some volume-management software to handle it efficiently.
Using Symbolic Links

• A good option is to vary the RAID level according to how critical a type of data is. For example, store semi-important data that can be regenerated on a RAID 0 disk, but store really important data such as host information and logs on a RAID 0+1 or RAID N disk. RAID N can be a problem if you have many writes, due to the time required to update the parity bits.

• You can also set the parameters for the file system that the database uses:

  If you do not need to know when files were last accessed (which is not really useful on a database server), you can mount your file systems with the `-o noatime` option. That skips updates to the last access time in inodes on the file system, which avoids some disk seeks.

  On many operating systems, you can set a file system to be updated asynchronously by mounting it with the `-o async` option. If your computer is reasonably stable, this should give you better performance without sacrificing too much reliability. (This flag is on by default on Linux.)

Using NFS with MySQL

Caution is advised when considering using NFS with MySQL. Potential issues, which vary by operating system and NFS version, include:

• MySQL data and log files placed on NFS volumes becoming locked and unavailable for use. Locking issues may occur in cases where multiple instances of MySQL access the same data directory or where MySQL is shut down improperly, due to a power outage, for example. NFS version 4 addresses underlying locking issues with the introduction of advisory and lease-based locking. However, sharing a data directory among MySQL instances is not recommended.

• Data inconsistencies introduced due to messages received out of order or lost network traffic. To avoid this issue, use TCP with `hard` and `intr` mount options.

• Maximum file size limitations. NFS Version 2 clients can only access the lowest 2GB of a file (signed 32 bit offset). NFS Version 3 clients support larger files (up to 64 bit offsets). The maximum supported file size also depends on the local file system of the NFS server.

Using NFS within a professional SAN environment or other storage system tends to offer greater reliability than using NFS outside of such an environment. However, NFS within a SAN environment may be slower than directly attached or bus-attached non-rotational storage.

If you choose to use NFS, NFS Version 4 or later is recommended, as is testing your NFS setup thoroughly before deploying into a production environment.

8.12.3 Using Symbolic Links

You can move databases or tables from the database directory to other locations and replace them with symbolic links to the new locations. You might want to do this, for example, to move a database to a file system with more free space or increase the speed of your system by spreading your tables to different disks.

The recommended way to do this is to symlink entire database directories to a different disk. Symlink MyISAM tables only as a last resort.

To determine the location of your data directory, use this statement:

```
SHOW VARIABLES LIKE 'datadir';
```

8.12.3.1 Using Symbolic Links for Databases on Unix
Using Symbolic Links

On Unix, the way to symlink a database is first to create a directory on some disk where you have free space and then to create a soft link to it from the MySQL data directory.

```
shell> mkdir /dr1/databases/test
shell> ln -s /dr1/databases/test /path/to/datadir
```

MySQL does not support linking one directory to multiple databases. Replacing a database directory with a symbolic link works as long as you do not make a symbolic link between databases. Suppose that you have a database `db1` under the MySQL data directory, and then make a symlink `db2` that points to `db1`:

```
shell> cd /path/to/datadir
shell> ln -s db1 db2
```

The result is that, for any table `tbl_a` in `db1`, there also appears to be a table `tbl_a` in `db2`. If one client updates `db1.tbl_a` and another client updates `db2.tbl_a`, problems are likely to occur.

### 8.12.3.2 Using Symbolic Links for MyISAM Tables on Unix

Symlinks are fully supported only for MyISAM tables. For files used by tables for other storage engines, you may get strange problems if you try to use symbolic links.

Do not symlink tables on systems that do not have a fully operational `realpath()` call. (Linux and Solaris support `realpath()`). To determine whether your system supports symbolic links, check the value of the `have_symlink` system variable using this statement:

```
SHOW VARIABLES LIKE 'have_symlink';
```

The handling of symbolic links for MyISAM tables works as follows:

- In the data directory, you always have the table format (.frm) file, the data (.MYD) file, and the index (.MYI) file. The data file and index file can be moved elsewhere and replaced in the data directory by symlinks. The format file cannot.

- You can symlink the data file and the index file independently to different directories.

- To instruct a running MySQL server to perform the symlinking, use the `DATA DIRECTORY` and `INDEX DIRECTORY` options to `CREATE TABLE`. See Section 13.1.17, “CREATE TABLE Statement”. Alternatively, if `mysqld` is not running, symlinking can be accomplished manually using `ln -s` from the command line.

  ```
  Note
  The path used with either or both of the `DATA DIRECTORY` and `INDEX DIRECTORY` options may not include the MySQL data directory. (Bug #32167)
  ```

- `myisamchk` does not replace a symlink with the data file or index file. It works directly on the file to which the symlink points. Any temporary files are created in the directory where the data file or index file is located. The same is true for the `ALTER TABLE, OPTIMIZE TABLE, and REPAIR TABLE` statements.

  ```
  Note
  When you drop a table that is using symlinks, both the symlink and the file to which the symlink points are dropped. This is an extremely good reason not to run `mysqld` as the root operating system user or permit operating system users to have write access to MySQL database directories.
  ```

- If you rename a table with `ALTER TABLE ... RENAME` or `RENAME TABLE` and you do not move the table to another database, the symlinks in the database directory are renamed to the new names and the data file and index file are renamed accordingly.
Using Symbolic Links

- If you use `ALTER TABLE ... RENAME` or `RENAME TABLE` to move a table to another database, the table is moved to the other database directory. If the table name changed, the symlinks in the new database directory are renamed to the new names and the data file and index file are renamed accordingly.

- If you are not using symlinks, start `mysqld` with the `--skip-symbolic-links` option to ensure that no one can use `mysqld` to drop or rename a file outside of the data directory.

These table symlink operations are not supported:

- `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.

- As indicated previously, only the data and index files can be symbolic links. The `.frm` file must never be a symbolic link. Attempting to do this (for example, to make one table name a synonym for another) produces incorrect results. Suppose that you have a database `db1` under the MySQL data directory, a table `tbl1` in this database, and in the `db1` directory you make a symlink `tbl2` that points to `tbl1`:

```shell
shell> cd /path/to/datadir/db1
shell> ln -s tbl1.frm tbl2.frm
shell> ln -s tbl1.MYD tbl2.MYD
shell> ln -s tbl1.MYI tbl2.MYI
```

Problems result if one thread reads `db1.tbl1` and another thread updates `db1.tbl2`:

- The query cache is “fooled” (it has no way of knowing that `tbl1` has not been updated, so it returns outdated results).

- `ALTER` statements on `tbl2` fail.

### 8.12.3.3 Using Symbolic Links for Databases on Windows

On Windows, symbolic links can be used for database directories. This enables you to put a database directory at a different location (for example, on a different disk) by setting up a symbolic link to it. Use of database symlinks on Windows is similar to their use on Unix, although the procedure for setting up the link differs.

Suppose that you want to place the database directory for a database named `mydb` at `D:\data\mydb`. To do this, create a symbolic link in the MySQL data directory that points to `D:\data\mydb`. However, before creating the symbolic link, make sure that the `D:\data\mydb` directory exists by creating it if necessary. If you already have a database directory named `mydb` in the data directory, move it to `D:\data`. Otherwise, the symbolic link will be ineffective. To avoid problems, make sure that the server is not running when you move the database directory.

The procedure for creating the database symbolic link depends on your version of Windows.

On Windows, you can create a symlink using the `mklink` command. This command requires administrative privileges.

1. Change location into the data directory:

   ```command
   C:\> cd \path\to\datadir
   ```

2. In the data directory, create a symlink named `mydb` that points to the location of the database directory:

   ```command
   C:\> mklink /d mydb D:\data\mydb
   ```

After this, all tables created in the database `mydb` are created in `D:\data\mydb`. 
Alternatively, on any version of Windows supported by MySQL, you can create a symbolic link to a MySQL database by creating a .sym file in the data directory that contains the path to the destination directory. The file should be named \texttt{db\_name.sym}, where \texttt{db\_name} is the database name.

Support for database symbolic links on Windows using .sym files is enabled by default. If you do not need .sym file symbolic links, you can disable support for them by starting \texttt{mysqld} with the \texttt{--skip-symbolic-links} option. To determine whether your system supports .sym file symbolic links, check the value of the \texttt{have\_symlink} system variable using this statement:

\begin{verbatim}
SHOW VARIABLES LIKE 'have\_symlink';
\end{verbatim}

To create a .sym file symlink, use this procedure:

1. Change location into the data directory:
\begin{verbatim}
C:\> cd \path\to\datadir
\end{verbatim}

2. In the data directory, create a text file named \texttt{mydb\_sym} that contains this path name:
\begin{verbatim}
D:\data\mydb
\end{verbatim}

\textbf{Note} The path name to the new database and tables should be absolute. If you specify a relative path, the location will be relative to the \texttt{mydb\_sym} file.

After this, all tables created in the database \texttt{mydb} are created in \texttt{D:\data\mydb}.

The following limitations apply to the use of .sym files for database symbolic linking on Windows. These limitations do not apply for symlinks created using \texttt{mklink}.

- The symbolic link is not used if a directory with the same name as the database exists in the MySQL data directory.
- The \texttt{--innodb\_file\_per\_table} option cannot be used.
- If you run \texttt{mysqld} as a service, you cannot use a mapped drive to a remote server as the destination of the symbolic link. As a workaround, you can use the full path (\texttt{\\servername\path\}).

### 8.12.4 Optimizing Memory Use

#### 8.12.4.1 How MySQL Uses Memory

MySQL allocates buffers and caches to improve performance of database operations. You can improve MySQL performance by increasing the values of certain cache and buffer-related system variables. You can also modify these variables to run MySQL on systems with limited memory.

The following list describes some of the ways that MySQL uses memory. Where applicable, relevant system variables are referenced. Some items are storage engine or feature specific.

- The \texttt{InnoDB} buffer pool is a memory area that holds cached \texttt{InnoDB} data for tables, indexes, and other auxiliary buffers. For efficiency of high-volume read operations, the buffer pool is divided into \texttt{pages} that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the LRU algorithm. For more information, see Section 14.8.1, “Buffer Pool”.

The size of the buffer pool is important for system performance:

- \texttt{InnoDB} allocates memory for the entire buffer pool at server startup, using \texttt{malloc()} operations. The \texttt{innodb\_buffer\_pool\_size} system variable defines the buffer pool size. Typically, a
Optimizing Memory Use

recommended `innodb_buffer_pool_size` value is 50 to 75 percent of system memory. For more information, see Configuring InnoDB Buffer Pool Size.

- On systems with a large amount of memory, you can improve concurrency by dividing the buffer pool into multiple `buffer pool instances`. The `innodb_buffer_pool_instances` system variable defines the number of buffer pool instances.

- A buffer pool that is too small may cause excessive churning as pages are flushed from the buffer pool only to be required again a short time later.

- A buffer pool that is too large may cause swapping due to competition for memory.

- All threads share the `MyISAM` key buffer. The `key_buffer_size` system variable determines its size.

  For each `MyISAM` table the server opens, the index file is opened once; the data file is opened once for each concurrently running thread that accesses the table. For each concurrent thread, a table structure, column structures for each column, and a buffer of size $3 \times N$ are allocated (where $N$ is the maximum row length, not counting `BLOB` columns). A `BLOB` column requires five to eight bytes plus the length of the `BLOB` data. The `MyISAM` storage engine maintains one extra row buffer for internal use.

  - The `myisam_use_mmap` system variable can be set to 1 to enable memory-mapping for all `MyISAM` tables.

  - If an internal in-memory temporary table becomes too large (as determined using the `tmp_table_size` and `max_heap_table_size` system variables), MySQL automatically converts the table from in-memory to on-disk format. On-disk temporary tables use the `MyISAM` storage engine. You can increase the permissible temporary table size as described in Section 8.4.4, “Internal Temporary Table Use in MySQL”.

  For `MEMORY` tables explicitly created with `CREATE TABLE`, only the `max_heap_table_size` system variable determines how large a table can grow, and there is no conversion to on-disk format.

  - The MySQL Performance Schema is a feature for monitoring MySQL server execution at a low level. For performance reasons, fixed memory buffers for Performance Schema are allocated at server startup and do not change in size while the server is running.

  - Each thread that the server uses to manage client connections requires some thread-specific space. The following list indicates these and which system variables control their size:

    - A stack (`thread_stack`)
    - A connection buffer (`net_buffer_length`)
    - A result buffer (`net_buffer_length`)

    The connection buffer and result buffer each begin with a size equal to `net_buffer_length` bytes, but are dynamically enlarged up to `max_allowed_packet` bytes as needed. The result buffer shrinks to `net_buffer_length` bytes after each SQL statement. While a statement is running, a copy of the current statement string is also allocated.

    - All threads share the same base memory.

    - When a thread is no longer needed, the memory allocated to it is released and returned to the system unless the thread goes back into the thread cache. In that case, the memory remains allocated.

    - Each request that performs a sequential scan of a table allocates a `read buffer`. The `read_buffer_size` system variable determines the buffer size.
Optimizing Memory Use

• When reading rows in an arbitrary sequence (for example, following a sort), a random-read buffer may be allocated to avoid disk seeks. The read_rnd_buffer_size system variable determines the buffer size.

• All joins are executed in a single pass, and most joins can be done without even using a temporary table. Most temporary tables are memory-based hash tables. Temporary tables with a large row length (calculated as the sum of all column lengths) or that contain BLOB columns are stored on disk.

• Most requests that perform a sort allocate a sort buffer and zero to two temporary files depending on the result set size. See Section B.4.3.5, “Where MySQL Stores Temporary Files”.

• Almost all parsing and calculating is done in thread-local and reusable memory pools. No memory overhead is needed for small items, thus avoiding the normal slow memory allocation and freeing. Memory is allocated only for unexpectedly large strings.

• For each table having BLOB columns, a buffer is enlarged dynamically to read in larger BLOB values. If you scan a table, the buffer grows as large as the largest BLOB value.

• MySQL requires memory and descriptors for the table cache. Handler structures for all in-use tables are saved in the table cache and managed as “First In, First Out” (FIFO). The table_open_cache system variable defines the initial table cache size; see Section 8.4.3.1, “How MySQL Opens and Closes Tables”.

MySQL also requires memory for the table definition cache. The table_definition_cache system variable defines the number of table definitions (from .frm files) that can be stored in the table definition cache. If you use a large number of tables, you can create a large table definition cache to speed up the opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the table cache.

• A FLUSH TABLES statement or mysqladmin flush-tables command closes all tables that are not in use at once and marks all in-use tables to be closed when the currently executing thread finishes. This effectively frees most in-use memory. FLUSH TABLES does not return until all tables have been closed.

• The server caches information in memory as a result of GRANT, CREATE USER, CREATE SERVER, and INSTALL PLUGIN statements. This memory is not released by the corresponding REVOKE, DROP USER, DROP SERVER, and UNINSTALL PLUGIN statements, so for a server that executes many instances of the statements that cause caching, there will be an increase in cached memory use unless it is freed with FLUSH PRIVILEGES.

ps and other system status programs may report that mysqld uses a lot of memory. This may be caused by thread stacks on different memory addresses. For example, the Solaris version of ps counts the unused memory between stacks as used memory. To verify this, check available swap with swap -s. We test mysqld with several memory-leakage detectors (both commercial and Open Source), so there should be no memory leaks.

8.12.4.2 Enabling Large Page Support

Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

In MySQL, large pages can be used by InnoDB, to allocate memory for its buffer pool and additional memory pool.

Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature is available for
Optimizing Memory Use

recent SPARC platforms. It can be enabled or disabled by using the `--super-large-pages` or `--skip-super-large-pages` option.

MySQL also supports the Linux implementation of large page support (which is called HugeTLB in Linux).

Before large pages can be used on Linux, the kernel must be enabled to support them and it is necessary to configure the HugeTLB memory pool. For reference, the HugeTBL API is documented in the `Documentation/vm/hugetlbpage.txt` file of your Linux sources.

The kernel for some recent systems such as Red Hat Enterprise Linux appear to have the large pages feature enabled by default. To check whether this is true for your kernel, use the following command and look for output lines containing “huge”:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

The nonempty command output indicates that large page support is present, but the zero values indicate that no pages are configured for use.

If your kernel needs to be reconfigured to support large pages, consult the `hugetlbpage.txt` file for instructions.

Assuming that your Linux kernel has large page support enabled, configure it for use by MySQL using the following commands. Normally, you put these in an `rc` file or equivalent startup file that is executed during the system boot sequence, so that the commands execute each time the system starts. The commands should execute early in the boot sequence, before the MySQL server starts. Be sure to change the allocation numbers and the group number as appropriate for your system.

```
# Set the number of pages to be used.
# Each page is normally 2MB, so a value of 20 = 40MB.
# This command actually allocates memory, so this much
# memory must be available.
echo 20 > /proc/sys/vm/nr_hugepages

# Set the group number that is permitted to access this
# memory (102 in this case). The mysql user must be a
# member of this group.
echo 102 > /proc/sys/vm/hugetlb_shm_group

# Increase the amount of shmem permitted per segment
# (12G in this case).
echo 1560281088 > /proc/sys/kernel/shmmax

# Increase total amount of shared memory. The value
# is the number of pages. At 4KB/page, 4194304 = 16GB.
echo 4194304 > /proc/sys/kernel/shmall
```

For MySQL usage, you normally want the value of `shmmax` to be close to the value of `shmall`.

To verify the large page configuration, check `/proc/meminfo` again as described previously. Now you should see some nonzero values:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:      20
HugePages_Free:       20
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

The final step to make use of the `hugetlb_shm_group` is to give the `mysql` user an “unlimited” value for the memlock limit. This can be done either by editing `/etc/security/limits.conf` or by adding the following command to your `mysqld_safe` script:

```
ulimit -l unlimited
```

Adding the `ulimit` command to `mysqld_safe` causes the `root` user to set the memlock limit to `unlimited` before switching to the `mysql` user. (This assumes that `mysqld_safe` is started by `root`.)

Large page support in MySQL is disabled by default. To enable it, start the server with the `--large-pages` option. For example, you can use the following lines in the server `my.cnf` file:

```
[mysqld]
large-pages
```

With this option, InnoDB uses large pages automatically for its buffer pool and additional memory pool. If InnoDB cannot do this, it falls back to use of traditional memory and writes a warning to the error log:

```
Warning: Using conventional memory pool
```

To verify that large pages are being used, check `/proc/meminfo` again:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:      20
HugePages_Free:       20
HugePages_Rsvd:        2
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

**8.12.5 Optimizing Network Use**

**8.12.5.1 How MySQL Handles Client Connections**

This section describes aspects of how the MySQL server manages client connections.

- **Network Interfaces and Connection Manager Threads**
- **Client Connection Thread Management**
- **Connection Volume Management**

**Network Interfaces and Connection Manager Threads**

The server is capable of listening for client connections on multiple network interfaces. Connection manager threads handle client connection requests on the network interfaces that the server listens to:

- On all platforms, one manager thread handles TCP/IP connection requests.
- On Unix, the same manager thread also handles Unix socket file connection requests.
- On Windows, a manager thread handles shared-memory connection requests, and another handles named-pipe connection requests.

The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

**Client Connection Thread Management**

Connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when
necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

In this connection thread model, there are as many threads as there are clients currently connected, which has some disadvantages when server workload must scale to handle large numbers of connections. For example, thread creation and disposal becomes expensive. Also, each thread requires server and kernel resources, such as stack space. To accommodate a large number of simultaneous connections, the stack size per thread must be kept small, leading to a situation where it is either too small or the server consumes large amounts of memory. Exhaustion of other resources can occur as well, and scheduling overhead can become significant.

As of MySQL 5.5.16, MySQL Enterprise Edition includes a thread pool plugin that provides an alternative thread-handling model designed to reduce overhead and improve performance. It implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections. See Section 5.5.3, "MySQL Enterprise Thread Pool".

To control and monitor how the server manages threads that handle client connections, several system and status variables are relevant. (See Section 5.1.7, “Server System Variables”, and Section 5.1.9, “Server Status Variables”.)

The thread_cache_size system variable determines the thread cache size. A value of 0 disables caching, which causes a thread to be set up for each new connection and disposed of when the connection terminates. To enable \( N \) inactive connection threads to be cached, set thread_cache_size to \( N \) at server startup or at runtime. A connection thread becomes inactive when the client connection with which it was associated terminates.

To monitor the number of threads in the cache and how many threads have been created because a thread could not be taken from the cache, check the Threads_cached and Threads_created status variables.

When the thread stack is too small, this limits the complexity of the SQL statements which the server can handle, the recursion depth of stored procedures, and other memory-consuming actions. To set a stack size of \( N \) bytes for each thread, start the server with thread_stack. set to \( N \) at server startup.

**Connection Volume Management**

To control the maximum number of clients the server permits to connect simultaneously, set the max_connections system variable at server startup or at runtime. It may be necessary to increase max_connections if more clients attempt to connect simultaneously then the server is configured to handle (see Section B.4.2.7, “Too many connections”).

mysqld actually permits max_connections + 1 client connections. The extra connection is reserved for use by accounts that have the SUPER privilege. By granting the privilege to administrators and not to normal users (who should not need it), an administrator who also has the PROCESS privilege can connect to the server and use SHOW PROCESSLIST to diagnose problems even if the maximum number of unprivileged clients are connected. See Section 13.7.5.30, “SHOW PROCESSLIST Statement”.

The maximum number of connections MySQL supports (that is, the maximum value to which max_connections can be set) depends on several factors:

- The quality of the thread library on a given platform.
- The amount of RAM available.
- The amount of RAM is used for each connection.
Optimizing Network Use

- The workload from each connection.
- The desired response time.
- The number of file descriptors available.

Linux or Solaris should be able to support at least 500 to 1000 simultaneous connections routinely and as many as 10,000 connections if you have many gigabytes of RAM available and the workload from each is low or the response time target undemanding.

Increasing the `max_connections` value increases the number of file descriptors that `mysqld` requires. If the required number of descriptors are not available, the server reduces the value of `max_connections`. For comments on file descriptor limits, see Section 8.4.3.1, “How MySQL Opens and Closes Tables”.

Increasing the `open_files_limit` system variable may be necessary, which may also require raising the operating system limit on how many file descriptors can be used by MySQL. Consult your operating system documentation to determine whether it is possible to increase the limit and how to do so. See also Section B.4.2.18, “File Not Found and Similar Errors”.

8.12.5.2 DNS Lookup Optimization and the Host Cache

The MySQL server maintains a host cache in memory that contains information about clients: IP address, host name, and error information.

- Host Cache Operation
- Host Cache Configuration

**Host Cache Operation**

The server uses the host cache for several purposes:

- By caching the results of IP-to-host name lookups, the server avoids doing a Domain Name System (DNS) lookup for each client connection. Instead, for a given host, it needs to perform a lookup only for the first connection from that host.

- The cache contains information about errors that occur during the connection process. Some errors are considered “blocking.” If too many of these occur successively from a given host without a successful connection, the server blocks further connections from that host. The `max_connect_errors` system variable determines the permitted number of successive errors before blocking occurs (see Section B.4.2.6, “Host ‘host_name’ is blocked”).

For each new client connection, the server uses the client IP address to check whether the client host name is in the host cache. If so, the server refuses or continues to process the connection request depending on whether or not the host is blocked. If the host is not in the cache, the server attempts to resolve the host name. First, it resolves the IP address to a host name and resolves that host name back to an IP address. Then it compares the result to the original IP address to ensure that they are the same. The server stores information about the result of this operation in the host cache. If the cache is full, the least recently used entry is discarded.
The server performs host name resolution using the `gethostbyaddr()` and `gethostbyname()` system calls.

To unblock blocked hosts, flush the host cache by executing a `FLUSH HOSTS` statement or `mysqladmin flush-hosts` command.

It is possible for a blocked host to become unblocked even without flushing the host cache if activity from other hosts has occurred since the last connection attempt from the blocked host. This can occur because the server discards the least recently used cache entry to make room for a new entry if the cache is full when a connection arrives from a client IP not in the cache. If the discarded entry is for a blocked host, that host becomes unblocked.

Some connection errors are not associated with TCP connections, occur very early in the connection process (even before an IP address is known), or are not specific to any particular IP address (such as out-of-memory conditions).

**Host Cache Configuration**

The host cache is enabled by default. To disable it, start the server with the `--skip-host-cache` option. With the cache disabled, the server performs a DNS lookup every time a client connects.

To disable DNS host name lookups, start the server with the `skip_name_resolve` system variable enabled. In this case, the server uses only IP addresses and not host names to match connecting hosts to rows in the MySQL grant tables. Only accounts specified in those tables using IP addresses can be used. (A client may not be able to connect if no account exists that specifies the client IP address.)

If you have a very slow DNS and many hosts, you might be able to improve performance either by disabling DNS lookups by enabling `skip_name_resolve` or by increasing the `HOST_CACHE_SIZE` define (default value: 128) and recompiling the server.

To disallow TCP/IP connections entirely, start the server with the `skip_networking` system variable enabled.

**8.13 Measuring Performance (Benchmarking)**

To measure performance, consider the following factors:

- Whether you are measuring the speed of a single operation on a quiet system, or how a set of operations (a “workload”) works over a period of time. With simple tests, you usually test how changing one aspect (a configuration setting, the set of indexes on a table, the SQL clauses in a query) affects performance. Benchmarks are typically long-running and elaborate performance tests, where the results could dictate high-level choices such as hardware and storage configuration, or how soon to upgrade to a new MySQL version.

- For benchmarking, sometimes you must simulate a heavy database workload to get an accurate picture.

- Performance can vary depending on so many different factors that a difference of a few percentage points might not be a decisive victory. The results might shift the opposite way when you test in a different environment.

- Certain MySQL features help or do not help performance depending on the workload. For completeness, always test performance with those features turned on and turned off. The two most important features to try with each workload are the MySQL query cache, and the adaptive hash index for InnoDB tables.

This section progresses from simple and direct measurement techniques that a single developer can do, to more complicated ones that require additional expertise to perform and interpret the results.
8.13.1 Measuring the Speed of Expressions and Functions

To measure the speed of a specific MySQL expression or function, invoke the `BENCHMARK()` function using the `mysql` client program. Its syntax is `BENCHMARK(loop_count, expr)`. The return value is always zero, but `mysql` prints a line displaying approximately how long the statement took to execute. For example:

```sql
mysql> SELECT BENCHMARK(1000000, 1+1);
```

<table>
<thead>
<tr>
<th>BENCHMARK(1000000, 1+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

1 row in set (0.32 sec)

This result was obtained on a Pentium II 400MHz system. It shows that MySQL can execute 1,000,000 simple addition expressions in 0.32 seconds on that system.

The built-in MySQL functions are typically highly optimized, but there may be some exceptions. `BENCHMARK()` is an excellent tool for finding out if some function is a problem for your queries.

8.13.2 The MySQL Benchmark Suite

This benchmark suite is meant to tell any user what operations a given SQL implementation performs well or poorly. You can get a good idea for how the benchmarks work by looking at the code and results in the `sql-bench` directory in any MySQL source distribution.

To use the benchmark suite, the following requirements must be satisfied:

- The benchmark suite is provided with MySQL source distributions. You can either download a released distribution from [https://dev.mysql.com/downloads/](https://dev.mysql.com/downloads/), or use the current development source tree. (See Section 2.9.5, “Installing MySQL Using a Development Source Tree”.)

- The benchmark scripts are written in Perl and use the Perl DBI module to access database servers, so DBI must be installed. You also need the server-specific DBD drivers for each of the servers you want to test. For example, to test MySQL, PostgreSQL, and DB2, you must have the `DBD::mysql`, `DBD::Pg`, and `DBD::DB2` modules installed. See Section 2.13, “Perl Installation Notes”.

After you obtain a MySQL source distribution, you can find the benchmark suite located in its `sql-bench` directory. To run the benchmark tests, build MySQL, and then change location into the `sql-bench` directory and execute the `run-all-tests` script:

```shell
shell> cd sql-bench
shell> perl run-all-tests --server=server_name
```

`server_name` should be the name of one of the supported servers. To get a list of all options and supported servers, invoke this command:

```shell
shell> perl run-all-tests --help
```

The `crash-me` script also is located in the `sql-bench` directory. `crash-me` tries to determine what features a database system supports and what its capabilities and limitations are by actually running queries. For example, it determines:

- What data types are supported
- How many indexes are supported
- What functions are supported
• How big a query can be
• How big a VARCHAR column can be

For more information about benchmark results, visit http://www.mysql.com/why-mysql/benchmarks/.

8.13.3 Using Your Own Benchmarks

Benchmark your application and database to find out where the bottlenecks are. After fixing one bottleneck (or by replacing it with a “dummy” module), you can proceed to identify the next bottleneck. Even if the overall performance for your application currently is acceptable, you should at least make a plan for each bottleneck and decide how to solve it if someday you really need the extra performance.

For examples of portable benchmark programs, look at those in the MySQL benchmark suite. See Section 8.13.2, “The MySQL Benchmark Suite”. You can take any program from this suite and modify it for your own needs. By doing this, you can try different solutions to your problem and test which really is fastest for you.


It is very common for a problem to occur only when the system is very heavily loaded. We have had many customers who contact us when they have a (tested) system in production and have encountered load problems. In most cases, performance problems turn out to be due to issues of basic database design (for example, table scans are not good under high load) or problems with the operating system or libraries. Most of the time, these problems would be much easier to fix if the systems were not already in production.

To avoid problems like this, benchmark your whole application under the worst possible load:

• The mysqlslap program can be helpful for simulating a high load produced by multiple clients issuing queries simultaneously. See Section 4.5.7, “mysqlslap — Load Emulation Client”.

• You can also try benchmarking packages such as SysBench and DBT2, available at https://launchpad.net/sysbench, and http://osdldb.sourceforge.net/#dbt2.

These programs or packages can bring a system to its knees, so be sure to use them only on your development systems.

8.13.4 Measuring Performance with performance_schema

You can query the tables in the performance_schema database to see real-time information about the performance characteristics of your server and the applications it is running. See Chapter 22, MySQL Performance Schema for details.

8.14 Examining Thread Information

As you monitor the performance of your MySQL server, examine the process list, which is the set of threads currently executing within the server. Process list information is available from these sources:

• The SHOW [FULL] PROCESSLIST statement: Section 13.7.5.30, “SHOW PROCESSLIST Statement”

• The SHOW PROFILE statement: Section 13.7.5.32, “SHOW PROFILES Statement”

• The INFORMATION_SCHEMA PROCESSLIST table: Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”

• The mysqladmin processlist command: Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
You can always view information about your own threads. To view information about threads being executed for other accounts, you must have the `PROCESS` privilege.

Each process list entry contains several pieces of information:

- **Id** is the connection identifier for the client associated with the thread.
- **User** and **Host** indicate the account associated with the thread.
- **db** is the default database for the thread, or **NULL** if none is selected.
- **Command** and **State** indicate what the thread is doing.
  
  Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

- **Time** indicates how long the thread has been in its current state. The thread's notion of the current time may be altered in some cases: The thread can change the time with `SET TIMESTAMP = value`. For a thread running on a slave that is processing events from the master, the thread time is set to the time found in the events and thus reflects current time on the master and not the slave.

- **Info** contains the text of the statement being executed by the thread, or **NULL** if it is not executing one. By default, this value contains only the first 100 characters of the statement. To see the complete statements, use `SHOW FULL PROCESSLIST`.

The following sections list the possible **Command** values, and **State** values grouped by category. The meaning for some of these values is self-evident. For others, additional description is provided.

### 8.14.1 Thread Command Values

A thread can have any of the following **Command** values:

- **Binlog Dump**
  This is a thread on a master server for sending binary log contents to a slave server.

- **Change user**
  The thread is executing a change-user operation.

- **Close stmt**
  The thread is closing a prepared statement.

- **Connect**
  A replication slave is connected to its master.

- **Connect Out**
  A replication slave is connecting to its master.

- **Create DB**
  The thread is executing a create-database operation.

- **Daemon**
  This thread is internal to the server, not a thread that services a client connection.
Thread Command Values

- **Debug**
  The thread is generating debugging information.

- **Delayed insert**
  The thread is a delayed-insert handler.

- **Drop DB**
  The thread is executing a drop-database operation.

- **Error**

- **Execute**
  The thread is executing a prepared statement.

- **Fetch**
  The thread is fetching the results from executing a prepared statement.

- **Field List**
  The thread is retrieving information for table columns.

- **Init DB**
  The thread is selecting a default database.

- **Kill**
  The thread is killing another thread.

- **Long Data**
  The thread is retrieving long data in the result of executing a prepared statement.

- **Ping**
  The thread is handling a server-ping request.

- **Prepare**
  The thread is preparing a prepared statement.

- **Processlist**
  The thread is producing information about server threads.

- **Query**
  The thread is executing a statement.

- **Quit**
  The thread is terminating.

- **Refresh**
The thread is flushing table, logs, or caches, or resetting status variable or replication server information.

- **Register Slave**
  The thread is registering a slave server.

- **Reset stmt**
  The thread is resetting a prepared statement.

- **Set option**
  The thread is setting or resetting a client statement-execution option.

- **Shutdown**
  The thread is shutting down the server.

- **Sleep**
  The thread is waiting for the client to send a new statement to it.

- **Statistics**
  The thread is producing server-status information.

- **Table Dump**
  The thread is sending table contents to a slave server.

- **Time**
  Unused.

### 8.14.2 General Thread States

The following list describes thread State values that are associated with general query processing and not more specialized activities such as replication. Many of these are useful only for finding bugs in the server.

- **After create**
  This occurs when the thread creates a table (including internal temporary tables), at the end of the function that creates the table. This state is used even if the table could not be created due to some error.

- **Analyzing**
  The thread is calculating a MyISAM table key distributions (for example, for ANALYZE TABLE).

- **checking permissions**
  The thread is checking whether the server has the required privileges to execute the statement.

- **Checking table**
  The thread is performing a table check operation.
• **cleaning up**
  The thread has processed one command and is preparing to free memory and reset certain state variables.

• **closing tables**
  The thread is flushing the changed table data to disk and closing the used tables. This should be a fast operation. If not, verify that you do not have a full disk and that the disk is not in very heavy use.

• **converting HEAP to MyISAM**
  The thread is converting an internal temporary table from a MEMORY table to an on-disk MyISAM table.

• **copy to tmp table**
  The thread is processing an ALTER TABLE statement. This state occurs after the table with the new structure has been created but before rows are copied into it.

• **Copying to group table**
  If a statement has different ORDER BY and GROUP BY criteria, the rows are sorted by group and copied to a temporary table.

• **Copying to tmp table**
  The server is copying to a temporary table in memory.

• **Copying to tmp table on disk**
  The server is copying to a temporary table on disk. The temporary result set has become too large (see Section 8.4.4, “Internal Temporary Table Use in MySQL”). Consequently, the thread is changing the temporary table from in-memory to disk-based format to save memory.

• **Creating index**
  The thread is processing ALTER TABLE ... ENABLE KEYS for a MyISAM table.

• **Creating sort index**
  The thread is processing a SELECT that is resolved using an internal temporary table.

• **creating table**
  The thread is creating a table. This includes creation of temporary tables.

• **Creating tmp table**
  The thread is creating a temporary table in memory or on disk. If the table is created in memory but later is converted to an on-disk table, the state during that operation will be Copying to tmp table on disk.

• **deleting from main table**
  The server is executing the first part of a multiple-table delete. It is deleting only from the first table, and saving columns and offsets to be used for deleting from the other (reference) tables.

• **deleting from reference tables**
The server is executing the second part of a multiple-table delete and deleting the matched rows from the other tables.

- **discard_or_import_tablespace**
  
The thread is processing an `ALTER TABLE ... DISCARD TABLESPACE` or `ALTER TABLE ... IMPORT TABLESPACE` statement.

- **end**
  
  This occurs at the end but before the cleanup of `ALTER TABLE, CREATE VIEW, DELETE, INSERT, SELECT, or UPDATE` statements.

- **executing**
  
The thread has begun executing a statement.

- **Execution of init_command**
  
The thread is executing statements in the value of the `init_command` system variable.

- **freeing items**
  
The thread has executed a command. Some freeing of items done during this state involves the query cache. This state is usually followed by cleaning up.

- **FULLTEXT initialization**
  
The server is preparing to perform a natural-language full-text search.

- **init**
  
  This occurs before the initialization of `ALTER TABLE, DELETE, INSERT, SELECT, or UPDATE` statements. Actions taken by the server in this state include flushing the binary log, the InnoDB log, and some query cache cleanup operations.

  For the **end** state, the following operations could be happening:

  - Removing query cache entries after data in a table is changed
  - Writing an event to the binary log
  - Freeing memory buffers, including for blobs

- **Killed**
  
  Someone has sent a `KILL` statement to the thread and it should abort next time it checks the kill flag. The flag is checked in each major loop in MySQL, but in some cases it might still take a short time for the thread to die. If the thread is locked by some other thread, the kill takes effect as soon as the other thread releases its lock.

- **logging slow query**
  
The thread is writing a statement to the slow-query log.

- **login**
  
The initial state for a connection thread until the client has been authenticated successfully.
General Thread States

- **manage keys**
  The server is enabling or disabling a table index.

- **NULL**
  This state is used for the `SHOW PROCESSLIST` state.

- **Opening tables, Opening table**
  The thread is trying to open a table. This should be a very fast procedure, unless something prevents opening. For example, an `ALTER TABLE` or a `LOCK TABLE` statement can prevent opening a table until the statement is finished. It is also worth checking that your `table_open_cache` value is large enough.

- **optimizing**
  The server is performing initial optimizations for a query.

- **preparing**
  This state occurs during query optimization.

- **Purging old relay logs**
  The thread is removing unneeded relay log files.

- **query end**
  This state occurs after processing a query but before the `freeing items` state.

- **Reading from net**
  The server is reading a packet from the network.

- **Removing duplicates**
  The query was using `SELECT DISTINCT` in such a way that MySQL could not optimize away the distinct operation at an early stage. Because of this, MySQL requires an extra stage to remove all duplicated rows before sending the result to the client.

- **removing tmp table**
  The thread is removing an internal temporary table after processing a `SELECT` statement. This state is not used if no temporary table was created.

- **rename**
  The thread is renaming a table.

- **rename result table**
  The thread is processing an `ALTER TABLE` statement, has created the new table, and is renaming it to replace the original table.

- **Reopen tables**
  The thread got a lock for the table, but noticed after getting the lock that the underlying table structure changed. It has freed the lock, closed the table, and is trying to reopen it.

- **Repair by sorting**
General Thread States

The repair code is using a sort to create indexes.

- **Repair done**
  
  The thread has completed a multithreaded repair for a MyISAM table.

- **Repair with keycache**
  
  The repair code is using creating keys one by one through the key cache. This is much slower than Repair by sorting.

- **Rolling back**
  
  The thread is rolling back a transaction.

- **Saving state**
  
  For MyISAM table operations such as repair or analysis, the thread is saving the new table state to the .MYI file header. State includes information such as number of rows, the AUTO_INCREMENT counter, and key distributions.

- **Searching rows for update**
  
  The thread is doing a first phase to find all matching rows before updating them. This has to be done if the UPDATE is changing the index that is used to find the involved rows.

- **Sending data**
  
  The thread is reading and processing rows for a SELECT statement, and sending data to the client. Because operations occurring during this state tend to perform large amounts of disk access (reads), it is often the longest-running state over the lifetime of a given query.

- **setup**
  
  The thread is beginning an ALTER TABLE operation.

- **Sorting for group**
  
  The thread is doing a sort to satisfy a GROUP BY.

- **Sorting for order**
  
  The thread is doing a sort to satisfy an ORDER BY.

- **Sorting index**
  
  The thread is sorting index pages for more efficient access during a MyISAM table optimization operation.

- **Sorting result**
  
  For a SELECT statement, this is similar to Creating sort index, but for nontemporary tables.

- **statistics**
  
  The server is calculating statistics to develop a query execution plan. If a thread is in this state for a long time, the server is probably disk-bound performing other work.

- **System lock**
General Thread States

The thread has called `mysql_lock_tables()` and the thread state has not been updated since. This is a very general state that can occur for many reasons.

For example, the thread is going to request or is waiting for an internal or external system lock for the table. This can occur when InnoDB waits for a table-level lock during execution of `LOCK TABLES`. If this state is being caused by requests for external locks and you are not using multiple `mysqld` servers that are accessing the same MyISAM tables, you can disable external system locks with the `--skip-external-locking` option. However, external locking is disabled by default, so it is likely that this option will have no effect. For `SHOW PROFILE`, this state means the thread is requesting the lock (not waiting for it).

- **update**
  
The thread is getting ready to start updating the table.

- **Updating**
  
The thread is searching for rows to update and is updating them.

- **updating main table**
  
The server is executing the first part of a multiple-table update. It is updating only the first table, and saving columns and offsets to be used for updating the other (reference) tables.

- **updating reference tables**
  
The server is executing the second part of a multiple-table update and updating the matched rows from the other tables.

- **User lock**
  
The thread is going to request or is waiting for an advisory lock requested with a `GET_LOCK()` call. For `SHOW PROFILE`, this state means the thread is requesting the lock (not waiting for it).

- **User sleep**
  
The thread has invoked a `SLEEP()` call.

- **Waiting for commit lock**
  
  A statement that causes an explicit or implicit commit is waiting for release of a read lock or `FLUSH TABLES WITH READ LOCK` is waiting for a commit lock.

- **Waiting for global read lock**
  
  `FLUSH TABLES WITH READ LOCK` is waiting for a global read lock or the global `read_only` system variable is being set.

- **Waiting for tables**
  
The thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. However, to reopen the table, it must wait until all other threads have closed the table in question.

  This notification takes place if another thread has used `FLUSH TABLES` or one of the following statements on the table in question: `FLUSH TABLES tbl_name`, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, or `OPTIMIZE TABLE`. 
Delayed-Insert Thread States

- Waiting for table flush

The thread is executing `FLUSH TABLES` and is waiting for all threads to close their tables, or the thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. However, to reopen the table, it must wait until all other threads have closed the table in question.

This notification takes place if another thread has used `FLUSH TABLES` or one of the following statements on the table in question: `FLUSH TABLES tbl_name`, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, or `OPTIMIZE TABLE`.

- Waiting for lock_type lock

The server is waiting to acquire a `THR_LOCK` lock or a lock from the metadata locking subsystem, where `lock_type` indicates the type of lock.

This state indicates a wait for a `THR_LOCK`:

- Waiting for table level lock

These states indicate a wait for a metadata lock:

- Waiting for event metadata lock
- Waiting for global metadata lock
- Waiting for global read lock
- Waiting for schema metadata lock
- Waiting for stored function metadata lock
- Waiting for stored procedure metadata lock
- Waiting for table metadata lock
- Waiting for trigger metadata lock

For information about table lock indicators, see Section 8.11.1, “Internal Locking Methods”. For information about metadata locking, see Section 8.11.4, “Metadata Locking”.

- Waiting on cond

A generic state in which the thread is waiting for a condition to become true. No specific state information is available.

- Writing to net

The server is writing a packet to the network.

8.14.3 Delayed-Insert Thread States

These thread states are associated with processing for `DELAYED` inserts (see Section 13.2.5.3, “INSERT DELAYED Statement”). Some states are associated with connection threads that process `INSERT DELAYED` statements from clients. Other states are associated with delayed-insert handler threads that insert the rows. There is a delayed-insert handler thread for each table for which `INSERT DELAYED` statements are issued.
States associated with a connection thread that processes an `INSERT DELAYED` statement from the client:

- **allocating local table**
  The thread is preparing to feed rows to the delayed-insert handler thread.

- **Creating delayed handler**
  The thread is creating a handler for `DELAYED` inserts.

- **got handler lock**
  This occurs before the `allocating local table` state and after the `waiting for handler lock` state, when the connection thread gets access to the delayed-insert handler thread.

- **got old table**
  This occurs after the `waiting for handler open` state. The delayed-insert handler thread has signaled that it has ended its initialization phase, which includes opening the table for delayed inserts.

- **storing row into queue**
  The thread is adding a new row to the list of rows that the delayed-insert handler thread must insert.

- **waiting for delay_list**
  This occurs during the initialization phase when the thread is trying to find the delayed-insert handler thread for the table, and before attempting to gain access to the list of delayed-insert threads.

- **waiting for handler insert**
  An `INSERT DELAYED` handler has processed all pending inserts and is waiting for new ones.

- **waiting for handler lock**
  This occurs before the `allocating local table` state when the connection thread waits for access to the delayed-insert handler thread.

- **waiting for handler open**
  This occurs after the `Creating delayed handler` state and before the `got old table` state. The delayed-insert handler thread has just been started, and the connection thread is waiting for it to initialize.

States associated with a delayed-insert handler thread that inserts the rows:

- **insert**
  The state that occurs just before inserting rows into the table.

- **reschedule**
  After inserting a number of rows, the delayed-insert thread sleeps to let other threads do work.

- **upgrading lock**
  A delayed-insert handler is trying to get a lock for the table to insert rows.

- **Waiting for INSERT**
A delayed-insert handler is waiting for a connection thread to add rows to the queue (see storing row into queue).

### 8.14.4 Query Cache Thread States

These thread states are associated with the query cache (see Section 8.10.3, “The MySQL Query Cache”).

- **checking privileges on cached query**
  The server is checking whether the user has privileges to access a cached query result.

- **checking query cache for query**
  The server is checking whether the current query is present in the query cache.

- **invalidating query cache entries**
  Query cache entries are being marked invalid because the underlying tables have changed.

- **sending cached result to client**
  The server is taking the result of a query from the query cache and sending it to the client.

- **storing result in query cache**
  The server is storing the result of a query in the query cache.

- **Waiting for query cache lock**
  This state occurs while a session is waiting to take the query cache lock. This can happen for any statement that needs to perform some query cache operation, such as an `INSERT` or `DELETE` that invalidates the query cache, a `SELECT` that looks for a cached entry, `RESET QUERY CACHE`, and so forth.

### 8.14.5 Replication Master Thread States

The following list shows the most common states you may see in the State column for the master's Binlog Dump thread. If you see no Binlog Dump threads on a master server, this means that replication is not running—that is, that no slaves are currently connected.

- **Finished reading one binlog; switching to next binlog**
  The thread has finished reading a binary log file and is opening the next one to send to the slave.

- **Master has sent all binlog to slave; waiting for binlog to be updated**
  The thread has read all outstanding updates from the binary logs and sent them to the slave. The thread is now idle, waiting for new events to appear in the binary log resulting from new updates occurring on the master.

- **Sending binlog event to slave**
  Binary logs consist of events, where an event is usually an update plus some other information. The thread has read an event from the binary log and is now sending it to the slave.

- **Waiting to finalize termination**
Replication Slave I/O Thread States

A very brief state that occurs as the thread is stopping.

8.14.6 Replication Slave I/O Thread States

The following list shows the most common states you see in the State column for a slave server I/O thread. This state also appears in the Slave_IO_State column displayed by SHOW SLAVE STATUS, so you can get a good view of what is happening by using that statement.

- **Checking master version**
  A state that occurs very briefly, after the connection to the master is established.

- **Connecting to master**
  The thread is attempting to connect to the master.

- **Queueing master event to the relay log**
  The thread has read an event and is copying it to the relay log so that the SQL thread can process it.

- **Reconnecting after a failed binlog dump request**
  The thread is trying to reconnect to the master.

- **Reconnecting after a failed master event read**
  The thread is trying to reconnect to the master. When connection is established again, the state becomes *Waiting for master to send event*.

- **Registering slave on master**
  A state that occurs very briefly after the connection to the master is established.

- **Requesting binlog dump**
  A state that occurs very briefly, after the connection to the master is established. The thread sends to the master a request for the contents of its binary logs, starting from the requested binary log file name and position.

- **Waiting for master to send event**
  The thread has connected to the master and is waiting for binary log events to arrive. This can last for a long time if the master is idle. If the wait lasts for slave_net_timeout seconds, a timeout occurs. At that point, the thread considers the connection to be broken and makes an attempt to reconnect.

- **Waiting for master update**
  The initial state before Connecting to master.

- **Waiting for slave mutex on exit**
  A state that occurs briefly as the thread is stopping.

- **Waiting for the slave SQL thread to free enough relay log space**
  You are using a nonzero relay_log_space_limit value, and the relay logs have grown large enough that their combined size exceeds this value. The I/O thread is waiting until the SQL thread frees enough space by processing relay log contents so that it can delete some relay log files.
Replication Slave SQL Thread States

- **Waiting to reconnect after a failed binlog dump request**
  If the binary log dump request failed (due to disconnection), the thread goes into this state while it sleeps, then tries to reconnect periodically. The interval between retries can be specified using the `CHANGE MASTER TO` statement.

- **Waiting to reconnect after a failed master event read**
  An error occurred while reading (due to disconnection). The thread is sleeping for the number of seconds set by the `CHANGE MASTER TO` statement (default 60) before attempting to reconnect.

### 8.14.7 Replication Slave SQL Thread States

The following list shows the most common states you may see in the `State` column for a slave server SQL thread:

- **Waiting for the next event in relay log**
  The initial state before Reading event from the relay log.

- **Reading event from the relay log**
  The thread has read an event from the relay log so that the event can be processed.

- **Making temp file**
  The thread is executing a `LOAD DATA` statement and is creating a temporary file containing the data from which the slave will read rows.

- **Slave has read all relay log; waiting for the slave I/O thread to update it**
  The thread has processed all events in the relay log files, and is now waiting for the I/O thread to write new events to the relay log.

- **Waiting for slave mutex on exit**
  A very brief state that occurs as the thread is stopping.

  The `State` column for the I/O thread may also show the text of a statement. This indicates that the thread has read an event from the relay log, extracted the statement from it, and is executing it.

### 8.14.8 Replication Slave Connection Thread States

These thread states occur on a replication slave but are associated with connection threads, not with the I/O or SQL threads.

- **Changing master**
  The thread is processing a `CHANGE MASTER TO` statement.

- **Killing slave**
  The thread is processing a `STOP SLAVE` statement.

- **Opening master dump table**
  This state occurs after Creating table from master dump.
• Reading master dump table data
  This state occurs after Opening master dump table.
• Rebuilding the index on master dump table
  This state occurs after Reading master dump table data.

### 8.14.9 NDB Cluster Thread States

- Committing events to binlog
- Opening mysql.ndb_apply_status
- Processing events
  The thread is processing events for binary logging.
- Processing events from schema table
  The thread is doing the work of schema replication.
- Shutting down
- Syncing ndb table schema operation and binlog
  This is used to have a correct binary log of schema operations for NDB.
- Waiting for allowed to take ndbcluster global schema lock
  The thread is waiting for permission to take a global schema lock. Added in MySQL NDB Cluster 7.2.
- Waiting for event from ndbcluster
  The server is acting as an SQL node in an NDB Cluster, and is connected to a cluster management node.
- Waiting for first event from ndbcluster
- Waiting for ndbcluster binlog update to reach current position
- Waiting for ndbcluster global schema lock
  The thread is waiting for a global schema lock held by another thread to be released. Added in MySQL NDB Cluster 7.2.
- Waiting for ndbcluster to start
- Waiting for schema epoch
  The thread is waiting for a schema epoch (that is, a global checkpoint).

### 8.14.10 Event Scheduler Thread States

These states occur for the Event Scheduler thread, threads that are created to execute scheduled events, or threads that terminate the scheduler.

- Clearing
The scheduler thread or a thread that was executing an event is terminating and is about to end.

• **Initialized**
  
The scheduler thread or a thread that will execute an event has been initialized.

• **Waiting for next activation**
  
The scheduler has a nonempty event queue but the next activation is in the future.

• **Waiting for scheduler to stop**
  
The thread issued `SET GLOBAL event_scheduler=OFF` and is waiting for the scheduler to stop.

• **Waiting on empty queue**
  
The scheduler's event queue is empty and it is sleeping.
This chapter discusses the rules for writing the following elements of SQL statements when using MySQL:

- Literal values such as strings and numbers
- Identifiers such as database, table, and column names
- Keywords and reserved words
- User-defined and system variables
- Comments

### 9.1 Literal Values

This section describes how to write literal values in MySQL. These include strings, numbers, hexadecimal and bit values, boolean values, and NULL. The section also covers various nuances that you may encounter when dealing with these basic types in MySQL.

#### 9.1.1 String Literals

A string is a sequence of bytes or characters, enclosed within either single quote (') or double quote (") characters. Examples:

```
'a string'
"another_string"
```

Quoted strings placed next to each other are concatenated to a single string. The following lines are equivalent:

```
'a string'
'a' ' ' 'string'
```
If the `ANSI_QUOTES` SQL mode is enabled, string literals can be quoted only within single quotation marks because a string quoted within double quotation marks is interpreted as an identifier.

A binary string is a string of bytes. Every binary string has a character set and collation named binary. A nonbinary string is a string of characters. It has a character set other than binary and a collation that is compatible with the character set.

For both types of strings, comparisons are based on the numeric values of the string unit. For binary strings, the unit is the byte; comparisons use numeric byte values. For nonbinary strings, the unit is the character and some character sets support multibyte characters; comparisons use numeric character code values. Character code ordering is a function of the string collation. (For more information, see Section 10.8.5, "The binary Collation Compared to _bin Collations".)

A character string literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name]'string' [COLLATE collation_name]
```

Examples:

```sql
SELECT _latin1'string';
SELECT _binary'string';
SELECT _utf8'string' COLLATE utf8_danish_ci;
```

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```sql
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```

For information about these forms of string syntax, see Section 10.3.7, "The National Character Set", and Section 10.3.8, "Character Set Introducers".

Within a string, certain sequences have special meaning unless the `NO_BACKSLASH_ESCAPES` SQL mode is enabled. Each of these sequences begins with a backslash (\), known as the escape character. MySQL recognizes the escape sequences shown in Table 9.1, "Special Character Escape Sequences". For all other escape sequences, backslash is ignored. That is, the escaped character is interpreted as if it was not escaped. For example, \x is just x. These sequences are case-sensitive. For example, \B is interpreted as B. Escape processing is done according to the character set indicated by the `character_set_connection` system variable. This is true even for strings that are preceded by an introducer that indicates a different character set, as discussed in Section 10.3.6, "Character String Literal Character Set and Collation".

### Table 9.1 Special Character Escape Sequences

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Character Represented by Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>\0</td>
<td>An ASCII NUL (X'00') character</td>
</tr>
<tr>
<td>'</td>
<td>A single quote (') character</td>
</tr>
<tr>
<td>&quot;</td>
<td>A double quote (&quot;), character</td>
</tr>
<tr>
<td>\b</td>
<td>A backspace character</td>
</tr>
<tr>
<td>\n</td>
<td>A newline (linefeed) character</td>
</tr>
<tr>
<td>\r</td>
<td>A carriage return character</td>
</tr>
<tr>
<td>\t</td>
<td>A tab character</td>
</tr>
</tbody>
</table>
String Literals

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Character Represented by Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>\Z</td>
<td>ASCII 26 (Control+Z); see note following the table</td>
</tr>
<tr>
<td>\   \</td>
<td>A backslash () character</td>
</tr>
<tr>
<td>%</td>
<td>A % character; see note following the table</td>
</tr>
<tr>
<td>_</td>
<td>A _ character; see note following the table</td>
</tr>
</tbody>
</table>

The ASCII 26 character can be encoded as \Z to enable you to work around the problem that ASCII 26 stands for END-OF-FILE on Windows. ASCII 26 within a file causes problems if you try to use mysql db_name < file_name.

The \% and \_ sequences are used to search for literal instances of % and _ in pattern-matching contexts where they would otherwise be interpreted as wildcard characters. See the description of the LIKE operator in Section 12.7.1, “String Comparison Functions and Operators”. If you use \% or \_ outside of pattern-matching contexts, they evaluate to the strings \% and \_, not to % and _.

There are several ways to include quote characters within a string:

- A ' inside a string quoted with ' may be written as ' '.
- A " inside a string quoted with " may be written as " ".
- Precede the quote character by an escape character (\).
- A ' inside a string quoted with " needs no special treatment and need not be doubled or escaped. In the same way, " inside a string quoted with ' needs no special treatment.

The following SELECT statements demonstrate how quoting and escaping work:

```
mysql> SELECT 'hello', "hello", '"hello"', 'hel''lo', '\hello';
+-------+---------+-----------+--------+--------+
| hello | "hello" | ""hello"" | hel'lo | 'hello |
+-------+---------+-----------+--------+--------+
mysql> SELECT "hello", '"hello"', "'hello"', "hel''lo", "\hello";
+-------+---------+-----------+--------+--------+
| hello | "hello" | "'hello" | hel"lo | "hello |
+-------+---------+-----------+--------+--------+
mysql> SELECT 'This
Is
Four
Lines';
+------------------------+
| This
Is
Four
Lines | +------------------------+
mysql> SELECT 'disappearing\ backslash';
+-+------------------------+
| disappearing backslash | +------------------------+
```

To insert binary data into a string column (such as a BLOB column), you should represent certain characters by escape sequences. Backslash (\) and the quote character used to quote the string must be escaped. In certain client environments, it may also be necessary to escape NUL or Control+Z. The mysql client truncates quoted strings containing NUL characters if they are not escaped, and Control+Z may be taken for END-OF-FILE on Windows if not escaped. For the escape sequences that represent each of these characters, see Table 9.1, “Special Character Escape Sequences”.

1031
When writing application programs, any string that might contain any of these special characters must be properly escaped before the string is used as a data value in an SQL statement that is sent to the MySQL server. You can do this in two ways:

- Process the string with a function that escapes the special characters. In a C program, you can use the `mysql_real_escape_string()` C API function to escape characters. See Section 23.7.6.53, "mysql_real_escape_string()". Within SQL statements that construct other SQL statements, you can use the `QUOTE()` function. The Perl DBI interface provides a `quote` method to convert special characters to the proper escape sequences. See Section 23.9, "MySQL Perl API". Other language interfaces may provide a similar capability.

- As an alternative to explicitly escaping special characters, many MySQL APIs provide a placeholder capability that enables you to insert special markers into a statement string, and then bind data values to them when you issue the statement. In this case, the API takes care of escaping special characters in the values for you.

### 9.1.2 Numeric Literals

Number literals include exact-value (integer and `DECIMAL`) literals and approximate-value (floating-point) literals.

Integers are represented as a sequence of digits. Numbers may include . as a decimal separator. Numbers may be preceded by – or + to indicate a negative or positive value, respectively. Numbers represented in scientific notation with a mantissa and exponent are approximate-value numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: 1, .2, 3.4, −5, −6.78, +9.10.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: 1.2E3, 1.2E-3, −1.2E3, −1.2E-3.

Two numbers that look similar may be treated differently. For example, 2.34 is an exact-value (fixed-point) number, whereas 2.34E0 is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types. For more information about exact-value calculations, see Section 12.19, "Precision Math".

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

An integer may be used in floating-point context; it is interpreted as the equivalent floating-point number.

### 9.1.3 Date and Time Literals

Date and time values can be represented in several formats, such as quoted strings or as numbers, depending on the exact type of the value and other factors. For example, in contexts where MySQL expects a date, it interprets any of '2015-07-21', '20150721', and 20150721 as a date.

This section describes the acceptable formats for date and time literals. For more information about the temporal data types, such as the range of permitted values, see Section 11.2, "Date and Time Data Types".

**Standard SQL and ODBC Date and Time Literals.** Standard SQL permits temporal literals to be specified using a type keyword and a string. The space between the keyword and string is optional.
Date and Time Literals

MySQL recognizes those constructions and also the corresponding ODBC syntax:

```
TIME 'str'
TIMESTAMP 'str'
```

However, MySQL ignores the type keyword and each of the preceding constructions produces the string value `str`, with a type of VARCHAR.

String and Numeric Literals in Date and Time Context. MySQL recognizes DATE values in these formats:

- As a string in either 'YYYY-MM-DD' or 'YY-MM-DD' format. A "relaxed" syntax is permitted: Any punctuation character may be used as the delimiter between date parts. For example, '2012-12-31', '2012^12^31', and '2012@12@31' are equivalent.

- As a string with no delimiters in either 'YYYYMMDD' or 'YYMMDD' format, provided that the string makes sense as a date. For example, '20070523' and '070523' are interpreted as '2007-05-23', but '071332' is illegal (it has nonsensical month and day parts) and becomes '0000-00-00'.

- As a number in either YYYYMMDD or YYMMDD format, provided that the number makes sense as a date. For example, 19830905 and 830905 are interpreted as '1983-09-05'.

MySQL recognizes DATETIME and TIMESTAMP values in these formats:

- As a string in either 'YYYY-MM-DD hh:mm:ss' or 'YY-MM-DD hh:mm:ss' format. A "relaxed" syntax is permitted here, too: Any punctuation character may be used as the delimiter between date parts or time parts. For example, '2012-12-31 11:30:45', '2012^12^31 11+30+45', '2012/12/31 11*30*45', and '2012@12@31 11^30^45' are equivalent.

    The date and time parts can be separated by T rather than a space. For example, '2012-12-31 11:30:45' '2012-12-31T11:30:45' are equivalent.

- As a string with no delimiters in either 'YYYYMMDDhhmmss' or 'YYMMDDhhmmss' format, provided that the string makes sense as a date. For example, '20070523091528' and '070523091528' are interpreted as '2007-05-23 09:15:28', but '071122129015' is illegal (it has a nonsensical minute part) and becomes '0000-00-00 00:00:00'.

- As a number in either YYYYMMDDhhmmss or YYMMDDhhmmss format, provided that the number makes sense as a date. For example, 19830905132800 and 830905132800 are interpreted as '1983-09-05 13:28:00'.

A DATETIME or TIMESTAMP value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into DATETIME or TIMESTAMP columns. For information about fractional seconds support in MySQL, see Section 11.2.7, “Fractional Seconds in Time Values”.

Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:

- Year values in the range 00–69 become 2000–2069.

See also Section 11.2.9, “2-Digit Years in Dates”.
For values specified as strings that include date part delimiters, it is unnecessary to specify two digits for month or day values that are less than 10. '2015-6-9' is the same as '2015-06-09'. Similarly, for values specified as strings that include time part delimiters, it is unnecessary to specify two digits for hour, minute, or second values that are less than 10. '2015-10-30 1:2:3' is the same as '2015-10-30 01:02:03'.

Values specified as numbers should be 6, 8, 12, or 14 digits long. If a number is 8 or 14 digits long, it is assumed to be in YYYYMMDD or YYYYMMDDhhmmss format and that the year is given by the first 4 digits. If the number is 6 or 12 digits long, it is assumed to be in YYMMDD or YYMMDDhhmmss format and that the year is given by the first 2 digits. Numbers that are not one of these lengths are interpreted as though padded with leading zeros to the closest length.

Values specified as nondelimited strings are interpreted according their length. For a string 8 or 14 characters long, the year is assumed to be given by the first 4 characters. Otherwise, the year is assumed to be given by the first 2 characters. The string is interpreted from left to right to find year, month, day, hour, minute, and second values, for as many parts as are present in the string. This means you should not use strings that have fewer than 6 characters. For example, if you specify '9903', thinking that represents March, 1999, MySQL converts it to the “zero” date value. This occurs because the year and month values are 99 and 03, but the day part is completely missing. However, you can explicitly specify a value of zero to represent missing month or day parts. For example, to insert the value '1999-03-00', use '990300'.

MySQL recognizes TIME values in these formats:

- As a string in 'D hh:mm:ss' format. You can also use one of the following “relaxed” syntaxes: 'hh:mm:ss', 'hh:mm', 'D hh:mm', 'D hh', or 'ss'. Here D represents days and can have a value from 0 to 34.
- As a string with no delimiters in 'hhmmss' format, provided that it makes sense as a time. For example, '101112' is understood as '10:11:12', but '109712' is illegal (it has a nonsensical minute part) and becomes '00:00:00'.
- As a number in hhmmss format, provided that it makes sense as a time. For example, 101112 is understood as '10:11:12'. The following alternative formats are also understood: ss, mmss, or hhmmss.

A trailing fractional seconds part is recognized in the 'D hh:mm:ss.fraction', 'hh:mm:ss.fraction', 'hhmmss.fraction', and hhmmss.fraction time formats, where fraction is the fractional part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into TIME columns. For information about fractional seconds support in MySQL, see Section 11.2.7, “Fractional Seconds in Time Values”.

For TIME values specified as strings that include a time part delimiter, it is unnecessary to specify two digits for hours, minutes, or seconds values that are less than 10. '8:3:2' is the same as '08:03:02'.

### 9.1.4 Hexadecimal Literals

Hexadecimal literal values are written using X'val' or Oxval notation, where val contains hexadecimal digits (0..9, A..F). Lettercase of the digits and of any leading X does not matter. A leading 0x is case-sensitive and cannot be written as 0X.

Legal hexadecimal literals:

<table>
<thead>
<tr>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>X'01AF'</td>
</tr>
<tr>
<td>X'01af'</td>
</tr>
<tr>
<td>x'01AF'</td>
</tr>
<tr>
<td>x'01af'</td>
</tr>
<tr>
<td>0x01AF</td>
</tr>
</tbody>
</table>
Hexadecimal Literals

0x01af

Illegal hexadecimal literals:

X'0G'   (G is not a hexadecimal digit)
0X01AF  (0X must be written as 0x)

Values written using X'val' notation must contain an even number of digits or a syntax error occurs. To correct the problem, pad the value with a leading zero:

```sql
mysql> SET @s = X'FFF';
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use near 'X'FFF''
```

```sql
mysql> SET @s = X'0FFF';
Query OK, 0 rows affected (0.00 sec)
```

Values written using 0xval notation that contain an odd number of digits are treated as having an extra leading 0. For example, 0xaaa is interpreted as 0x0aaa.

By default, a hexadecimal literal is a binary string, where each pair of hexadecimal digits represents a character:

```sql
mysql> SELECT X'4D7953514C', CHARSET(X'4D7953514C');
+---------------+------------------------+
| X'4D7953514C' | CHARSET(X'4D7953514C') |
| MySQL         | binary                 |
+---------------+------------------------+
```

```sql
mysql> SELECT 0x5461626c65, CHARSET(0x5461626c65);
+--------------+-----------------------+
| 0x5461626c65 | CHARSET(0x5461626c65) |
| Table        | binary                |
+--------------+-----------------------+
```

A hexadecimal literal may have an optional character set introducer and COLLATE clause, to designate it as a string that uses a particular character set and collation:

```
[_charsetName] X'val' [COLLATE collationName]
```

Examples:

```
SELECT _latin1 X'4D7953514C';
SELECT _utf8 0x4D7953514C COLLATE utf8_danish_ci;
```

The examples use X'val' notation, but 0xval notation permits introducers as well. For information about introducers, see Section 10.3.8, “Character Set Introducers”.

In numeric contexts, MySQL treats a hexadecimal literal like a BIGINT (64-bit integer). To ensure numeric treatment of a hexadecimal literal, use it in numeric context. Ways to do this include adding 0 or using CAST(... AS UNSIGNED). For example, a hexadecimal literal assigned to a user-defined variable is a binary string by default. To assign the value as a number, use it in numeric context:

```sql
mysql> SET @v1 = X'41';
mysql> SET @v2 = X'41'+0;
mysql> SET @v3 = CAST(X'41' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
```

```
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
```

1035
An empty hexadecimal value (X'\0') evaluates to a zero-length binary string. Converted to a number, it produces 0:

```sql
mysql> SELECT CHARSET(X'\0'), LENGTH(X'\0');
+---------------------+-------------+
| CHARSET(X'\0')      | LENGTH(X'\0') |
| binary              | 0            |
+---------------------+-------------+
mysql>
```

The X'val' notation is based on standard SQL. The 0x notation is based on ODBC, for which hexadecimal strings are often used to supply values for BLOB columns.

To convert a string or a number to a string in hexadecimal format, use the HEX() function:

```sql
mysql> SELECT HEX('cat');
+------------+
| HEX('cat') |
+------------+
| 636174     |
+------------+

mysql> SELECT X'636174';
+-----------+
| X'636174' |
+-----------+
| cat       |
```

### 9.1.5 Bit-Value Literals

Bit-value literals are written using b'val' or 0bval notation. val is a binary value written using zeros and ones. Lettercase of any leading b does not matter. A leading 0b is case-sensitive and cannot be written as 0B.

Legal bit-value literals:

- b'01'
- B'01'
- 0b01

Illegal bit-value literals:

- b'2' (2 is not a binary digit)
- 0B01 (0B must be written as 0b)

By default, a bit-value literal is a binary string:

```sql
mysql> SELECT b'1000001', CHARSET(b'1000001');
+------------+---------------------+
| b'1000001' | CHARSET(b'1000001') |
| A          | binary              |
+------------+---------------------+
mysql>
```

```sql
mysql> SELECT 0b1100001, CHARSET(0b1100001);
+-----------+--------------------+
| 0b1100001 | CHARSET(0b1100001) |
```

```sql
mysql> SELECT b'1000001', CHARSET(b'1000001');
+------------+---------------------+
| b'1000001' | CHARSET(b'1000001') |
| A          | binary              |
+------------+---------------------+
mysql>
```
A bit-value literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_[charsetName]] b'val' [COLLATE collationName]
```

Examples:

```
SELECT _latin1 b'1000001';
SELECT _utf8 0b1000001 COLLATE utf8_danish_ci;
```

The examples use `b'val'` notation, but `0bval` notation permits introducers as well. For information about introducers, see Section 10.3.8, “Character Set Introducers”.

In numeric contexts, MySQL treats a bit literal like an integer. To ensure numeric treatment of a bit literal, use it in numeric context. Ways to do this include adding 0 or using `CAST(... AS UNSIGNED)`. For example, a bit literal assigned to a user-defined variable is a binary string by default. To assign the value as a number, use it in numeric context:

```
mysql> SET @v1 = b'1100001';
mysql> SET @v2 = b'1100001'+0;
mysql> SET @v3 = CAST(b'1100001' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
| a    |   97 |   97 |
+------+------+------+
```

An empty bit value (`b''`) evaluates to a zero-length binary string. Converted to a number, it produces 0:

```
mysql> SELECT CHARSET(b''), LENGTH(b'');
+--------------+-------------+
| CHARSET(b'') | LENGTH(b'') |
| binary       |           0 |
+--------------+-------------+
mysql> SELECT b''+0;
+-------+
| b''+0 |
|     0 |
+-------+
```

Bit-value notation is convenient for specifying values to be assigned to `BIT` columns:

```
mysql> CREATE TABLE t (b BIT(8));
mysql> INSERT INTO t SET b = b'11111111';
mysql> INSERT INTO t SET b = b'1010';
mysql> INSERT INTO t SET b = b'0101';
```

Bit values in result sets are returned as binary values, which may not display well. To convert a bit value to printable form, use it in numeric context or use a conversion function such as `BIN()` or `HEX()`. High-order 0 digits are not displayed in the converted value.

```
mysql> SELECT b+0, BIN(b), OCT(b), HEX(b) FROM t;
+--------+--------+--------+--------+
| b+0    | BIN(b) | OCT(b) | HEX(b) |
| 255    | 11111111 | 377    | FF     |
```
9.1.6 Boolean Literals

The constants `TRUE` and `FALSE` evaluate to 1 and 0, respectively. The constant names can be written in any lettercase.

```sql
mysql> SELECT TRUE, true, FALSE, false;
-> 1, 1, 0, 0
```

9.1.7 NULL Values

The `NULL` value means “no data.” `NULL` can be written in any lettercase. A synonym is `\N` (case-sensitive).

Be aware that the `NULL` value is different from values such as 0 for numeric types or the empty string for string types. For more information, see Section B.4.4.3, “Problems with NULL Values”.

For text file import or export operations performed with `LOAD DATA` or `SELECT ... INTO OUTFILE`, `NULL` is represented by the `\N` sequence. See Section 13.2.6, “LOAD DATA Statement”.

For sorting with `ORDER BY`, `NULL` values sort before other values for ascending sorts, after other values for descending sorts.

9.2 Schema Object Names

Certain objects within MySQL, including database, table, index, column, alias, view, stored procedure, partition, tablespace, and other object names are known as identifiers. This section describes the permissible syntax for identifiers in MySQL. Section 9.2.1, “Identifier Length Limits”, indicates the maximum length of each type of identifier. Section 9.2.3, “Identifier Case Sensitivity”, describes which types of identifiers are case-sensitive and under what conditions.

An identifier may be quoted or unquoted. If an identifier contains special characters or is a reserved word, you must quote it whenever you refer to it. (Exception: A reserved word that follows a period in a qualified name must be an identifier, so it need not be quoted.) Reserved words are listed at Section 9.3, “Keywords and Reserved Words”.

Internally, identifiers are converted to and are stored as Unicode (UTF-8). The permissible Unicode characters in identifiers are those in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted. Identifiers thus may contain these characters:

- Permitted characters in unquoted identifiers:
  - ASCII: [0-9,a-z,A-Z$_] (basic Latin letters, digits 0-9, dollar, underscore)
  - Extended: U+0080 .. U+FFFF

- Permitted characters in quoted identifiers include the full Unicode Basic Multilingual Plane (BMP), except U+0000:
  - ASCII: U+0001 .. U+007F
  - Extended: U+0080 .. U+FFFF

- ASCII NUL (U+0000) and supplementary characters (U+10000 and higher) are not permitted in quoted or unquoted identifiers.
Schema Object Names

- Identifiers may begin with a digit but unless quoted may not consist solely of digits.
- Database, table, and column names cannot end with space characters.

The identifier quote character is the backtick (`):

```sql
mysql> SELECT * FROM `select` WHERE `select`.id > 100;
```

If the `ANSI_QUOTES` SQL mode is enabled, it is also permissible to quote identifiers within double quotation marks:

```sql
mysql> CREATE TABLE "test" (col INT);
ERROR 1064: You have an error in your SQL syntax...
mysql> SET sql_mode='ANSI_QUOTES';
mysql> CREATE TABLE "test" (col INT);
Query OK, 0 rows affected (0.00 sec)
```

The `ANSI_QUOTES` mode causes the server to interpret double-quoted strings as identifiers. Consequently, when this mode is enabled, string literals must be enclosed within single quotation marks. They cannot be enclosed within double quotation marks. The server SQL mode is controlled as described in Section 5.1.10, “Server SQL Modes”.

Identifier quote characters can be included within an identifier if you quote the identifier. If the character to be included within the identifier is the same as that used to quote the identifier itself, then you need to double the character. The following statement creates a table named `a``b` that contains a column named `c``d`:

```sql
mysql> CREATE TABLE `a``b` (`c``d` INT);
```

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:

```sql
mysql> SELECT 1 AS `one`, 2 AS 'two';
```

```
+-----+-----+
| one | two |
+-----+-----+
|   1 |   2 |
+-----+-----+
```

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal.

It is recommended that you do not use names that begin with `Me` or `MeN`, where `M` and `N` are integers. For example, avoid using `1e` as an identifier, because an expression such as `1e+3` is ambiguous. Depending on context, it might be interpreted as the expression `1e + 3` or as the number `1e+3`.

Be careful when using `MD5()` to produce table names because it can produce names in illegal or ambiguous formats such as those just described.

A user variable cannot be used directly in an SQL statement as an identifier or as part of an identifier. See Section 9.4, “User-Defined Variables”, for more information and examples of workarounds.

Special characters in database and table names are encoded in the corresponding file system names as described in Section 9.2.4, “Mapping of Identifiers to File Names”. If you have databases or tables from an older version of MySQL that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of `#mysql50#`. For information about referring to such names or converting them to the newer encoding, see that section.
9.2.1 Identifier Length Limits

The following table describes the maximum length for each type of identifier.

<table>
<thead>
<tr>
<th>Identifier Type</th>
<th>Maximum Length (characters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database</td>
<td>64 (NDB storage engine: 63)</td>
</tr>
<tr>
<td>Table</td>
<td>64 (NDB storage engine: 63)</td>
</tr>
<tr>
<td>Column</td>
<td>64</td>
</tr>
<tr>
<td>Index</td>
<td>64</td>
</tr>
<tr>
<td>Constraint</td>
<td>64</td>
</tr>
<tr>
<td>Stored Program</td>
<td>64</td>
</tr>
<tr>
<td>View</td>
<td>64</td>
</tr>
<tr>
<td>Tablespace</td>
<td>64</td>
</tr>
<tr>
<td>Server</td>
<td>64</td>
</tr>
<tr>
<td>Log File Group</td>
<td>64</td>
</tr>
<tr>
<td>Alias</td>
<td>256 (see exception following table)</td>
</tr>
<tr>
<td>Compound Statement Label</td>
<td>16</td>
</tr>
</tbody>
</table>

Aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

For constraint definitions that include no constraint name, the server internally generates a name derived from the associated table name. For example, internally generated foreign key constraint names consist of the table name plus `_ibfk_` and a number. If the table name is close to the length limit for constraint names, the additional characters required for the constraint name may cause that name to exceed the limit, resulting in an error.

Identifiers are stored using Unicode (UTF-8). This applies to identifiers in table definitions that are stored in `.frm` files and to identifiers stored in the grant tables in the `mysql` database. The sizes of the identifier string columns in the grant tables are measured in characters. You can use multibyte characters without reducing the number of characters permitted for values stored in these columns.

NDB Cluster imposes a maximum length of 63 characters for names of databases and tables. See Section 18.1.7.5, “Limits Associated with Database Objects in NDB Cluster”.

Values such as user name and host names in MySQL account names are strings rather than identifiers. For information about the maximum length of such values as stored in grant tables, see Grant Table Scope Column Properties.
9.2.2 Identifier Qualifiers

Object names may be unqualified or qualified. An unqualified name is permitted in contexts where interpretation of the name is unambiguous. A qualified name includes at least one qualifier to clarify the interpretive context by overriding a default context or providing missing context.

For example, this statement creates a table using the unqualified name \texttt{t1}:

\begin{verbatim}
CREATE TABLE t1 (i INT);
\end{verbatim}

Because \texttt{t1} includes no qualifier to specify a database, the statement creates the table in the default database. If there is no default database, an error occurs.

This statement creates a table using the qualified name \texttt{db1.t1}:

\begin{verbatim}
CREATE TABLE db1.t1 (i INT);
\end{verbatim}

Because \texttt{db1.t1} includes a database qualifier \texttt{db1}, the statement creates \texttt{t1} in the database named \texttt{db1}, regardless of the default database. The qualifier \texttt{must} be specified if there is no default database. The qualifier \texttt{may} be specified if there is a default database, to specify a database different from the default, or to make the database explicit if the default is the same as the one specified.

Qualifiers have these characteristics:

- An unqualified name consists of a single identifier. A qualified name consists of multiple identifiers.

- The components of a multiple-part name must be separated by period (\texttt{.}) characters. The initial parts of a multiple-part name act as qualifiers that affect the context within which to interpret the final identifier.

- The qualifier character is a separate token and need not be contiguous with the associated identifiers. For example, \texttt{tbl_name.col_name} and \texttt{tbl_name . col_name} are equivalent.

- If any components of a multiple-part name require quoting, quote them individually rather than quoting the name as a whole. For example, write `my-table`.`my-column`, not `my-table.my-column`.

- A reserved word that follows a period in a qualified name must be an identifier, so in that context it need not be quoted.

- The syntax \texttt{.tbl_name} means the table \texttt{tbl_name} in the default database. This syntax is accepted for ODBC compatibility because some ODBC programs prefix table names with a \texttt{.} character.

The permitted qualifiers for object names depend on the object type:

- A database name is fully qualified and takes no qualifier:

\begin{verbatim}
CREATE DATABASE db1;
\end{verbatim}

- A table, view, or stored program name may be given a database-name qualifier. Examples of unqualified and qualified names in \texttt{CREATE} statements:

\begin{verbatim}
CREATE TABLE mytable ...;
CREATE VIEW myview ...;
CREATE PROCEDURE myproc ...;
CREATE FUNCTION myfunc ...;
CREATE EVENT myevent ...;
CREATE TABLE mydb.mytable ...;
CREATE VIEW mydb.myview ...;
CREATE PROCEDURE mydb.myproc ...;
CREATE FUNCTION mydb.myfunc ...;
\end{verbatim}
CREATE EVENT mydb.myevent ...;

• A trigger is associated with a table, so any qualifier applies to the table name:

CREATE TRIGGER mytrigger ... ON mytable ...;
CREATE TRIGGER mytrigger ... ON mydb.mytable ...;

• A column name may be given multiple qualifiers to indicate context in statements that reference it, as shown in the following table.

<table>
<thead>
<tr>
<th>Column Reference</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>col_name</td>
<td>Column col_name from whichever table used in the statement contains a column of that name</td>
</tr>
<tr>
<td>tbl_name.col_name</td>
<td>Column col_name from table tbl_name of the default database</td>
</tr>
<tr>
<td>db_name.tbl_name.col_name</td>
<td>Column col_name from table tbl_name of the database db_name</td>
</tr>
</tbody>
</table>

In other words, a column name may be given a table-name qualifier, which itself may be given a database-name qualifier. Examples of unqualified and qualified column references in `SELECT` statements:

```
SELECT c1 FROM mytable
WHERE c2 > 100;

SELECT mytable.c1 FROM mytable
WHERE mytable.c2 > 100;

SELECT mydb.mytable.c1 FROM mydb.mytable
WHERE mydb.mytable.c2 > 100;
```

You need not specify a qualifier for an object reference in a statement unless the unqualified reference is ambiguous. Suppose that column c1 occurs only in table t1, c2 only in t2, and c in both t1 and t2. Any unqualified reference to c is ambiguous in a statement that refers to both tables and must be qualified as t1.c or t2.c to indicate which table you mean:

```
SELECT c1, c2, t1.c FROM t1 INNER JOIN t2
WHERE t2.c > 100;
```

Similarly, to retrieve from a table t in database db1 and from a table t in database db2 in the same statement, you must qualify the table references: For references to columns in those tables, qualifiers are required only for column names that appear in both tables. Suppose that column c1 occurs only in table db1.t, c2 only in db2.t, and c in both db1.t and db2.t. In this case, c is ambiguous and must be qualified but c1 and c2 need not be:

```
SELECT c1, c2, db1.t.c FROM db1.t INNER JOIN db2.t
WHERE db2.t.c > 100;
```

Table aliases enable qualified column references to be written more simply:

```
SELECT c1, c2, t1.c FROM db1.t AS t1 INNER JOIN db2.t AS t2
WHERE t2.c > 100;
```

### 9.2.3 Identifier Case Sensitivity

In MySQL, databases correspond to directories within the data directory. Each table within a database corresponds to at least one file within the database directory (and possibly more, depending on the storage engine). Triggers also correspond to files. Consequently, the case sensitivity of the underlying...
Identifier Case Sensitivity

operating system plays a part in the case sensitivity of database, table, and trigger names. This means
such names are not case-sensitive in Windows, but are case-sensitive in most varieties of Unix. One
notable exception is macOS, which is Unix-based but uses a default file system type (HFS+) that is not
case-sensitive. However, macOS also supports UFS volumes, which are case-sensitive just as on any
Unix. See Section 1.7.1, “MySQL Extensions to Standard SQL”. The lower_case_table_names system
variable also affects how the server handles identifier case sensitivity, as described later in this section.

Note

Although database, table, and trigger names are not case sensitive on some
platforms, you should not refer to one of these using different cases within the same
statement. The following statement would not work because it refers to a table both
as my_table and as MY_TABLE:

    mysql> SELECT * FROM my_table WHERE MY_TABLE.col=1;

Column, index, stored routine, and event names are not case sensitive on any platform, nor are column
aliases.

However, names of logfile groups are case-sensitive. This differs from standard SQL.

By default, table aliases are case-sensitive on Unix, but not so on Windows or macOS. The following
statement would not work on Unix, because it refers to the alias both as a and as A:

    mysql> SELECT col_name FROM tbl_name AS a
       WHERE a.col_name = 1 OR A.col_name = 2;

However, this same statement is permitted on Windows. To avoid problems caused by such differences,
it is best to adopt a consistent convention, such as always creating and referring to databases and tables
using lowercase names. This convention is recommended for maximum portability and ease of use.

How table and database names are stored on disk and used in MySQL is affected by the
lower_case_table_names system variable, which you can set when starting mysqld.
lower_case_table_names can take the values shown in the following table. This variable does not
affect case sensitivity of trigger identifiers. On Unix, the default value of lower_case_table_names is 0.
On Windows, the default value is 1. On macOS, the default value is 2.

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
</table>
| 0     | Table and database names are stored on disk using the lettercase specified in the CREATE
       TABLE or CREATE DATABASE statement. Name comparisons are case sensitive. You should
       not set this variable to 0 if you are running MySQL on a system that has case-insensitive file
       names (such as Windows or macOS). If you force this variable to 0 with --lower-case-
       table-names=0 on a case-insensitive file system and access MyISAM tablenames using
different lettercases, index corruption may result. |
| 1     | Table names are stored in lowercase on disk and name comparisons are not case-sensitive.
       MySQL converts all table names to lowercase on storage and lookup. This behavior also
       applies to database names and table aliases. |
| 2     | Table and database names are stored on disk using the lettercase specified in the
       CREATE TABLE or CREATE DATABASE statement, but MySQL converts them to
       lowercase on lookup. Name comparisons are not case sensitive. This works only on file
       systems that are not case-sensitive! InnoDB table names are stored in lowercase, as for
       lower_case_table_names=1. |

If you are using MySQL on only one platform, you do not normally have to change the
lower_case_table_names variable from its default value. However, you may encounter difficulties if you
want to transfer tables between platforms that differ in file system case sensitivity. For example, on Unix, you can have two different tables named `my_table` and `MY_TABLE`, but on Windows these two names are considered identical. To avoid data transfer problems arising from lettercase of database or table names, you have two options:

- Use `lower_case_table_names=1` on all systems. The main disadvantage with this is that when you use `SHOW TABLES` or `SHOW DATABASES`, you do not see the names in their original lettercase.

- Use `lower_case_table_names=0` on Unix and `lower_case_table_names=2` on Windows. This preserves the lettercase of database and table names. The disadvantage of this is that you must ensure that your statements always refer to your database and table names with the correct lettercase on Windows. If you transfer your statements to Unix, where lettercase is significant, they do not work if the lettercase is incorrect.

**Exception:** If you are using InnoDB tables and you are trying to avoid these data transfer problems, you should set `lower_case_table_names` to 1 on all platforms to force names to be converted to lowercase.

If you plan to set the `lower_case_table_names` system variable to 1 on Unix, you must first convert your old database and table names to lowercase before stopping `mysqld` and restarting it with the new variable setting. To do this for an individual table, use `RENAME TABLE`:

```
RENAME TABLE T1 TO t1;
```

To convert one or more entire databases, dump them before setting `lower_case_table_names`, then drop the databases, and reload them after setting `lower_case_table_names`:

1. Use `mysqldump` to dump each database:

   ```
   mysqldump --databases db1 > db1.sql
   mysqldump --databases db2 > db2.sql
   ...
   ```

   Do this for each database that must be recreated.

2. Use `DROP DATABASE` to drop each database.

3. Stop the server, set `lower_case_table_names`, and restart the server.

4. Reload the dump file for each database. Because `lower_case_table_names` is set, each database and table name will be converted to lowercase as it is recreated:

   ```
   mysql < db1.sql
   mysql < db2.sql
   ...
   ```

Object names may be considered duplicates if their uppercase forms are equal according to a binary collation. That is true for names of cursors, conditions, procedures, functions, savepoints, stored routine parameters, stored program local variables, and plugins. It is not true for names of columns, constraints, databases, partitions, statements prepared with `PREPARE`, tables, triggers, users, and user-defined variables.

File system case sensitivity can affect searches in string columns of `INFORMATION_SCHEMA` tables. For more information, see Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

### 9.2.4 Mapping of Identifiers to File Names

There is a correspondence between database and table identifiers and names in the file system. For the basic structure, MySQL represents each database as a directory in the data directory, and each table by
one or more files in the appropriate database directory. For the table format files (.FRM), the data is always
stored in this structure and location.

For the data and index files, the exact representation on disk is storage engine specific. These files
may be stored in the same location as the FRM files, or the information may be stored in a separate file. InnoDB data is stored in the InnoDB data files. If you are using tablespaces with InnoDB, then the specific
tablespace files you create are used instead.

Any character is legal in database or table identifiers except ASCII NUL (X'00'). MySQL encodes
any characters that are problematic in the corresponding file system objects when it creates database
directories or table files:

- Basic Latin letters (a..zA..Z), digits (0..9) and underscore (_) are encoded as is. Consequently, their
case sensitivity directly depends on file system features.

- All other national letters from alphabets that have uppercase/lowercase mapping are encoded as shown
in the following table. Values in the Code Range column are UCS-2 values.

<table>
<thead>
<tr>
<th>Code Range</th>
<th>Pattern</th>
<th>Number</th>
<th>Used</th>
<th>Unused</th>
<th>Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>00C0..017F</td>
<td>[@][0..4][g..z]</td>
<td>5*20=100</td>
<td>97</td>
<td>3</td>
<td>Latin-1 Supplement + Latin Extended-A</td>
</tr>
<tr>
<td>0370..03FF</td>
<td>[@][5..9][g..z]</td>
<td>5*20=100</td>
<td>88</td>
<td>12</td>
<td>Greek and Coptic</td>
</tr>
<tr>
<td>0400..052F</td>
<td>[@][g..z][0..6]</td>
<td>20*7=140</td>
<td>137</td>
<td>3</td>
<td>Cyrillic + Cyrillic Supplement</td>
</tr>
<tr>
<td>0530..058F</td>
<td>[@][g..z][7..8]</td>
<td>20*2=40</td>
<td>38</td>
<td>2</td>
<td>Armenian</td>
</tr>
<tr>
<td>2160..217F</td>
<td>[@][g..z][9]</td>
<td>20*1=20</td>
<td>16</td>
<td>4</td>
<td>Number Forms</td>
</tr>
<tr>
<td>0180..02AF</td>
<td>[@][g..z][a..k]</td>
<td>20*11=220</td>
<td>203</td>
<td>17</td>
<td>Latin Extended-B + IPA Extensions</td>
</tr>
<tr>
<td>1E00..1EFF</td>
<td>[@][g..z][i..r]</td>
<td>20*7=140</td>
<td>136</td>
<td>4</td>
<td>Latin Extended Additional</td>
</tr>
<tr>
<td>1F00..1FFF</td>
<td>[@][g..z][s..z]</td>
<td>20*8=160</td>
<td>144</td>
<td>16</td>
<td>Greek Extended</td>
</tr>
<tr>
<td>.... ....</td>
<td>[@][a..f][g..z]</td>
<td>6*20=120</td>
<td>0</td>
<td>120</td>
<td>RESERVED</td>
</tr>
<tr>
<td>24B6..24E9</td>
<td>[@][@][a..z]</td>
<td>26</td>
<td>26</td>
<td>0</td>
<td>Enclosed Alphanumerics</td>
</tr>
<tr>
<td>FF21..FF5A</td>
<td>[@][a..z][@]</td>
<td>26</td>
<td>26</td>
<td>0</td>
<td>Halfwidth and Fullwidth forms</td>
</tr>
</tbody>
</table>

One of the bytes in the sequence encodes lettercase. For example: LATIN CAPITAL LETTER A WITH GRAVE is encoded as @0G, whereas LATIN SMALL LETTER A WITH GRAVE is encoded as @0g. Here the third byte (G or g) indicates lettercase. (On a case-insensitive file system, both letters will be treated as the same.)

For some blocks, such as Cyrillic, the second byte determines lettercase. For other blocks, such as
Latin1 Supplement, the third byte determines lettercase. If two bytes in the sequence are letters (as
in Greek Extended), the leftmost letter character stands for lettercase. All other letter bytes must be in
lowercase.

- All nonletter characters except underscore (_), as well as letters from alphabets that do not have
uppercase/lowercase mapping (such as Hebrew) are encoded using hexadecimal representation using
lowercase letters for hexadecimal digits a..f:

0x003F -> @03f
0xFFFF -> @fff
The hexadecimal values correspond to character values in the ucs2 double-byte character set.

On Windows, some names such as nul, prn, and aux are encoded by appending @@ to the name when the server creates the corresponding file or directory. This occurs on all platforms for portability of the corresponding database object between platforms.

If you have databases or tables from a version of MySQL older than 5.1.6 that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of #mysql50# in the output from INFORMATION_SCHEMA tables or SHOW statements. For example, if you have a table named a@b and its name encoding has not been updated, SHOW TABLES displays it like this:

```
mysql> SHOW TABLES;
+----------------+
| Tables_in_test |
+----------------+
| #mysql50#a@b   |
+----------------+
```

To refer to such a name for which the encoding has not been updated, you must supply the #mysql50# prefix:

```
mysql> SHOW COLUMNS FROM `a@b`;
ERROR 1146 (42S02): Table 'test.a@b' doesn't exist
```

```
mysql> SHOW COLUMNS FROM `#mysql50#a@b`;
+-------+---------+------+-----+---------+-------+
<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Null</th>
<th>Key</th>
<th>Default</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>int(11)</td>
<td>YES</td>
<td></td>
<td>NULL</td>
<td></td>
</tr>
</tbody>
</table>
+-------+---------+------+-----+---------+-------+
```

To update old names to eliminate the need to use the special prefix to refer to them, re-encode them with mysqlcheck. The following commands update all names to the new encoding:

```
mysqlcheck --check-upgrade --all-databases
mysqlcheck --fix-db-names --fix-table-names --all-databases
```

To check only specific databases or tables, omit --all-databases and provide the appropriate database or table arguments. For information about mysqlcheck invocation syntax, see Section 4.5.3, "mysqlcheck — A Table Maintenance Program".

Note

The #mysql50# prefix is intended only to be used internally by the server. You should not create databases or tables with names that use this prefix.

Also, mysqlcheck cannot fix names that contain literal instances of the @ character that is used for encoding special characters. If you have databases or tables that contain this character, use mysqldump to dump them before upgrading to MySQL 5.1.6 or later, and then reload the dump file after upgrading.

9.2.5 Function Name Parsing and Resolution

MySQL supports built-in (native) functions, user-defined functions (UDFs), and stored functions. This section describes how the server recognizes whether the name of a built-in function is used as a function call or as an identifier, and how the server determines which function to use in cases when functions of different types exist with a given name.
Function Name Parsing and Resolution

• Built-In Function Name Parsing
• Function Name Resolution

**Built-In Function Name Parsing**

The parser uses default rules for parsing names of built-in functions. These rules can be changed by enabling the `IGNORE_SPACE` SQL mode.

When the parser encounters a word that is the name of a built-in function, it must determine whether the name signifies a function call or is instead a nonexpression reference to an identifier such as a table or column name. For example, in the following statements, the first reference to `count` is a function call, whereas the second reference is a table name:

```sql
SELECT COUNT(*) FROM mytable;
CREATE TABLE count (i INT);
```

The parser should recognize the name of a built-in function as indicating a function call only when parsing what is expected to be an expression. That is, in nonexpression context, function names are permitted as identifiers.

However, some built-in functions have special parsing or implementation considerations, so the parser uses the following rules by default to distinguish whether their names are being used as function calls or as identifiers in nonexpression context:

- To use the name as a function call in an expression, there must be no whitespace between the name and the following `( parenthesis character.
- Conversely, to use the function name as an identifier, it must not be followed immediately by a parenthesis.

The requirement that function calls be written with no whitespace between the name and the parenthesis applies only to the built-in functions that have special considerations. `COUNT` is one such name. The `sql_functions[]` array in the `sql/lex.h` source file lists the names of these special functions for which following whitespace determines their interpretation.

The following list names the functions in MySQL 5.5 that are affected by the `IGNORE_SPACE` setting and listed as special in the `sql/lex.h` source file. You may find it easiest to treat the no-whitespace requirement as applying to all function calls.

- `ADDDATE`
- `BIT_AND`
- `BIT_OR`
- `BIT_XOR`
- `CAST`
- `COUNT`
- `CURDATE`
- `CURTIME`
- `DATE_ADD`
- `DATE_SUB`
Function Name Parsing and Resolution

- EXTRACT
- GROUP_CONCAT
- MAX
- MID
- MIN
- NOW
- POSITION
- SESSION_USER
- STD
- STDERR
- STDERR_POP
- STDERR_SAMP
- SUBDATE
- SUBSTR
- SUBSTRING
- SUM
- SYSDATE
- SYSTEM_USER
- TRIM
- VARIANCE
- VAR_POP
- VAR_SAMP

For functions not listed as special in sql/lex.h, whitespace does not matter. They are interpreted as function calls only when used in expression context and may be used freely as identifiers otherwise. ASCII is one such name. However, for these nonaffected function names, interpretation may vary in expression context: `func_name()` is interpreted as a built-in function if there is one with the given name; if not, `func_name()` is interpreted as a user-defined function or stored function if one exists with that name.

The IGNORE_SPACE SQL mode can be used to modify how the parser treats function names that are whitespace-sensitive:

- With IGNORE_SPACE disabled, the parser interprets the name as a function call when there is no whitespace between the name and the following parenthesis. This occurs even when the function name is used in nonexpression context:

  mysql> CREATE TABLE count(i INT);
  ERROR 1064 (42000): You have an error in your SQL syntax ...
  near 'count(i INT)'
To eliminate the error and cause the name to be treated as an identifier, either use whitespace following the name or write it as a quoted identifier (or both):

```sql
CREATE TABLE count (i INT);
CREATE TABLE 'count' (i INT);
CREATE TABLE 'count' (i INT);
```

- With `IGNORE_SPACE` enabled, the parser loosens the requirement that there be no whitespace between the function name and the following parenthesis. This provides more flexibility in writing function calls. For example, either of the following function calls are legal:

```sql
SELECT COUNT(*) FROM mytable;
SELECT COUNT(*) FROM mytable;
```

However, enabling `IGNORE_SPACE` also has the side effect that the parser treats the affected function names as reserved words (see Section 9.3, “Keywords and Reserved Words”). This means that a space following the name no longer signifies its use as an identifier. The name can be used in function calls with or without following whitespace, but causes a syntax error in nonexpression context unless it is quoted. For example, with `IGNORE_SPACE` enabled, both of the following statements fail with a syntax error because the parser interprets `count` as a reserved word:

```sql
CREATE TABLE count (i INT);
CREATE TABLE count (i INT);
```

To use the function name in nonexpression context, write it as a quoted identifier:

```sql
CREATE TABLE 'count' (i INT);
CREATE TABLE 'count' (i INT);
```

To enable the `IGNORE_SPACE` SQL mode, use this statement:

```sql
SET sql_mode = 'IGNORE_SPACE';
```

`IGNORE_SPACE` is also enabled by certain other composite modes such as `ANSI` that include it in their value:

```sql
SET sql_mode = 'ANSI';
```

Check Section 5.1.10, “Server SQL Modes”, to see which composite modes enable `IGNORE_SPACE`.

To minimize the dependency of SQL code on the `IGNORE_SPACE` setting, use these guidelines:

- Avoid creating UDFs or stored functions that have the same name as a built-in function.
- Avoid using function names in nonexpression context. For example, these statements use `count` (one of the affected function names affected by `IGNORE_SPACE`), so they fail with or without whitespace following the name if `IGNORE_SPACE` is enabled:

```sql
CREATE TABLE count (I INT);
CREATE TABLE count (I INT);
```

If you must use a function name in nonexpression context, write it as a quoted identifier:

```sql
CREATE TABLE 'count' (I INT);
CREATE TABLE 'count' (I INT);
```

**Function Name Resolution**

The following rules describe how the server resolves references to function names for function creation and invocation:
• Built-in functions and user-defined functions

An error occurs if you try to create a UDF with the same name as a built-in function.

• Built-in functions and stored functions

It is possible to create a stored function with the same name as a built-in function, but to invoke the stored function it is necessary to qualify it with a schema name. For example, if you create a stored function named PI in the test schema, invoke it as test.PI() because the server resolves PI() without a qualifier as a reference to the built-in function. The server generates a warning if the stored function name collides with a built-in function name. The warning can be displayed with SHOW WARNINGS.

• User-defined functions and stored functions

User-defined functions and stored functions share the same namespace, so you cannot create a UDF and a stored function with the same name.

The preceding function name resolution rules have implications for upgrading to versions of MySQL that implement new built-in functions:

• If you have already created a user-defined function with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use DROP FUNCTION to drop the UDF and CREATE FUNCTION to re-create the UDF with a different nonconflicting name. Then modify any affected code to use the new name.

• If a new version of MySQL implements a built-in function with the same name as an existing stored function, you have two choices: Rename the stored function to use a nonconflicting name, or change calls to the function so that they use a schema qualifier (that is, use schema_name.func_name() syntax). In either case, modify any affected code accordingly.

9.3 Keywords and Reserved Words

Keywords are words that have significance in SQL. Certain keywords, such as SELECT, DELETE, or BIGINT, are reserved and require special treatment for use as identifiers such as table and column names. This may also be true for the names of built-in functions.

Nonreserved keywords are permitted as identifiers without quoting. Reserved words are permitted as identifiers if you quote them as described in Section 9.2, “Schema Object Names”:

mysql> CREATE TABLE interval (begin INT, end INT);
ERROR 1064 (42000): You have an error in your SQL syntax ...
near 'interval (begin INT, end INT)'

BEGIN and END are keywords but not reserved, so their use as identifiers does not require quoting. INTERVAL is a reserved keyword and must be quoted to be used as an identifier:

mysql> CREATE TABLE `interval` (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)

Exception: A word that follows a period in a qualified name must be an identifier, so it need not be quoted even if it is reserved:

mysql> CREATE TABLE mydb.interval (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)

Names of built-in functions are permitted as identifiers but may require care to be used as such. For example, COUNT is acceptable as a column name. However, by default, no whitespace is permitted in
function invocations between the function name and the following `()` character. This requirement enables
the parser to distinguish whether the name is used in a function call or in nonfunction context. For further
details on recognition of function names, see Section 9.2.5, “Function Name Parsing and Resolution”.

- MySQL 5.5 Keywords and Reserved Words
- MySQL 5.5 New Keywords and Reserved Words
- MySQL 5.5 Removed Keywords and Reserved Words

MySQL 5.5 Keywords and Reserved Words

The following list shows the keywords and reserved words in MySQL 5.5, along with changes to individual
words from version to version. Reserved keywords are marked with (R). In addition, `_FILENAME` is
reserved.

At some point, you might upgrade to a higher version, so it is a good idea to have a look at future reserved
words, too. You can find these in the manuals that cover higher versions of MySQL. Most of the reserved
words in the list are forbidden by standard SQL as column or table names (for example, `GROUP`). A few are
reserved because MySQL needs them and uses a yacc parser.

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

A
- ACCESSIBLE (R)
- ACTION
- ADD (R)
- AFTER
- AGAINST
- AGGREGATE
- ALGORITHM
- ALL (R)
- ALTER (R)
- ANALYZE (R)
- AND (R)
- ANY
- AS (R)
- ASC (R)
- ASCII
- ASENSITIVE (R)
- AT
• AUTHORS
• AUTOEXTEND_SIZE
• AUTO_INCREMENT
• AVG
• AVG_ROW_LENGTH

B
• BACKUP
• BEFORE (R)
• BEGIN
• BETWEEN (R)
• BIGINT (R)
• BINARY (R)
• BINLOG
• BIT
• BLOB (R)
• BLOCK
• BOOL
• BOOLEAN
• BOTH (R)
• BTREE
• BY (R)
• BYTE

C
• CACHE
• CALL (R)
• CASCADE (R)
• CASCADED
• CASE (R)
• CATALOG_NAME
• CHAIN
• CHANGE (R)
• CHANGED
• CHAR (R)
• CHARACTER (R)
• CHARSET
• CHECK (R)
• CHECKSUM
• CIPHER
• CLASS_ORIGIN
• CLIENT
• CLOSE
• COALESCE
• CODE
• COLLATE (R)
• COLLATION
• COLUMN (R)
• COLUMNS
• COLUMN_NAME
• COMMENT
• COMMIT
• COMMITTED
• COMPACT
• COMPLETION
• COMPRESSED
• CONCURRENT
• CONDITION (R)
• CONNECTION
• CONSISTENT
• CONSTRAINT (R)
• CONSTRAINT_CATALOG
MySQL 5.5 Keywords and Reserved Words

- CONSTRAINT_NAME
- CONSTRAINT_SCHEMA
- CONTAINS
- CONTEXT
- CONTINUE (R)
- CONTRIBUTORS
- CONVERT (R)
- CPU
- CREATE (R)
- CROSS (R)
- CUBE
- CURRENT_DATE (R)
- CURRENT_TIME (R)
- CURRENT_TIMESTAMP (R)
- CURRENT_USER (R)
- CURSOR (R)
- CURSOR_NAME

D
- DATA
- DATABASE (R)
- DATABASES (R)
- DATAFILE
- DATE
- DATETIME
- DAY
- DAY_HOUR (R)
- DAY_MICROSECOND (R)
- DAY_MINUTE (R)
- DAY_SECOND (R)
- DEALLOCATE
• DEC (R)
• DECIMAL (R)
• DECLARE (R)
• DEFAULT (R)
• DEFINER
• DELAYED (R)
• DELAY_KEY_WRITE
• DELETE (R)
• DESC (R)
• DESCRIBE (R)
• DES_KEY_FILE
• DETERMINISTIC (R)
• DIRECTORY
• DISABLE
• DISCARD
• DISK
• DISTINCT (R)
• DISTINCTROW (R)
• DIV (R)
• DO
• DOUBLE (R)
• DROP (R)
• DUAL (R)
• DUMPFILE
• DUPLICATE
• DYNAMIC
• EACH (R)
• ELSE (R)
• ELSEIF (R)
• ENABLE
• ENCLOSED (R)
• END
• ENDS
• ENGINE
• ENGINES
• ENUM
• ERROR; added in 5.5.3 (nonreserved)
• ERRORS
• ESCAPE
• ESCAPED (R)
• EVENT
• EVENTS
• EVERY
• EXECUTE
• EXISTS (R)
• EXIT (R)
• EXPANSION
• EXPLAIN (R)
• EXTENDED
• EXTENT_SIZE
• F
• FALSE (R)
• FAST
• FAULTS
• FETCH (R)
• FIELDS
• FILE
• FIRST
• FIXED
MySQL 5.5 Keywords and Reserved Words

- `FLOAT (R)`
- `FLOAT4 (R)`
- `FLOAT8 (R)`
- `FLUSH`
- `FOR (R)`
- `FORCE (R)`
- `FOREIGN (R)`
- `FOUND`
- `FRAC_SECOND`; removed in 5.5.3
- `FROM (R)`
- `FULL`
- `FULLTEXT (R)`
- `FUNCTION`
- `G`
  - `GENERAL`; added in 5.5.3 (reserved); became nonreserved in 5.5.8
- `GEOMETRY`
- `GEOMETRYCOLLECTION`
- `GET_FORMAT`
- `GLOBAL`
- `GRANT (R)`
- `GRANTS`
- `GROUP (R)`
- `H`
  - `HANDLER`
  - `HASH`
  - `HAVING (R)`
  - `HELP`
  - `HIGH_PRIORITY (R)`
- `HOST`
- `HOSTS`
MySQL 5.5 Keywords and Reserved Words

• HOUR
• HOUR_MICROSECOND (R)
• HOUR_MINUTE (R)
• HOUR_SECOND (R)
• IDENTIFIED
• IF (R)
• IGNORE (R)
• IGNORE_SERVER_IDS; became nonreserved in 5.5.8
• IMPORT
• IN (R)
• INDEX (R)
• INDEXES
• INFILE (R)
• INITIAL_SIZE
• INNER (R)
• INNODB; removed in 5.5.3
• INNODB; removed in 5.5.3
• INOUT (R)
• INSENSITIVE (R)
• INSERT (R)
• INSERT_METHOD
• INSTALL
• INT (R)
• INT1 (R)
• INT2 (R)
• INT3 (R)
• INT4 (R)
• INT8 (R)
• INTEGER (R)
• INTERVAL (R)
• INTO (R)
• INVOKER
• IO
• IO_THREAD
• IPC
• IS (R)
• ISOLATION
• ISSUER
• ITERATE (R)
• J
• JOIN (R)
• K
• KEY (R)
• KEYS (R)
• KEY_BLOCK_SIZE
• KILL (R)
• L
• LANGUAGE
• LAST
• LEADING (R)
• LEAVE (R)
• LEAVES
• LEFT (R)
• LESS
• LEVEL
• LIKE (R)
• LIMIT (R)
• LINEAR (R)
• LINES (R)
• LINestring
• LIst
• LOAD (R)
• LOCAL
• LOCALTime (R)
• LOCALTimestamp (R)
• LOCK (R)
• LOCKS
• LOGfile
• LOGS
• LONG (R)
• LONGblob (R)
• LONGtext (R)
• LOOP (R)
• LOW_PRIORITY (R)

M
• MASTER
• MASTER_CONNECT_RETRY
• MASTER_HEARTBEAT_PERIOD; became nonreserved in 5.5.8
• MASTER_HOST
• MASTER_LOG_FILE
• MASTER_LOG_POS
• MASTER_PASSWORD
• MASTER_PORT
• MASTER_SERVER_ID
• MASTER_SSL
• MASTER_SSL_CA
• MASTER_SSL_CAPATH
• MASTER_SSL_CERT
• MASTER_SSL_CIPHER
• MASTER_SSL_KEY
• MASTER_SSL_VERIFY_SERVER_CERT (R)
• MASTER_USER
• MATCH (R)
• MAXVALUE (R)
• MAX_CONNECTIONS_PER_HOUR
• MAX QUERIES_PER_HOUR
• MAX_ROWS
• MAX SIZE
• MAX_UPDATES_PER_HOUR
• MAX_USER_CONNECTIONS
• MEDIUM
• MEDIUMBLOB (R)
• MEDIUMINT (R)
• MEDIUMTEXT (R)
• MEMORY
• MERGE
• MESSAGE_TEXT
• MICROSECOND
• MIDDLEINT (R)
• MIGRATE
• MINUTE
• MINUTE_MICROSECOND (R)
• MINUTE_SECOND (R)
• MIN_ROWS
• MOD (R)
• MODE
• MODIFIES (R)
• MODIFY
• MONTH
• MULTILINESTRING
• MULTIPOINT
• MULTIPOLYGON
• MUTEX
• MYSQL_ERRNO

N
• NAME
• NAMES
• NATIONAL
• NATURAL (R)
• NCHAR
• NDB
• NDBCLUSTER
• NEW
• NEXT
• NO
• NODEGROUP
• NONE
• NOT (R)
• NO_WAIT
• NO_WRITE_TO_BINLOG (R)
• NULL (R)
• NUMERIC (R)
• NVARCHAR

O
• OFFSET
• OLD_PASSWORD
• ON (R)
• ONE
• ONE_SHOT
MySQL 5.5 Keywords and Reserved Words

- OPEN
- OPTIMIZE (R)
- OPTION (R)
- OPTIONALLY (R)
- OPTIONS
- OR (R)
- ORDER (R)
- OUT (R)
- OUTER (R)
- OUTFILE (R)
- OWNER
- PACK_KEYS
- PAGE
- PARSER
- PARTIAL
- PARTITION
- PARTITIONING
- PARTITIONS
- PASSWORD
- PHASE
- PLUGIN
- PLUGINS
- POINT
- POLYGON
- PORT
- PRECISION (R)
- PREPARE
- PRESERVE
- PREV
• **PRIMARY (R)**
• **PRIVILEGES**
• **PROCEDURE (R)**
• **PROCESSLIST**
• **PROFILE**
• **PROFILES**
• **PROXY**: added in 5.5.7 (nonreserved)
• **PURGE (R)**

Q
• **QUARTER**
• **QUERY**
• **QUICK**

R
• **RANGE (R)**
• **READ (R)**
• **READS (R)**
• **READ_ONLY**
• **READ_WRITE (R)**
• **REAL (R)**
• **REBUILD**
• **RECOVER**
• **REDOFILE**
• **REDO_BUFFER_SIZE**
• **REDUNDANT**
• **REFERENCES (R)**
• **REGEXP (R)**
• **RELAY**: added in 5.5.3 (nonreserved)
• **RELAYLOG**
• **RELAY_LOG_FILE**
• **RELAY_LOG_POS**
MySQL 5.5 Keywords and Reserved Words

- RELAY_THREAD
- RELEASE (R)
- RELOAD
- REMOVE
- RENAME (R)
- REORGANIZE
- REPAIR
- REPEAT (R)
- REPEATABLE
- REPLACE (R)
- REPLICATION
- REQUIRE (R)
- RESET
- RESIGNAL (R)
- RESTORE
- RESTRICT (R)
- RESUME
- RETURN (R)
- RETURNS
- REVOKE (R)
- RIGHT (R)
- RLIKE (R)
- ROLLBACK
- ROLLUP
- ROUTINE
- ROW
- ROWS
- ROW_FORMAT
- RTREE
- S
• SAVEPOINT
• SCHEDULE
• SCHEMA (R)
• SCHEMAS (R)
• SCHEMA_NAME
• SECOND
• SECOND_MICROSECOND (R)
• SECURITY
• SELECT (R)
• SENSITIVE (R)
• SEPARATOR (R)
• SERIAL
• SERIALIZABLE
• SERVER
• SESSION
• SET (R)
• SHARE
• SHOW (R)
• SHUTDOWN
• SIGNAL (R)
• SIGNED
• SIMPLE
• SLAVE
• SLOW; added in 5.5.3 (reserved); became nonreserved in 5.5.8
• SMALLINT (R)
• SNAPSHOT
• SOCKET
• SOME
• SONAME
• SOUNDS
MySQL 5.5 Keywords and Reserved Words

- SOURCE
- SPATIAL (R)
- SPECIFIC (R)
- SQL (R)
- SQLEXCEPTION (R)
- SQLSTATE (R)
- SQLWARNING (R)
- SQL_BIG_RESULT (R)
- SQL_BUFFER_RESULT
- SQL_CACHE
- SQL_CALC_FOUND_ROWS (R)
- SQL_NO_CACHE
- SQL_SMALL_RESULT (R)
- SQL_THREAD
- SQL_TSI_DAY
- SQL_TSI_FRAC_SECOND; removed in 5.5.3
- SQL_TSI_HOUR
- SQL_TSI_MINUTE
- SQL_TSI_MONTH
- SQL_TSI_QUARTER
- SQL_TSI_SECOND
- SQL_TSI_WEEK
- SQL_TSI_YEAR
- SSL (R)
- START
- STARTING (R)
- STARTS
- STATUS
- STOP
- STORAGE
• \textbf{STRAIGHT\_JOIN} (R)
• \textbf{STRING}
• \textbf{SUBCLASS\_ORIGIN}
• \textbf{SUBJECT}
• \textbf{SUBPARTITION}
• \textbf{SUBPARTITIONS}
• \textbf{SUPER}
• \textbf{SUSPEND}
• \textbf{SWAPS}
• \textbf{SWITCHES}
• \textbf{T}
  • \textbf{TABLE} (R)
  • \textbf{TABLES}
  • \textbf{TABLESPACE}
  • \textbf{TABLE\_CHECKSUM}
  • \textbf{TABLE\_NAME}
  • \textbf{TEMPORARY}
  • \textbf{TEMPTABLE}
  • \textbf{TERMINATED} (R)
  • \textbf{TEXT}
  • \textbf{THAN}
  • \textbf{THEN} (R)
  • \textbf{TIME}
  • \textbf{TIMESTAMP}
  • \textbf{TIMESTAMPADD}
  • \textbf{TIMESTAMPDIFF}
  • \textbf{TINYBLOB} (R)
  • \textbf{TINYINT} (R)
  • \textbf{TINYTEXT} (R)
  • \textbf{TO} (R)
• TRAILING (R)
• TRANSACTION
• TRIGGER (R)
• TRIGGERS
• TRUE (R)
• TRUNCATE
• TYPE
• TYPES

U
• UNCOMMITTED
• UNDEFINED
• UNDO (R)
• UNDOFILE
• UNDO_BUFFER_SIZE
• UNICODE
• UNINSTALL
• UNION (R)
• UNIQUE (R)
• UNKNOWN
• UNLOCK (R)
• UNSIGNED (R)
• UNTIL
• UPDATE (R)
• UPGRADE
• USAGE (R)
• USE (R)
• USER
• USER_RESOURCES
• USE_FRM
• USING (R)
• UTC_DATE (R)
• UTC_TIME (R)
• UTC_TIMESTAMP (R)
V
• VALUE
• VALUES (R)
• VARBINARY (R)
• VARCHAR (R)
• VARCHARACTER (R)
• VARIABLES
• VARYING (R)
• VIEW
W
• WAIT
• WARNINGS
• WEEK
• WHEN (R)
• WHERE (R)
• WHILE (R)
• WITH (R)
• WORK
• WRAPPER
• WRITE (R)
X
• X509
• XA
• XML
• XOR (R)
Y
• YEAR
MySQL 5.5 New Keywords and Reserved Words

The following list shows the keywords and reserved words that are added in MySQL 5.5, compared to MySQL 5.1. Reserved keywords are marked with (R).

C | E | G | I | M | P | R | S | T | X
C
• CATALOG_NAME
• CLASS_ORIGIN
• COLUMN_NAME
• CONSTRAINT_CATALOG
• CONSTRAINT_NAME
• CONSTRAINT_SCHEMA
• CURSOR_NAME
E
• ERROR
G
• GENERAL
I
• IGNORE_SERVER_IDS
M
• MASTER_HEARTBEAT_PERIOD
• MESSAGE_TEXT
• MYSQL_ERRNO
P
• PROXY
R
• RELAY
• RELAYLOG
MySQL 5.5 Removed Keywords and Reserved Words

The following list shows the keywords and reserved words that are removed in MySQL 5.5, compared to MySQL 5.1. Reserved keywords are marked with (R).

- RESIGNAL (R)
- SCHEMA_NAME
- SIGNAL (R)
- SLOW
- SUBCLASS_ORIGIN
- TABLE_NAME
- XML

9.4 User-Defined Variables

You can store a value in a user-defined variable in one statement and refer to it later in another statement. This enables you to pass values from one statement to another.

User variables are written as `@var_name`, where the variable name `var_name` consists of alphanumeric characters, `-`, and `$`. A user variable name can contain other characters if you quote it as a string or identifier (for example, `@'my-var'`, `"my-var"`, or `@`my-var`).

User-defined variables are session specific. A user variable defined by one client cannot be seen or used by other clients. All variables for a given client session are automatically freed when that client exits.

User variable names are not case-sensitive.

One way to set a user-defined variable is by issuing a `SET` statement:

```
SET @var_name = expr [, @var_name = expr] ...
```

For `SET`, either `=` or `:=` can be used as the assignment operator.

User variables can be assigned a value from a limited set of data types: integer, decimal, floating-point, binary or nonbinary string, or NULL value. Assignment of decimal and real values does not preserve the precision or scale of the value. A value of a type other than one of the permissible types is converted to...
User-Defined Variables

a permissible type. For example, a value having a temporal or spatial data type is converted to a binary string.

If a user variable is assigned a nonbinary (character) string value, it has the same character set and collation as the string. The coercibility of user variables is implicit. (This is the same coercibility as for table column values.)

Hexadecimal or bit values assigned to user variables are treated as binary strings. To assign a hexadecimal or bit value as a number to a user variable, use it in numeric context. For example, add 0 or use \( \text{CAST(... AS UNSIGNED)} \):

```sql
mysql> SET @v1 = X'41';
mysql> SET @v2 = X'41'+0;
mysql> SET @v3 = \text{CAST(X'}41\text{' AS UNSIGNED)};
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
| A    | 65   | 65   |
+------+------+------+
```

```sql
mysql> SET @v1 = b'1000001';
mysql> SET @v2 = b'1000001'+0;
mysql> SET @v3 = \text{CAST(b}'1000001\text{' AS UNSIGNED)};
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
| A    | 65   | 65   |
+------+------+------+
```

If the value of a user variable is selected in a result set, it is returned to the client as a string.

If you refer to a variable that has not been initialized, it has a value of \text{NULL} and a type of string.

User variables may be used in most contexts where expressions are permitted. This does not currently include contexts that explicitly require a literal value, such as in the LIMIT clause of a SELECT statement, or the IGNORE N LINES clause of a LOAD DATA statement.

You can also assign a value to a user variable in statements other than SET. In this case, the assignment operator must be \( := \) and not \( = \) because the latter is treated as the comparison operator \( = \) in statements other than SET:

```sql
mysql> SET @t1=1, @t2=2, @t3:=4;
mysql> SELECT @t1, @t2, @t3 := @t1+@t2+@t3;
+------+------+------+--------------------+
| @t1  | @t2  | @t3  | @t4 := @t1+@t2+@t3 |
| 1    | 2    | 4    |                  7  |
+------+------+------+--------------------+
```

As a general rule, other than in SET statements, you should never assign a value to a user variable and read the value within the same statement. For example, to increment a variable, this is okay:

```sql
SET @a = @a + 1;
```

For other statements, such as SELECT, you might get the results you expect, but this is not guaranteed. In the following statement, you might think that MySQL will evaluate \( @a \) first and then do an assignment second:

```sql
SELECT @a, @a:=@a+1, ...
```

However, the order of evaluation for expressions involving user variables is undefined.
Another issue with assigning a value to a variable and reading the value within the same non-SET statement is that the default result type of a variable is based on its type at the start of the statement. The following example illustrates this:

```
mysql> SET @a='test';
mysql> SELECT @a,(@a:=20) FROM tbl_name;
```

For this SELECT statement, MySQL reports to the client that column one is a string and converts all accesses of @a to strings, even though @a is set to a number for the second row. After the SELECT statement executes, @a is regarded as a number for the next statement.

To avoid problems with this behavior, either do not assign a value to and read the value of the same variable within a single statement, or else set the variable to 0, 0.0, or '' to define its type before you use it.

In a SELECT statement, each select expression is evaluated only when sent to the client. This means that in a HAVING, GROUP BY, or ORDER BY clause, referring to a variable that is assigned a value in the select expression list does not work as expected:

```
mysql> SELECT (@aa:=id) AS a, (@aa+3) AS b FROM tbl_name HAVING b=5;
```

The reference to b in the HAVING clause refers to an alias for an expression in the select list that uses @aa. This does not work as expected: @aa contains the value of id from the previous selected row, not from the current row.

User variables are intended to provide data values. They cannot be used directly in an SQL statement as an identifier or as part of an identifier, such as in contexts where a table or database name is expected, or as a reserved word such as SELECT. This is true even if the variable is quoted, as shown in the following example:

```
mysql> SELECT c1 FROM t;
+----+
| c1 |
+----+
| 0  |
| 1  |
+----+
2 rows in set (0.00 sec)
mysql> SET @col = "c1";
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| c1   |
+------+
1 row in set (0.00 sec)
mysql> SELECT `@col` FROM t;
ERROR 1054 (42S22): Unknown column '@col' in 'field list'
```

mysql> SET @col = "`c1`";
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| `c1` |
+------+
An exception to this principle that user variables cannot be used to provide identifiers, is when you are constructing a string for use as a prepared statement to execute later. In this case, user variables can be used to provide any part of the statement. The following example illustrates how this can be done:

```sql
mysql> SET @c = "c1";
Query OK, 0 rows affected (0.00 sec)

mysql> SET @s = CONCAT("SELECT ", @c, " FROM t");
Query OK, 0 rows affected (0.00 sec)

mysql> PREPARE stmt FROM @s;
Query OK, 0 rows affected (0.04 sec)
Statement prepared

mysql> EXECUTE stmt;

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

2 rows in set (0.00 sec)

mysql> DEALLOCATE PREPARE stmt;
Query OK, 0 rows affected (0.00 sec)
```


A similar technique can be used in application programs to construct SQL statements using program variables, as shown here using PHP 5:

```php
<?php
    $mysqli = new mysqli("localhost", "user", "pass", "test");
    if( $mysqli->connect_errno() )
        die("Connection failed: %s\n", $mysqli->connect_error);

    $col = "c1";
    $query = "SELECT $col FROM t";
    $result = $mysqli->query($query);
    while($row = $result->fetch_assoc())
    {
        echo "<p>\n" . $row["$col"] . "</p>\n";
    }
    $result->close();
    $mysqli->close();
?>
```

Assembling an SQL statement in this fashion is sometimes known as “Dynamic SQL”.

**9.5 Expressions**

This section lists the grammar rules that expressions must follow in MySQL and provides additional information about the types of terms that may appear in expressions.
Expression Syntax

The following grammar rules define expression syntax in MySQL. The grammar shown here is based on that given in the sql/sql_yacc.yy file of MySQL source distributions. For additional information about some of the expression terms, see Expression Term Notes.

```plaintext
expr:
  expr OR expr
  | expr \| expr
  | expr XOR expr
  | expr AND expr
  | expr \&\& expr
  | NOT expr
  | ! expr
  | boolean_primary IS [NOT] {TRUE | FALSE | UNKNOWN}
  | boolean_primary

boolean_primary:
  boolean_primary IS [NOT] NULL
  | boolean_primary \<\> predicate
  | boolean_primary comparison_operator predicate
  | boolean_primary comparison_operator {ALL | ANY} (subquery)
  | predicate

comparison_operator: = | \>= | > | \<= | < | <> | !=

predicate:
  bit_expr [NOT] IN (subquery)
  | bit_expr [NOT] IN (expr [, expr] ...)
  | bit_expr [NOT] BETWEEN bit_expr AND predicate
  | bit_expr SOUNDS LIKE bit_expr
  | bit_expr [NOT] LIKE simple_expr [ESCAPE simple_expr]
  | bit_expr [NOT] REGEXP bit_expr
  | bit_expr

bit_expr:
  bit_expr | bit_expr
  | bit_expr \& bit_expr
  | bit_expr \<\< bit_expr
  | bit_expr >> bit_expr
  | bit_expr + bit_expr
  | bit_expr - bit_expr
  | bit_expr * bit_expr
  | bit_expr / bit_expr
  | bit_expr DIV bit_expr
  | bit_expr MOD bit_expr
  | bit_expr \% bit_expr
  | bit_expr \^ bit_expr
  | bit_expr + interval_expr
  | bit_expr - interval_expr
  | simple_expr

simple_expr:
  literal
  | identifier
  | function_call
  | simple_expr COLLATE collation_name
  | param_marker
  | variable
```
For operator precedence, see Section 12.3.1, “Operator Precedence”. The precedence and meaning of some operators depends on the SQL mode:

- By default, `||` is a logical OR operator. With `PIPES_AS_CONCAT` enabled, `||` is string concatenation, with a precedence between `~` and the unary operators.

- By default, `!` has a higher precedence than `NOT`. With `HIGH_NOT_PRECEDENCE` enabled, `!` and `NOT` have the same precedence.

See Section 5.1.10, “Server SQL Modes”.

**Expression Term Notes**

For literal value syntax, see Section 9.1, “Literal Values”.

For identifier syntax, see Section 9.2, “Schema Object Names”.

Variables can be user variables, system variables, or stored program local variables or parameters:

- User variables: Section 9.4, “User-Defined Variables”
- System variables: Section 5.1.8, “Using System Variables”
- Stored program local variables: Section 13.6.4.1, “Local Variable DECLARE Statement”
- Stored program parameters: Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”

`param_marker` is `?` as used in prepared statements for placeholders. See Section 13.5.1, “PREPARE Statement”.

`(subquery)` indicates a subquery that returns a single value; that is, a scalar subquery. See Section 13.2.10.1, “The Subquery as Scalar Operand”.

`(identifier expr)` is ODBC escape syntax and is accepted for ODBC compatibility. The value is `expr`. The `{` and `}` curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

`match_expr` indicates a MATCH expression. See Section 12.9, “Full-Text Search Functions”.

`case_expr` indicates a CASE expression. See Section 12.4, “Control Flow Functions”.

`interval_expr` represents a temporal interval. See Temporal Intervals.

**Temporal Intervals**
Temporal Intervals

`interval_expr` in expressions represents a temporal interval. Intervals have this syntax:

```
INTERVAL expr unit
```

`expr` represents a quantity. `unit` represents the unit for interpreting the quantity; it is a specifier such as `HOUR`, `DAY`, or `WEEK`. The `INTERVAL` keyword and the `unit` specifier are not case sensitive.

The following table shows the expected form of the `expr` argument for each `unit` value.

**Table 9.2 Temporal Interval Expression and Unit Arguments**

<table>
<thead>
<tr>
<th><code>unit</code> Value</th>
<th>Expected <code>expr</code> Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICROSECOND</td>
<td>MICROSECONDS</td>
</tr>
<tr>
<td>SECOND</td>
<td>SECONDS</td>
</tr>
<tr>
<td>MINUTE</td>
<td>MINUTES</td>
</tr>
<tr>
<td>HOUR</td>
<td>HOURS</td>
</tr>
<tr>
<td>DAY</td>
<td>DAYS</td>
</tr>
<tr>
<td>WEEK</td>
<td>WEEKS</td>
</tr>
<tr>
<td>MONTH</td>
<td>MONTHS</td>
</tr>
<tr>
<td>QUARTER</td>
<td>QUARTERS</td>
</tr>
<tr>
<td>YEAR</td>
<td>YEARS</td>
</tr>
<tr>
<td>SECOND_MICROSECOND</td>
<td>'SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>SECOND_MICROSECOND</td>
<td>'SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>MINUTE_MICROSECOND</td>
<td>'MINUTES:SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>MINUTE_MICROSECOND</td>
<td>'MINUTES:SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>MINUTE_SECOND</td>
<td>'MINUTES:SECONDS'</td>
</tr>
<tr>
<td>HOUR_MICROSECOND</td>
<td>'HOURS:MINUTES:SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>HOUR_SECOND</td>
<td>'HOURS:MINUTES:SECONDS'</td>
</tr>
<tr>
<td>HOUR_MINUTE</td>
<td>'HOURS:MINUTES'</td>
</tr>
<tr>
<td>DAY_MICROSECOND</td>
<td>'DAYS HOURS:MINUTES:SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>DAY_MICROSECOND</td>
<td>'DAYS HOURS:MINUTES:SECONDS.MICROSECONDS'</td>
</tr>
<tr>
<td>DAY_SECOND</td>
<td>'DAYS HOURS:MINUTES:SECONDS'</td>
</tr>
<tr>
<td>DAY_MINUTE</td>
<td>'DAYS HOURS:MINUTES'</td>
</tr>
<tr>
<td>DAY_HOUR</td>
<td>'DAYS HOURS'</td>
</tr>
<tr>
<td>YEAR_MONTH</td>
<td>'YEARS-MONTHS'</td>
</tr>
</tbody>
</table>

MySQL permits any punctuation delimiter in the `expr` format. Those shown in the table are the suggested delimiters.

Temporal intervals are used for certain functions, such as `DATE_ADD()` and `DATE_SUB()`:

```
mysql> SELECT DATE_ADD('2018-05-01', INTERVAL 1 DAY);
-> '2018-05-02'
mysql> SELECT DATE_SUB('2018-05-01', INTERVAL 1 YEAR);
-> '2017-05-01'
mysql> SELECT DATE_ADD('2020-12-31 23:59:59', INTERVAL 1 SECOND);
-> '2021-01-01 00:00:00'
mysql> SELECT DATE_ADD('2018-12-31 23:59:59', INTERVAL 1 DAY);
-> '2019-01-01 23:59:59'
mysql> SELECT DATE_ADD('2100-12-31 23:59:59', INTERVAL 1 YEAR);
-> '2101-01-01 00:00:00'
```
Temporal Intervals

Temporal arithmetic also can be performed in expressions using `INTERVAL` together with the `+` or `−` operator:

```
date  + INTERVAL expr unit
```
```
date  - INTERVAL expr unit
```
`INTERVAL expr unit` is permitted on either side of the `+` operator if the expression on the other side is a date or datetime value. For the `−` operator, `INTERVAL expr unit` is permitted only on the right side, because it makes no sense to subtract a date or datetime value from an interval.

```
mysql> SELECT '2018-12-31 23:59:59' + INTERVAL 1 SECOND;
-> '2019-01-01 00:00:00'
```
```
mysql> SELECT INTERVAL 1 DAY + '2018-12-31';
-> '2019-01-01'
```
```
mysql> SELECT '2025-01-01' - INTERVAL 1 SECOND;
-> '2024-12-31 23:59:59'
```

The `EXTRACT()` function uses the same kinds of `unit` specifiers as `DATE_ADD()` or `DATE_SUB()`, but extracts parts from the date rather than performing date arithmetic:

```
mysql> SELECT EXTRACT(YEAR_MONTH FROM '2019-07-02 01:02:03');
-> 201907
```
```
mysql> SELECT EXTRACT(YEAR FROM '2019-07-02');
-> 2019
```

Temporal intervals can be used in `CREATE EVENT` statements:

```
CREATE EVENT myevent
ON SCHEDULE AT CURRENT_TIMESTAMP + INTERVAL 1 HOUR
DO
  UPDATE myschema.mytable SET mycol = mycol + 1;
```

If you specify an interval value that is too short (does not include all the interval parts that would be expected from the `unit` keyword), MySQL assumes that you have left out the leftmost parts of the interval value. For example, if you specify a `unit` of `DAY_SECOND`, the value of `expr` is expected to have days, hours, minutes, and seconds parts. If you specify a value like `'1:10'`, MySQL assumes that the days and hours parts are missing and the value represents minutes and seconds. In other words, `'1:10' DAY_SECOND` is interpreted in such a way that it is equivalent to `'1:10' MINUTE_SECOND`. This is analogous to the way that MySQL interprets `TIME` values as representing elapsed time rather than as a time of day.

`expr` is treated as a string, so be careful if you specify a nonstring value with `INTERVAL`. For example, with an interval specifier of `HOUR_MINUTE`, `'6/4'` is treated as 6 hours, four minutes, whereas `6/4` evaluates to `1.5000` and is treated as 1 hour, 5000 minutes:

```
mysql> SELECT '6/4', 6/4;
-> 1.5000
mysql> SELECT DATE_ADD('2019-01-01', INTERVAL '6/4' HOUR_MINUTE);
```
To ensure interpretation of the interval value as you expect, a `CAST()` operation may be used. To treat 6/4 as 1 hour, 5 minutes, cast it to a `DECIMAL` value with a single fractional digit:

```sql
mysql> SELECT CAST(6/4 AS DECIMAL(3,1));
-> 1.5
mysql> SELECT DATE_ADD('1970-01-01 12:00:00', INTERVAL CAST(6/4 AS DECIMAL(3,1)) HOUR_MINUTE);
-> '1970-01-01 13:05:00'
```

If you add to or subtract from a date value something that contains a time part, the result is automatically converted to a datetime value:

```sql
mysql> SELECT DATE_ADD('2023-01-01', INTERVAL 1 DAY);
-> '2023-01-02'
mysql> SELECT DATE_ADD('2023-01-01', INTERVAL 1 HOUR);
-> '2023-01-01 01:00:00'
```

If you add `MONTH`, `YEAR_MONTH`, or `YEAR` and the resulting date has a day that is larger than the maximum day for the new month, the day is adjusted to the maximum days in the new month:

```sql
mysql> SELECT DATE_ADD('2019-01-30', INTERVAL 1 MONTH);
-> '2019-02-28'
```

Date arithmetic operations require complete dates and do not work with incomplete dates such as '2016-07-00' or badly malformed dates:

```sql
mysql> SELECT DATE_ADD('2016-07-00', INTERVAL 1 DAY);
-> NULL
mysql> SELECT '2005-03-32' + INTERVAL 1 MONTH;
-> NULL
```

### 9.6 Comment Syntax

MySQL Server supports three comment styles:

- **From a `#` character to the end of the line.**
- **From a `--` sequence to the end of the line.** In MySQL, the `--` (double-dash) comment style requires the second dash to be followed by at least one whitespace or control character (such as a space, tab, newline, and so on). This syntax differs slightly from standard SQL comment syntax, as discussed in Section 1.7.2.4, “`--` as the Start of a Comment”.
- **From a `/*` sequence to the following `*/` sequence, as in the C programming language.** This syntax enables a comment to extend over multiple lines because the beginning and closing sequences need not be on the same line.

The following example demonstrates all three comment styles:

```sql
mysql> SELECT 1+1;     # This comment continues to the end of line
mysql> SELECT 1+1;     -- This comment continues to the end of line
mysql> SELECT 1 /* this is an in-line comment */ + 1;
mysql> SELECT 1+ /*
   * this is a multiple-line comment */ 1;
```
Comment Syntax

Nested comments are not supported. (Under some conditions, nested comments might be permitted, but usually are not, and users should avoid them.)

MySQL Server supports certain variants of C-style comments. These enable you to write code that includes MySQL extensions, but is still portable, by using comments of the following form:

`/*! MySQL-specific code */`

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the `STRAIGHT_JOIN` keyword in the following statement, but other servers will not:

```
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the `!` character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The `KEY_BLOCK_SIZE` keyword in the following comment is executed only by servers from MySQL 5.1.10 or higher:

```
CREATE TABLE t1(a INT, KEY (a)) /*!50110 KEY_BLOCK_SIZE=1024 */;
```

The comment syntax just described applies to how the `mysqld` server parses SQL statements. The `mysql` client program also performs some parsing of statements before sending them to the server. (It does this to determine statement boundaries within a multiple-statement input line.) For information about differences between the server and `mysql` client parsers, see Section 4.5.1.6, “mysql Client Tips”.

Comments in `/*!12345 ... */` format are not stored on the server. If this format is used to comment stored programs, the comments are not retained in the program body.

The use of short-form `mysql` commands such as `\C` within multiple-line `*/ ... */` comments is not supported.
# Chapter 10 Character Sets, Collations, Unicode

## Table of Contents

10.1 Character Sets and Collations in General ......................................................... 1084  
10.2 Character Sets and Collations in MySQL ....................................................... 1085  
  10.2.1 Character Set Repertoire ............................................................................. 1086  
  10.2.2 UTF-8 for Metadata .................................................................................... 1088  
10.3 Specifying Character Sets and Collations ....................................................... 1089  
  10.3.1 Collation Naming Conventions .................................................................... 1090  
  10.3.2 Server Character Set and Collation ........................................................... 1091  
  10.3.3 Database Character Set and Collation ....................................................... 1091  
  10.3.4 Table Character Set and Collation ............................................................. 1092  
  10.3.5 Column Character Set and Collation .......................................................... 1093  
  10.3.6 Character String Literal Character Set and Collation ............................... 1094  
  10.3.7 The National Character Set ........................................................................ 1096  
  10.3.8 Character Set Introducers .......................................................................... 1097  
  10.3.9 Examples of Character Set and Collation Assignment ............................... 1098  
  10.3.10 Compatibility with Other DBMSs ............................................................. 1099  
10.4 Connection Character Sets and Collations ...................................................... 1099  
10.5 Configuring Application Character Set and Collation .................................. 1106  
10.6 Error Message Character Set .......................................................................... 1107  
10.7 Column Character Set Conversion ................................................................. 1108  
10.8 Collation Issues ................................................................................................. 1110  
  10.8.1 Using COLLATE in SQL Statements .......................................................... 1110  
  10.8.2 COLLATE Clause Precedence ..................................................................... 1110  
  10.8.3 Character Set and Collation Compatibility ............................................... 1111  
  10.8.4 Collation Coercibility in Expressions ....................................................... 1111  
  10.8.5 The binary Collation Compared to _bin Collations ..................................... 1112  
  10.8.6 Examples of the Effect of Collation ........................................................... 1114  
  10.8.7 Using Collation in INFORMATION_SCHEMA Searches ............................... 1116  
10.9 Unicode Support ............................................................................................... 1118  
  10.9.1 The utf8mb4 Character Set (4-Byte UTF-8 Unicode Encoding) .............. 1119  
  10.9.2 The utf8mb3 Character Set (3-Byte UTF-8 Unicode Encoding) .............. 1120  
  10.9.3 The utf8 Character Set (Alias for utf8mb3) ............................................ 1120  
  10.9.4 The ucs2 Character Set (UCS-2 Unicode Encoding) .................................. 1121  
  10.9.5 The utf16 Character Set (UTF-16 Unicode Encoding) ............................ 1121  
  10.9.6 The utf32 Character Set (UTF-32 Unicode Encoding) ............................ 1121  
  10.9.7 Converting Between 3-Byte and 4-Byte Unicode Character Sets ............ 1122  
10.10 Supported Character Sets and Collations ...................................................... 1124  
  10.10.1 Unicode Character Sets ............................................................................ 1125  
  10.10.2 West European Character Sets ................................................................. 1129  
  10.10.3 Central European Character Sets ............................................................. 1130  
  10.10.4 South European and Middle East Character Sets .................................. 1131  
  10.10.5 Baltic Character Sets ................................................................................ 1132  
  10.10.6 Cyrillic Character Sets .............................................................................. 1132  
  10.10.7 Asian Character Sets ................................................................................ 1133  
  10.10.8 The Binary Character Set ....................................................................... 1136  
10.11 Restrictions on Character Sets .................................................................... 1137  
10.12 Setting the Error Message Language ............................................................. 1138  
10.13 Adding a Character Set ................................................................................ 1139  
  10.13.1 Character Definition Arrays ..................................................................... 1141
MySQL includes character set support that enables you to store data using a variety of character sets and perform comparisons according to a variety of collations. You can specify character sets at the server, database, table, and column level.

This chapter discusses the following topics:

- What are character sets and collations?
- The multiple-level default system for character set assignment.
- Syntax for specifying character sets and collations.
- Affected functions and operations.
- Unicode support.
- The character sets and collations that are available, with notes.
- Selecting the language for error messages.
- Selecting the locale for day and month names.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the utf8 Unicode character set, issue this statement after connecting to the server:

```
SET NAMES 'utf8';
```

For more information about configuring character sets for application use and character set-related issues in client/server communication, see Section 10.5, “Configuring Application Character Set and Collation”, and Section 10.4, “Connection Character Sets and Collations”.

### 10.1 Character Sets and Collations in General

A **character set** is a set of symbols and encodings. A **collation** is a set of rules for comparing characters in a character set. Let's make the distinction clear with an example of an imaginary character set.

Suppose that we have an alphabet with four letters: A, B, a, b. We give each letter a number: A = 0, B = 1, a = 2, b = 3. The letter A is a symbol, the number 0 is the encoding for A, and the combination of all four letters and their encodings is a **character set**.

Suppose that we want to compare two string values, A and B. The simplest way to do this is to look at the encodings: 0 for A and 1 for B. Because 0 is less than 1, we say A is less than B. What we've just done is apply a collation to our character set. The collation is a set of rules (only one rule in this case): “compare the encodings.” We call this simplest of all possible collations a **binary collation**.
But what if we want to say that the lowercase and uppercase letters are equivalent? Then we would have at least two rules: (1) treat the lowercase letters a and b as equivalent to A and B; (2) then compare the encodings. We call this a case-insensitive collation. It is a little more complex than a binary collation.

In real life, most character sets have many characters: not just A and B but whole alphabets, sometimes multiple alphabets or eastern writing systems with thousands of characters, along with many special symbols and punctuation marks. Also in real life, most collations have many rules, not just for whether to distinguish lettercase, but also for whether to distinguish accents (an “accent” is a mark attached to a character as in German ö), and for multiple-character mappings (such as the rule that ö = oe in one of the two German collations).

MySQL can do these things for you:

- Store strings using a variety of character sets.
- Compare strings using a variety of collations.
- Mix strings with different character sets or collations in the same server, the same database, or even the same table.
- Enable specification of character set and collation at any level.

To use these features effectively, you must know what character sets and collations are available, how to change the defaults, and how they affect the behavior of string operators and functions.

## 10.2 Character Sets and Collations in MySQL

MySQL Server supports multiple character sets. To display the available character sets, use the `INFORMATION_SCHEMA CHARACTER_SETS` table or the `SHOW CHARACTER SET` statement. A partial listing follows. For more complete information, see Section 10.10, “Supported Character Sets and Collations”.

```
mysql> SHOW CHARACTER SET;
+----------+---------------------------------+---------------------+--------+
| Charset  | Description                     | Default collation   | Maxlen |
+----------+---------------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese        | big5_chinese_ci     | 2      |
| latin1   | cp1252 West European            | latin1_swedish_ci   | 1      |
| latin2   | ISO 8859-2 Central European     | latin2_general_ci   | 1      |
| utf8     | UTF-8 Unicode                   | utf8_general_ci     | 3      |
| ucs2     | UCS-2 Unicode                   | ucs2_general_ci     | 2      |
| utf8mb4  | UTF-8 Unicode                   | utf8mb4_general_ci  | 4      |
| binary   | Binary pseudo charset           | binary              | 1      |
```

By default, the `SHOW CHARACTER SET` statement displays all available character sets. It takes an optional `LIKE` or `WHERE` clause that indicates which character set names to match. For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+----------+---------------------------------+---------------------+--------+
| Charset  | Description                     | Default collation   | Maxlen |
+----------+---------------------------------+---------------------+--------+
| latin1   | cp1252 West European            | latin1_swedish_ci   | 1      |
| latin2   | ISO 8859-2 Central European     | latin2_general_ci   | 1      |
| latin5   | ISO 8859-9 Turkish              | latin5_turkish_ci   | 1      |
| latin7   | ISO 8859-13 Baltic              | latin7_general_ci   | 1      |
```
A given character set always has at least one collation, and most character sets have several. To list the display collations for a character set, use the `INFORMATION_SCHEMA COLLATIONS` table or the `SHOW COLLATION` statement.

By default, the `SHOW COLLATION` statement displays all available collations. It takes an optional `LIKE` or `WHERE` clause that indicates which collation names to display. For example, to see the collations for the default character set, `latin1` (cp1252 West European), use this statement:

```sql
mysql> SHOW COLLATION WHERE Charset = 'latin1';
```

<table>
<thead>
<tr>
<th>Collation</th>
<th>Charset</th>
<th>Id</th>
<th>Default</th>
<th>Compiled</th>
<th>Sortlen</th>
</tr>
</thead>
<tbody>
<tr>
<td>latin1_german1_ci</td>
<td>latin1</td>
<td>5</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_swedish_ci</td>
<td>latin1</td>
<td>8</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_danish_ci</td>
<td>latin1</td>
<td>15</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_german2_ci</td>
<td>latin1</td>
<td>31</td>
<td></td>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>latin1_bin</td>
<td>latin1</td>
<td>47</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_general_ci</td>
<td>latin1</td>
<td>48</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_general_cs</td>
<td>latin1</td>
<td>49</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>latin1_spanish_ci</td>
<td>latin1</td>
<td>94</td>
<td></td>
<td>Yes</td>
<td>1</td>
</tr>
</tbody>
</table>

The `latin1` collations have the following meanings.

<table>
<thead>
<tr>
<th>Collation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>latin1_bin</td>
<td>Binary according to <code>latin1</code> encoding</td>
</tr>
<tr>
<td>latin1_danish_ci</td>
<td>Danish/Norwegian</td>
</tr>
<tr>
<td>latin1_general_ci</td>
<td>Multilingual (Western European)</td>
</tr>
<tr>
<td>latin1_general_cs</td>
<td>Multilingual (ISO Western European), case-sensitive</td>
</tr>
<tr>
<td>latin1_german1_ci</td>
<td>German DIN-1 (dictionary order)</td>
</tr>
<tr>
<td>latin1_german2_ci</td>
<td>German DIN-2 (phone book order)</td>
</tr>
<tr>
<td>latin1_spanish_ci</td>
<td>Modern Spanish</td>
</tr>
<tr>
<td>latin1_swedish_ci</td>
<td>Swedish/Finnish</td>
</tr>
</tbody>
</table>

Collations have these general characteristics:

- Two different character sets cannot have the same collation.

- Each character set has a default collation. For example, the default collations for `latin1` and `utf8` are `latin1_swedish_ci` and `utf8_general_ci`, respectively. The `INFORMATION_SCHEMA CHARACTER_SETS` table and the `SHOW CHARACTER SET` statement indicate the default collation for each character set. The `INFORMATION_SCHEMA COLLATIONS` table and the `SHOW COLLATION` statement have a column that indicates for each collation whether it is the default for its character set (`Yes` if so, empty if not).

- Collation names start with the name of the character set with which they are associated, generally followed by one or more suffixes indicating other collation characteristics. For additional information about naming conventions, see Section 10.3.1, "Collation Naming Conventions".

When a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing an inappropriate collation, perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

**10.2.1 Character Set Repertoire**
The repertoire of a character set is the collection of characters in the set.

String expressions have a repertoire attribute, which can have two values:

- **ASCII**: The expression can contain only characters in the Unicode range \(U+0000\) to \(U+007F\).
- **UNICODE**: The expression can contain characters in the Unicode range \(U+0000\) to \(U+10FFFF\). This includes characters in the Basic Multilingual Plane (BMP) range \((U+0000\) to \(U+FFFF\)) and supplementary characters outside the BMP range \((U+10000\) to \(U+10FFFF\)).

The ASCII range is a subset of UNICODE range, so a string with ASCII repertoire can be converted safely without loss of information to the character set of any string with UNICODE repertoire or to a character set that is a superset of ASCII. (All MySQL character sets are supersets of ASCII with the exception of swe7, which reuses some punctuation characters for Swedish accented characters.) The use of repertoire enables character set conversion in expressions for many cases where MySQL would otherwise return an “illegal mix of collations” error.

The following discussion provides examples of expressions and their repertoires, and describes how the use of repertoire changes string expression evaluation:

- The repertoire for a string constant depends on string content and may differ from the repertoire of the string character set. Consider these statements:

```sql
SET NAMES utf8; SELECT 'abc';
SELECT _utf8'def';
SELECT N'MySQL';
```

Although the character set is utf8 in each of the preceding cases, the strings do not actually contain any characters outside the ASCII range, so their repertoire is ASCII rather than UNICODE.

- A column having the ascii character set has ASCII repertoire because of its character set. In the following table, \(c1\) has ASCII repertoire:

```sql
CREATE TABLE t1 (c1 CHAR(1) CHARACTER SET ascii);
```

The following example illustrates how repertoire enables a result to be determined in a case where an error occurs without repertoire:

```sql
CREATE TABLE t1 (c1 CHAR(1) CHARACTER SET latin1,
c2 CHAR(1) CHARACTER SET ascii);
INSERT INTO t1 VALUES ('a','b');
SELECT CONCAT(c1,c2) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (latin1_swedish_ci,IMPLICIT)
and (ascii_general_ci,IMPLICIT) for operation 'concat'
```

Using repertoire, subset to superset (ascii to latin1) conversion can occur and a result is returned:

```
+---------------+
| CONCAT(c1,c2) |
+---------------+
| ab            |
```

- Functions with one string argument inherit the repertoire of their argument. The result of `UPPER(_utf8'abc')` has ASCII repertoire because its argument has ASCII repertoire.
• For functions that return a string but do not have string arguments and use `character_set_connection` as the result character set, the result repertoire is `ASCII` if `character_set_connection` is `ascii`, and `UNICODE` otherwise:

```sql
FORMAT(numeric_column, 4);
```

Use of repertoire changes how MySQL evaluates the following example:

```sql
SET NAMES ascii;
CREATE TABLE t1 (a INT, b VARCHAR(10) CHARACTER SET latin1);
INSERT INTO t1 VALUES (1,'b');
SELECT CONCAT(FORMAT(a, 4), b) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (ascii_general_ci,COERCIBLE)
and (latin1_swedish_ci,IMPLICIT) for operation 'concat'
```

With repertoire, a result is returned:

```
+-------------------------+
| CONCAT(FORMAT(a, 4), b) |
+-------------------------+
| 1.0000b                 |
+-------------------------+
```

• Functions with two or more string arguments use the “widest” argument repertoire for the result repertoire (`UNICODE` is wider than `ASCII`). Consider the following `CONCAT()` calls:

```sql
CONCAT(_ucs2 X'0041', _ucs2 X'0042')
CONCAT(_ucs2 X'0041', _ucs2 X'00C2')
```

For the first call, the repertoire is `ASCII` because both arguments are within the range of the `ascii` character set. For the second call, the repertoire is `UNICODE` because the second argument is outside the `ascii` character set range.

• The repertoire for function return values is determined based only on the repertoire of the arguments that affect the result’s character set and collation.

```sql
IF(column1 < column2, 'smaller', 'greater')
```

The result repertoire is `ASCII` because the two string arguments (the second argument and the third argument) both have `ASCII` repertoire. The first argument does not matter for the result repertoire, even if the expression uses string values.

### 10.2.2 UTF-8 for Metadata

*Metadata* is “the data about the data.” Anything that describes the database—as opposed to being the *contents* of the database—is metadata. Thus column names, database names, user names, version names, and most of the string results from *SHOW* are metadata. This is also true of the contents of tables in *INFORMATION_SCHEMA* because those tables by definition contain information about database objects.

Representation of metadata must satisfy these requirements:

• All metadata must be in the same character set. Otherwise, neither the *SHOW* statements nor *SELECT* statements for tables in *INFORMATION_SCHEMA* would work properly because different rows in the same column of the results of these operations would be in different character sets.

• Metadata must include all characters in all languages. Otherwise, users would not be able to name columns and tables using their own languages.
To satisfy both requirements, MySQL stores metadata in a Unicode character set, namely UTF-8. This does not cause any disruption if you never use accented or non-Latin characters. But if you do, you should be aware that metadata is in UTF-8.

The metadata requirements mean that the return values of the `USER()`, `CURRENT_USER()`, `SESSION_USER()`, `SYSTEM_USER()`, `DATABASE()`, and `VERSION()` functions have the UTF-8 character set by default.

The server sets the `character_set_system` system variable to the name of the metadata character set:

```
mysql> SHOW VARIABLES LIKE '_character_set_system';
+----------------------+-------+
| Variable_name         | Value |
+----------------------+-------+
| character_set_system  | utf8  |
+----------------------+-------+
```

Storage of metadata using Unicode does not mean that the server returns headers of columns and the results of `DESCRIBE` functions in the `character_set_system` character set by default. When you use `SELECT column1 FROM t`, the name `column1` itself is returned from the server to the client in the character set determined by the value of the `character_set_results` system variable, which has a default value of `utf8`. If you want the server to pass metadata results back in a different character set, use the `SET NAMES` statement to force the server to perform character set conversion. `SET NAMES` sets the `character_set_results` and other related system variables. (See Section 10.4, “Connection Character Sets and Collations”.) Alternatively, a client program can perform the conversion after receiving the result from the server. It is more efficient for the client to perform the conversion, but this option is not always available for all clients.

If `character_set_results` is set to `NULL`, no conversion is performed and the server returns metadata using its original character set (the set indicated by `character_set_system`).

Error messages returned from the server to the client are converted to the client character set automatically, as with metadata.

If you are using (for example) the `USER()` function for comparison or assignment within a single statement, don't worry. MySQL performs some automatic conversion for you.

```
SELECT * FROM t1 WHERE USER() = latin1_column;
```

This works because the contents of `latin1_column` are automatically converted to UTF-8 before the comparison.

```
INSERT INTO t1 (latin1_column) SELECT USER();
```

This works because the contents of `USER()` are automatically converted to `latin1` before the assignment.

Although automatic conversion is not in the SQL standard, the standard does say that every character set is (in terms of supported characters) a “subset” of Unicode. Because it is a well-known principle that “what applies to a superset can apply to a subset,” we believe that a collation for Unicode can apply for comparisons with non-Unicode strings. For more information about coercion of strings, see Section 10.8.4, “Collation Coercibility in Expressions”.

### 10.3 Specifying Character Sets and Collations

There are default settings for character sets and collations at four levels: server, database, table, and column. The description in the following sections may appear complex, but it has been found in practice that multiple-level defaulting leads to natural and obvious results.
**Collation Naming Conventions**

**Character Set** is used in clauses that specify a character set. **Charset** can be used as a synonym for **character set**.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the utf8 Unicode character set, issue this statement after connecting to the server:

```sql
SET NAMES 'utf8';
```

For more information about character set-related issues in client/server communication, see Section 10.4, "Connection Character Sets and Collations".

### 10.3.1 Collation Naming Conventions

MySQL collation names follow these conventions:

- A collation name starts with the name of the character set with which it is associated, generally followed by one or more suffixes indicating other collation characteristics. For example, `utf8_general_ci` and `latin1_swedish_ci` are collations for the `utf8` and `latin1` character sets, respectively. The `binary` character set has a single collation, also named `binary`, with no suffixes.

- A language-specific collation includes a language name. For example, `utf8_turkish_ci` and `utf8_hungarian_ci` sort characters for the `utf8` character set using the rules of Turkish and Hungarian, respectively.

- Collation suffixes indicate whether a collation is case-sensitive, accent-sensitive, or kana-sensitive (or some combination thereof), or binary. The following table shows the suffixes used to indicate these characteristics.

<table>
<thead>
<tr>
<th>Suffix</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ai</td>
<td>Accent-insensitive</td>
</tr>
<tr>
<td>_as</td>
<td>Accent-sensitive</td>
</tr>
<tr>
<td>_ci</td>
<td>Case-insensitive</td>
</tr>
<tr>
<td>_cs</td>
<td>Case-sensitive</td>
</tr>
<tr>
<td>_bin</td>
<td>Binary</td>
</tr>
</tbody>
</table>

For nonbinary collation names that do not specify accent sensitivity, it is determined by case sensitivity. If a collation name does not contain _ai or _as, _ci in the name implies _ai and _cs in the name implies _as. For example, `latin1_general_ci` is explicitly case-insensitive and implicitly accent-insensitive, and `latin1_general_cs` is explicitly case-sensitive and implicitly accent-sensitive.

For the **binary** collation of the **binary** character set, comparisons are based on numeric byte values. For the _bin collation of a nonbinary character set, comparisons are based on numeric character code values, which differ from byte values for multibyte characters. For information about the differences between the **binary** collation of the **binary** character set and the _bin collations of nonbinary character sets, see Section 10.8.5, "The binary Collation Compared to _bin Collations".

- For Unicode character sets, the `xxx_general_mysql500_ci` collations preserve the pre-5.1.24 ordering of the original `xxx_general_ci` collations and permit upgrades for tables created before MySQL 5.1.24 (Bug #27877).
10.3.2 Server Character Set and Collation

MySQL Server has a server character set and a server collation. These can be set at server startup on the command line or in an option file and changed at runtime.

Initially, the server character set and collation depend on the options that you use when you start `mysqld`. You can use `--character-set-server` for the character set. Along with it, you can add `--collation-server` for the collation. If you don’t specify a character set, that is the same as saying `--character-set-server=latin1`. If you specify only a character set (for example, `latin1`) but not a collation, that is the same as saying `--character-set-server=latin1 --collation-server=latin1_swedish_ci` because `latin1_swedish_ci` is the default collation for `latin1`. Therefore, the following three commands all have the same effect:

```
mysqld
mysqld --character-set-server=latin1
mysqld --character-set-server=latin1 --collation-server=latin1_swedish_ci
```

One way to change the settings is by recompiling. To change the default server character set and collation when building from sources, use the `DEFAULT_CHARSET` and `DEFAULT_COLLATION` options for CMake. For example:

```
cmake . -DDEFAULT_CHARSET=latin1
```

Or:

```
cmake . -DDEFAULT_CHARSET=latin1 -DDEFAULT_COLLATION=latin1_german1_ci
```

Both `mysqld` and CMake verify that the character set/collation combination is valid. If not, each program displays an error message and terminates.

The server character set and collation are used as default values if the database character set and collation are not specified in `CREATE DATABASE` statements. They have no other purpose.

The current server character set and collation can be determined from the values of the `character_set_server` and `collation_server` system variables. These variables can be changed at runtime.

10.3.3 Database Character Set and Collation

Every database has a database character set and a database collation. The `CREATE DATABASE` and `ALTER DATABASE` statements have optional clauses for specifying the database character set and collation:

```
CREATE DATABASE db_name
[[DEFAULT] CHARACTER SET charset_name]
[[DEFAULT] COLLATE collation_name]

ALTER DATABASE db_name
[[DEFAULT] CHARACTER SET charset_name]
[[DEFAULT] COLLATE collation_name]
```

The keyword `SCHEMA` can be used instead of `DATABASE`.

All database options are stored in a text file named `db.opt` that can be found in the database directory.

The `CHARACTER SET` and `COLLATE` clauses make it possible to create databases with different character sets and collations on the same MySQL server.
Example:

```
CREATE DATABASE db_name CHARACTER SET latin1 COLLATE latin1_swedish_ci;
```

MySQL chooses the database character set and database collation in the following manner:

- If both `CHARACTER SET charset_name` and `COLLATE collation_name` are specified, character set `charset_name` and collation `collation_name` are used.

- If `CHARACTER SET charset_name` is specified without `COLLATE`, character set `charset_name` and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement or query the `INFORMATION_SCHEMA CHARACTER_SETS` table.

- If `COLLATE collation_name` is specified without `CHARACTER SET`, the character set associated with `collation_name` and collation `collation_name` are used.

- Otherwise (neither `CHARACTER SET` nor `COLLATE` is specified), the server character set and server collation are used.

The character set and collation for the default database can be determined from the values of the `character_set_database` and `collation_database` system variables. The server sets these variables whenever the default database changes. If there is no default database, the variables have the same value as the corresponding server-level system variables, `character_set_server` and `collation_server`.

To see the default character set and collation for a given database, use these statements:

```
USE db_name;
SELECT @@character_set_database, @@collation_database;
```

Alternatively, to display the values without changing the default database:

```
SELECT DEFAULT_CHARACTER_SET_NAME, DEFAULT_COLLATION_NAME
FROM INFORMATION_SCHEMA.SCHEMATA WHERE SCHEMA_NAME = 'db_name';
```

The database character set and collation affect these aspects of server operation:

- For `CREATE TABLE` statements, the database character set and collation are used as default values for table definitions if the table character set and collation are not specified. To override this, provide explicit `CHARACTER SET` and `COLLATE` table options.

- For `LOAD DATA` statements that include no `CHARACTER SET` clause, the server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. To override this, provide an explicit `CHARACTER SET` clause.

- For stored routines (procedures and functions), the database character set and collation in effect at routine creation time are used as the character set and collation of character data parameters for which the declaration includes no `CHARACTER SET` or a `COLLATE` attribute. To override this, provide `CHARACTER SET` and `COLLATE` explicitly.

### 10.3.4 Table Character Set and Collation

Every table has a table character set and a table collation. The `CREATE TABLE` and `ALTER TABLE` statements have optional clauses for specifying the table character set and collation:

```
CREATE TABLE tbl_name (column_list)
    [[DEFAULT] CHARACTER SET charset_name]
    [COLLATE collation_name]

ALTER TABLE tbl_name
```
Column Character Set and Collation

Example:

```sql
CREATE TABLE t1 ( ... )
CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

MySQL chooses the table character set and collation in the following manner:

- If both `CHARACTER SET charset_name` and `COLLATE collation_name` are specified, character set `charset_name` and collation `collation_name` are used.

- If `CHARACTER SET charset_name` is specified without `COLLATE`, character set `charset_name` and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement or query the `INFORMATION_SCHEMA CHARACTER_SETS` table.

- If `COLLATE collation_name` is specified without `CHARACTER SET`, the character set associated with `collation_name` and collation `collation_name` are used.

- Otherwise (neither `CHARACTER SET` nor `COLLATE` is specified), the database character set and collation are used.

The table character set and collation are used as default values for column definitions if the column character set and collation are not specified in individual column definitions. The table character set and collation are MySQL extensions; there are no such things in standard SQL.

### 10.3.5 Column Character Set and Collation

Every “character” column (that is, a column of type `CHAR`, `VARCHAR`, a `TEXT` type, or any synonym) has a column character set and a column collation. Column definition syntax for `CREATE TABLE` and `ALTER TABLE` has optional clauses for specifying the column character set and collation:

```sql
col_name (CHAR | VARCHAR | TEXT) (col_length)
[CHARACTER SET charset_name]
[COLLATE collation_name]
```

These clauses can also be used for `ENUM` and `SET` columns:

```sql
col_name (ENUM | SET) (val_list)
[CHARACTER SET charset_name]
[COLLATE collation_name]
```

Examples:

```sql
CREATE TABLE t1
(
  col1 VARCHAR(5)
  CHARACTER SET latin1
  COLLATE latin1_german1_ci
);

ALTER TABLE t1 MODIFY
  col1 VARCHAR(5)
  CHARACTER SET latin1
  COLLATE latin1_swedish_ci;
```

MySQL chooses the column character set and collation in the following manner:

- If both `CHARACTER SET charset_name` and `COLLATE collation_name` are specified, character set `charset_name` and collation `collation_name` are used.
CREATE TABLE t1
{
    col1 CHAR(10) CHARACTER SET utf8 COLLATE utf8_unicode_ci
} CHARACTER SET latin1 COLLATE latin1_bin;

The character set and collation are specified for the column, so they are used. The column has character set utf8 and collation utf8_unicode_ci.

- If CHARACTER SET charset_name is specified without COLLATE, character set charset_name and its default collation are used.

CREATE TABLE t1
{
    col1 CHAR(10) CHARACTER SET utf8
} CHARACTER SET latin1 COLLATE latin1_bin;

The character set is specified for the column, but the collation is not. The column has character set utf8 and the default collation for utf8, which is utf8_general_ci. To see the default collation for each character set, use the SHOW CHARACTER SET statement or query the INFORMATION_SCHEMA CHARACTER_SETS table.

- If COLLATE collation_name is specified without CHARACTER SET, the character set associated with collation_name and collation collation_name are used.

CREATE TABLE t1
{
    col1 CHAR(10) COLLATE utf8_polish_ci
} CHARACTER SET latin1 COLLATE latin1_bin;

The collation is specified for the column, but the character set is not. The column has collation utf8_polish_ci and the character set is the one associated with the collation, which is utf8.

- Otherwise (neither CHARACTER SET nor COLLATE is specified), the table character set and collation are used.

CREATE TABLE t1
{
    col1 CHAR(10)
} CHARACTER SET latin1 COLLATE latin1_bin;

Neither the character set nor collation is specified for the column, so the table defaults are used. The column has character set latin1 and collation latin1_bin.

The CHARACTER SET and COLLATE clauses are standard SQL.

If you use ALTER TABLE to convert a column from one character set to another, MySQL attempts to map the data values, but if the character sets are incompatible, there may be data loss.

### 10.3.6 Character String Literal Character Set and Collation

Every character string literal has a character set and a collation.

For the simple statement SELECT 'string', the string has the connection default character set and collation defined by the character_set_connection and collation_connection system variables.

A character string literal may have an optional character set introducer and COLLATE clause, to designate it as a string that uses a particular character set and collation:

[_charset_name]'string' [COLLATE collation_name]
The \_charset\_name expression is formally called an introducer. It tells the parser, “the string that follows uses character set \ charset\_name.” An introducer does not change the string to the introducer character set like CONVERT() would do. It does not change the string value, although padding may occur. The introducer is just a signal. See Section 10.3.8, “Character Set Introducers”.

Examples:

```
SELECT 'abc';
SELECT \_latin1'abc';
SELECT \_binary'abc';
SELECT \_utf8'abc' COLLATE utf8_danish_ci;
```

Character set introducers and the COLLATE clause are implemented according to standard SQL specifications.

MySQL determines the character set and collation of a character string literal in the following manner:

- If both \_charset\_name and COLLATE collation\_name are specified, character set \ charset\_name and collation collation\_name are used. collation\_name must be a permitted collation for \ charset\_name.

- If \_charset\_name is specified but COLLATE is not specified, character set \ charset\_name and its default collation are used. To see the default collation for each character set, use the SHOW CHARACTER SET statement or query the INFORMATION_SCHEMA CHARACTER_SETS table.

- If \_charset\_name is not specified but COLLATE collation\_name is specified, the connection default character set given by the character_set_connection system variable and collation collation\_name are used. collation\_name must be a permitted collation for the connection default character set.

- Otherwise (neither \_charset\_name nor COLLATE collation\_name is specified), the connection default character set and collation given by the character_set_connection and collation_connection system variables are used.

Examples:

- A nonbinary string with latin1 character set and latin1_german1_ci collation:
  ```
  SELECT \_latin1'Müller' COLLATE latin1_german1_ci;
  ```

- A nonbinary string with utf8 character set and its default collation (that is, utf8_general_ci):
  ```
  SELECT \_utf8'Müller';
  ```

- A binary string with binary character set and its default collation (that is, binary):
  ```
  SELECT \_binary'Müller';
  ```

- A nonbinary string with the connection default character set and utf8_general_ci collation (fails if the connection character set is not utf8):
  ```
  SELECT 'Müller' COLLATE utf8_general_ci;
  ```

- A string with the connection default character set and collation:
  ```
  SELECT 'Müller';
  ```

An introducer indicates the character set for the following string, but does not change how the parser performs escape processing within the string. Escapes are always interpreted by the parser according to the character set given by character_set_connection.
The following examples show that escape processing occurs using `character_set_connection` even in the presence of an introducer. The examples use `SET NAMES` (which changes `character_set_connection`, as discussed in Section 10.4, “Connection Character Sets and Collations”), and display the resulting strings using the `HEX()` function so that the exact string contents can be seen.

Example 1:

```sql
mysql> SET NAMES latin1;
mysql> SELECT HEX('à\n'), HEX(_sjis'à
');
+------------+-----------------+
| HEX('à\n') | HEX(_sjis'à
') |
| E00A       | E00A            |
+------------+-----------------+
```

Here, ´à` (hexadecimal value E0) is followed by \n, the escape sequence for newline. The escape sequence is interpreted using the `character_set_connection` value of latin1 to produce a literal newline (hexadecimal value 0A). This happens even for the second string. That is, the _sjis introducer does not affect the parser’s escape processing.

Example 2:

```sql
mysql> SET NAMES sjis;
mysql> SELECT HEX('à\n'), HEX(_latin1'à
');
+------------+-------------------+
| HEX('à\n') | HEX(_latin1'à
') |
| E05C6E     | E05C6E            |
+------------+-------------------+
```

Here, `character_set_connection` is sjis, a character set in which the sequence of ´à` followed by \ (hexadecimal values 05 and 5C) is a valid multibyte character. Hence, the first two bytes of the string are interpreted as a single sjis character, and the \ is not interpreted as an escape character. The following n (hexadecimal value 6E) is not interpreted as part of an escape sequence. This is true even for the second string; the _latin1 introducer does not affect escape processing.

### 10.3.7 The National Character Set

Standard SQL defines `NCHAR` or `NATIONAL CHAR` as a way to indicate that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. For example, these data type declarations are equivalent:

- `CHAR(10) CHARACTER SET utf8`
- `NATIONAL CHARACTER(10)`
- `NCHAR(10)`

As are these:

- `VARCHAR(10) CHARACTER SET utf8`
- `NATIONAL VARCHAR(10)`
- `NVARCHAR(10)`
- `NCHAR VARCHAR(10)`
- `NATIONAL CHARACTER VARYING(10)`
- `NATIONAL CHAR VARYING(10)`

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```sql
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```
10.3.8 Character Set Introducers

A character string literal, hexadecimal literal, or bit-value literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name] literal [COLLATE collation_name]
```

The `_charset_name` expression is formally called an introducer. It tells the parser, “the string that follows uses character set `_charset_name`.” An introducer does not change the string to the introducer character set like `CONVERT()` would do. It does not change the string value, although padding may occur. The introducer is just a signal.

For character string literals, space between the introducer and the string is permitted but optional.

For character set literals, an introducer indicates the character set for the following string, but does not change how the parser performs escape processing within the string. Escapes are always interpreted by the parser according to the character set given by the `character_set_connection` system variable. For additional discussion and examples, see Section 10.3.6, “Character String Literal Character Set and Collation”.

Examples:

```sql
SELECT 'abc';
SELECT _latin1'abc';
SELECT _binary'abc';
SELECT _utf8'abc' COLLATE utf8_danish_ci;
SELECT _latin1 X'4D7953514C';
SELECT _utf8 0x4D7953514C COLLATE utf8_danish_ci;
SELECT _latin1 b'1000001';
SELECT _utf8 0b1000001 COLLATE utf8_danish_ci;
```

Character set introducers and the `COLLATE` clause are implemented according to standard SQL specifications.

Character string literals can be designated as binary strings by using the `_binary` introducer. Hexadecimal literals and bit-value literals are binary strings by default, so `_binary` is permitted, but unnecessary.

MySQL determines the character set and collation of a character string literal, hexadecimal literal, or bit-value literal in the following manner:

- If both `_charset_name` and `COLLATE collation_name` are specified, character set `_charset_name` and collation `collation_name` are used. `collation_name` must be a permitted collation for `_charset_name`.

- If `_charset_name` is specified but `COLLATE` is not specified, character set `_charset_name` and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement or query the `INFORMATION_SCHEMA CHARACTER_SETS` table.

- If `_charset_name` is not specified but `COLLATE collation_name` is specified:
  - For a character string literal, the connection default character set given by the `character_set_connection` system variable and collation `collation_name` are used. `collation_name` must be a permitted collation for the connection default character set.
  - For a hexadecimal literal or bit-value literal, the only permitted collation is `binary` because these types of literals are binary strings by default.
• Otherwise (neither _charset_name nor COLLATE collation_name is specified):
  • For a character string literal, the connection default character set and collation given by the character_set_connection and collation_connection system variables are used.
  • For a hexadecimal literal or bit-value literal, the character set and collation are binary.

Examples:

• Nonbinary strings with latin1 character set and latin1_german1_ci collation:

  SELECT _latin1'Müller' COLLATE latin1_german1_ci;
  SELECT _latin1 X'0A0D' COLLATE latin1_german1_ci;
  SELECT _latin1 b'0110' COLLATE latin1_german1_ci;

• Nonbinary strings with utf8 character set and its default collation (that is, utf8_general_ci):

  SELECT _utf8'Müller';
  SELECT _utf8 X'0A0D';
  SELECT _utf8 b'0110';

• Binary strings with binary character set and its default collation (that is, binary):

  SELECT _binary'Müller';
  SELECT _utf8 X'0A0D';
  SELECT _utf8 b'0110';

The hexadecimal literal and bit-value literal need no introducer because they are binary strings by default.

• A nonbinary string with the connection default character set and utf8_general_ci collation (fails if the connection character set is not utf8):

  SELECT 'Müller' COLLATE utf8_general_ci;

This construction (COLLATE only) does not work for hexadecimal literals or bit literals because their character set is binary no matter the connection character set, and binary is not compatible with the utf8_general_ci collation. The only permitted COLLATE clause in the absence of an introducer is COLLATE binary.

• A string with the connection default character set and collation:

  SELECT 'Müller';

10.3.9 Examples of Character Set and Collation Assignment

The following examples show how MySQL determines default character set and collation values.

Example 1: Table and Column Definition

```sql
CREATE TABLE t1
(
  c1 CHAR(10) CHARACTER SET latin1 COLLATE latin1_german1_ci
) DEFAULT CHARACTER SET latin2 COLLATE latin2_bin;
```

Here we have a column with a latin1 character set and a latin1_german1_ci collation. The definition is explicit, so that is straightforward. Notice that there is no problem with storing a latin1 column in a latin2 table.

Example 2: Table and Column Definition
This time we have a column with a *latin1* character set and a default collation. Although it might seem natural, the default collation is not taken from the table level. Instead, because the default collation for *latin1* is always *latin1_swedish_ci*, column *c1* has a collation of *latin1_swedish_ci* (not *latin1_danish_ci*).

**Example 3: Table and Column Definition**

```sql
CREATE TABLE t1
(
  c1 CHAR(10) COLLATE latin1_danish_ci
) DEFAULT CHARACTER SET latin1;
```

We have a column with a default character set and a default collation. In this circumstance, MySQL checks the table level to determine the column character set and collation. Consequently, the character set for column *c1* is *latin1* and its collation is *latin1_danish_ci*.

**Example 4: Database, Table, and Column Definition**

```sql
CREATE DATABASE d1
  CHARACTER SET latin2 COLLATE latin2_czech_ci;
USE d1;
CREATE TABLE t1
(
  c1 CHAR(10)
);
```

We create a column without specifying its character set and collation. We’re also not specifying a character set and a collation at the table level. In this circumstance, MySQL checks the database level to determine the table settings, which thereafter become the column settings.) Consequently, the character set for column *c1* is *latin2* and its collation is *latin2_czech_ci*.

### 10.3.10 Compatibility with Other DBMSs

For MaxDB compatibility these two statements are the same:

```sql
CREATE TABLE t1 (f1 CHAR(N) UNICODE);
CREATE TABLE t1 (f1 CHAR(N) CHARACTER SET ucs2);
```

### 10.4 Connection Character Sets and Collations

A “connection” is what a client program makes when it connects to the server, to begin a session within which it interacts with the server. The client sends SQL statements, such as queries, over the session connection. The server sends responses, such as result sets or error messages, over the connection back to the client.

- Connection Character Set and Collation System Variables
- Impermissible Client Character Sets
- Client Program Connection Character Set Configuration
- SQL Statements for Connection Character Set Configuration
- Connection Character Set Error Handling
Connection Character Set and Collation System Variables

Several character set and collation system variables relate to a client's interaction with the server. Some of these have been mentioned in earlier sections:

- The `character_set_server` and `collation_server` system variables indicate the server character set and collation. See Section 10.3.2, “Server Character Set and Collation”.

- The `character_set_database` and `collation_database` system variables indicate the character set and collation of the default database. See Section 10.3.3, “Database Character Set and Collation”.

Additional character set and collation system variables are involved in handling traffic for the connection between a client and the server. Every client has session-specific connection-related character set and collation system variables. These session system variable values are initialized at connect time, but can be changed within the session.

Several questions about character set and collation handling for client connections can be answered in terms of system variables:

- What character set are statements in when they leave the client?

  The server takes the `character_set_client` system variable to be the character set in which statements are sent by the client.

  **Note**
  
  Some character sets cannot be used as the client character set. See Impermissible Client Character Sets.

- What character set should the server translate statements to after receiving them?

  To determine this, the server uses the `character_set_connection` and `collation_connection` system variables:

  - The server converts statements sent by the client from `character_set_client` to `character_set_connection`. Exception: For string literals that have an introducer such as `_utf8mb4` or `_latin2`, the introducer determines the character set. See Section 10.3.8, “Character Set Introducers”.

  - `collation_connection` is important for comparisons of literal strings. For comparisons of strings with column values, `collation_connection` does not matter because columns have their own collation, which has a higher collation precedence (see Section 10.8.4, “Collation Coercibility in Expressions”).

- What character set should the server translate query results to before shipping them back to the client?

  The `character_set_results` system variable indicates the character set in which the server returns query results to the client. This includes result data such as column values, result metadata such as column names, and error messages.

  To tell the server to perform no conversion of result sets or error messages, set `character_set_results` to `NULL` or `binary`:

  ```sql
  SET character_set_results = NULL;
  SET character_set_results = binary;
  ```

  For more information about character sets and error messages, see Section 10.6, “Error Message Character Set”.

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1100
To see the values of the character set and collation system variables that apply to the current session, use this statement:

```
SELECT * FROM INFORMATION_SCHEMA.SESSION_VARIABLES
WHERE VARIABLE_NAME IN ('character_set_client', 'character_set_connection', 'character_set_results', 'collation_connection') ORDER BY VARIABLE_NAME;
```

The following simpler statements also display the connection variables, but include other related variables as well. They can be useful to see all character set and collation system variables:

```
SHOW SESSION VARIABLES LIKE 'character_set\_%';
SHOW SESSION VARIABLES LIKE 'collation\_%';
```

Clients can fine-tune the settings for these variables, or depend on the defaults (in which case, you can skip the rest of this section). If you do not use the defaults, you must change the character settings for each connection to the server.

**Impermissible Client Character Sets**

The `character_set_client` system variable cannot be set to certain character sets:

- ucs2
- utf16
- utf32

Attempting to use any of those character sets as the client character set produces an error:

```
mysql> SET character_set_client = 'ucs2';
ERROR 1231 (42000): Variable 'character_set_client' can't be set to the value of 'ucs2'
```

The same error occurs if any of those character sets are used in the following contexts, all of which result in an attempt to set `character_set_client` to the named character set:

- The `--default-character-set=charset_name` command option used by MySQL client programs such as `mysql` and `mysqladmin`.
- The `SET NAMES 'charset_name'` statement.
- The `SET CHARACTER SET 'charset_name'` statement.

**Client Program Connection Character Set Configuration**

When a client connects to the server, it indicates which character set it wants to use for communication with the server. (Actually, the client indicates the default collation for that character set, from which the server can determine the character set.) The server uses this information to set the `character_set_client`, `character_set_results`, `character_set_connection` system variables to the character set, and `collation_connection` to the character set default collation. In effect, the server performs the equivalent of a `SET NAMES` operation.

If the server does not support the requested character set or collation, it falls back to using the server character set and collation to configure the connection. For additional detail about this fallback behavior, see **Connection Character Set Error Handling**.

The `mysql`, `mysqladmin`, `mysqlcheck`, `mysqlimport`, and `mysqlshow` client programs determine the default character set to use as follows:
• In the absence of other information, each client uses the compiled-in default character set, usually \texttt{latin1}.

• Each client can autodetect which character set to use based on the operating system setting, such as the value of the \texttt{LANG} or \texttt{LC\_ALL} locale environment variable on Unix systems or the code page setting on Windows systems. For systems on which the locale is available from the OS, the client uses it to set the default character set rather than using the compiled-in default. For example, setting \texttt{LANG} to \texttt{ru\_RU.KOI8\_R} causes the \texttt{koi8r} character set to be used. Thus, users can configure the locale in their environment for use by MySQL clients.

The OS character set is mapped to the closest MySQL character set if there is no exact match. If the client does not support the matching character set, it uses the compiled-in default. For example, \texttt{ucs2} is not supported as a connection character set, so it maps to the compiled-in default.

C applications can use character set autodetection based on the OS setting by invoking \texttt{mysql\_options()} as follows before connecting to the server:

\begin{verbatim}
mysql_options(mysql,
    MYSQL\_SET\_CHARSET\_NAME,
    MYSQL\_AUTODETECT\_CHARSET\_NAME);
\end{verbatim}

• Each client supports a \texttt{--default-character-set} option, which enables users to specify the character set explicitly to override whatever default the client otherwise determines.

\begin{itemize}
  \item Note
  
  Some character sets cannot be used as the client character set. Attempting to use them with \texttt{--default-character-set} produces an error. See \texttt{Impermissible Client Character Sets}.

  \item Note
  
  Before MySQL 5.5, in the absence of other information, the MySQL client programs used the compiled-in default character set, usually \texttt{latin1}. An implication of this difference is that if your environment is configured to use a non-\texttt{latin1} locale, MySQL client programs will use a different connection character set than previously, as though you had issued an implicit \texttt{SET NAMES} statement. If the previous behavior is required, start the client with the \texttt{--default-character-set=latin1} option.
\end{itemize}

With the \texttt{mysql} client, to use a character set different from the default, you could explicitly execute a \texttt{SET NAMES} statement every time you connect to the server (see \texttt{Client Program Connection Character Set Configuration}). To accomplish the same result more easily, specify the character set in your option file. For example, the following option file setting changes the three connection-related character set system variables set to \texttt{koi8r} each time you invoke \texttt{mysql}:

```
[mysql]
default-character-set=koi8r
```

If you are using the \texttt{mysql} client with auto-reconnect enabled (which is not recommended), it is preferable to use the \texttt{charset} command rather than \texttt{SET NAMES}. For example:

```
mysql> charset koi8r
Charset changed
```

The \texttt{charset} command issues a \texttt{SET NAMES} statement, and also changes the default character set that \texttt{mysql} uses when it reconnects after the connection has dropped.
When configuration client programs, you must also consider the environment within which they execute. See Section 10.5, “Configuring Application Character Set and Collation”.

SQL Statements for Connection Character Set Configuration

After a connection has been established, clients can change the character set and collation system variables for the current session. These variables can be changed individually using SET statements, but two more convenient statements affect the connection-related character set system variables as a group:

• SET NAMES 'charset_name' [COLLATE 'collation_name']

SET NAMES indicates what character set the client will use to send SQL statements to the server. Thus, SET NAMES 'cp1251' tells the server, “future incoming messages from this client are in character set cp1251.” It also specifies the character set that the server should use for sending results back to the client. (For example, it indicates what character set to use for column values if you use a SELECT statement that produces a result set.)

A SET NAMES 'charset_name' statement is equivalent to these three statements:

```
SET character_set_client = charset_name;
SET character_set_results = charset_name;
SET character_set_connection = charset_name;
```

Setting character_set_connection to charset_name also implicitly sets collation_connection to the default collation for charset_name. It is unnecessary to set that collation explicitly. To specify a particular collation to use for collation_connection, add a COLLATE clause:

```
SET NAMES 'charset_name' COLLATE 'collation_name'
```

• SET CHARACTER SET 'charset_name'

SET CHARACTER SET is similar to SET NAMES but sets character_set_connection and collation_connection to character_set_database and collation_database (which, as mentioned previously, indicate the character set and collation of the default database).

A SET CHARACTER SET charset_name statement is equivalent to these three statements:

```
SET character_set_client = charset_name;
SET character_set_results = charset_name;
SET collation_connection = @@collation_database;
```

Setting collation_connection also implicitly sets character_set_connection to the character set associated with the collation (equivalent to executing SET character_set_connection = @@character_set_database). It is unnecessary to set character_set_connection explicitly.

Note

Some character sets cannot be used as the client character set. Attempting to use them with SET NAMES or SET CHARACTER SET produces an error. See Impermissible Client Character Sets.

Example: Suppose that column1 is defined as CHAR(5) CHARACTER SET latin2. If you do not say SET NAMES or SET CHARACTER SET, then for SELECT column1 FROM t, the server sends back all the values for column1 using the character set that the client specified when it connected. On the other hand, if you say SET NAMES 'latin1' or SET CHARACTER SET 'latin1' before issuing the SELECT statement, the server converts the latin2 values to latin1 just before sending results back. Conversion may be lossy for characters that are not in both character sets.
Connection Character Set Error Handling

Attempts to use an inappropriate connection character set or collation can produce an error, or cause the server to fall back to its default character set and collation for a given connection. This section describes problems that can occur when configuring the connection character set. These problems can occur when establishing a connection or when changing the character set within an established connection.

- Connect-Time Error Handling
- Runtime Error Handling

Connect-Time Error Handling

Some character sets cannot be used as the client character set; see Impermissible Client Character Sets. If you specify a character set that is valid but not permitted as a client character set, the server returns an error:

```
shell> mysql --default-character-set=ucs2
ERROR 1231 (42000): Variable 'character_set_client' can't be set to the value of 'ucs2'
```

If you specify a character set that the client does not recognize, it produces an error:

```
shell> mysql --default-character-set=bogus
mysql: Character set 'bogus' is not a compiled character set and is not specified in the '/usr/local/mysql/share/charsets/Index.xml' file
ERROR 2019 (HY000): Can't initialize character set bogus
```

If you specify a character set that the client recognizes but the server does not, the server falls back to its default character set and collation. Suppose that the server is configured to use `latin1` and `latin1_swedish_ci` as its defaults, and that it does not recognize `gb18030` as a valid character set. A client that specifies `--default-character-set=gb18030` is able to connect to the server, but the resulting character set is not what the client wants:

```
mysql> SHOW SESSION VARIABLES LIKE 'character\_set\_%';
+--------------------------+--------+
| Variable_name            | Value  |
|--------------------------+--------+
| character_set_client     | latin1 |
| character_set_connection | latin1 |
| ...                      |        |
| character_set_results    | latin1 |
| ...                      |        |
mysql> SHOW SESSION VARIABLES LIKE 'collation_connection';
+--------------------------+--------+
| Variable_name            | Value  |
|--------------------------+--------+
| collation_connection     | latin1_swedish_ci |
```

You can see that the connection system variables have been set to reflect a character set and collation of `latin1` and `latin1_swedish_ci`. This occurs because the server cannot satisfy the client character set request and falls back to its defaults.

In this case, the client cannot use the character set that it wants because the server does not support it. The client must either be willing to use a different character set, or connect to a different server that supports the desired character set.

The same problem occurs in a more subtle context: When the client tells the server to use a character set that the server recognizes, but the default collation for that character set on the client side is not known
Connection Character Set Error Handling

on the server side. This occurs, for example, when a MySQL 8.0 client wants to connect to a MySQL 5.7 server using utf8mb4 as the client character set. A client that specifies `--default-character-set=utf8mb4` is able to connect to the server. However, as in the previous example, the server falls back to its default character set and collation, not what the client requested:

```sql
mysql> SHOW SESSION VARIABLES LIKE 'character_set\_%';
+--------------------------+--------+
| Variable_name            | Value  |
|--------------------------+--------+
| character_set_client     | latin1 |
| character_set_connection | latin1 |
|...                       |...     |
| character_set_results    | latin1 |
|...                       |...     |
mysql>
```

Why does this occur? After all, utf8mb4 is known to the 8.0 client and the 5.7 server, so both of them recognize it. To understand this behavior, it is necessary to understand that when the client tells the server which character set it wants to use, it really tells the server the default collation for that character set. Therefore, the aforementioned behavior occurs due to a combination of factors:

- The default collation for utf8mb4 differs between MySQL 5.7 and 8.0 (`utf8mb4_general_ci` for 5.7, `utf8mb4_0900_ai_ci` for 8.0).
- When the 8.0 client requests a character set of utf8mb4, what it sends to the server is the default 8.0 utf8mb4 collation; that is, `utf8mb4_0900_ai_ci`.
- `utf8mb4_0900_ai_ci` is implemented only as of MySQL 8.0, so the 5.7 server does not recognize it.
- Because the 5.7 server does not recognize `utf8mb4_0900_ai_ci`, it cannot satisfy the client character set request, and falls back to its default character set and collation (`latin1` and `latin1_swedish_ci`).

In this case, the client can still use utf8mb4 by issuing a `SET NAMES 'utf8mb4'` statement after connecting. The resulting collation is the 5.7 default utf8mb4 collation; that is, `utf8mb4_general_ci`. If the client additionally wants a collation of `utf8mb4_0900_ai_ci`, it cannot achieve that because the server does not recognize that collation. The client must either be willing to use a different utf8mb4 collation, or connect to a server from MySQL 8.0 or higher.

Runtime Error Handling

Within an established connection, the client can request a change of connection character set and collation with `SET NAMES` or `SET CHARACTER SET`.

Some character sets cannot be used as the client character set; see Impermissible Client Character Sets. If you specify a character set that is valid but not permitted as a client character set, the server returns an error:

```sql
mysql> SET NAMES 'ucs2';
ERROR 1231 (42000): Variable 'character_set_client' can't be set to the value of 'ucs2'
```

If the server does not recognize the character set (or the collation), it produces an error:

```sql
mysql> SET NAMES 'bogus';
ERROR 1115 (42000): Unknown character set: 'bogus'
```
Configuring Application Character Set and Collation

mysql> SET NAMES 'utf8mb4' COLLATE 'bogus';
ERROR 1273 (HY000): Unknown collation: 'bogus'

Tip
A client that wants to verify whether its requested character set was honored by the server can execute the following statement after connecting and checking that the result is the expected character set:

```
SELECT @@character_set_client;
```

10.5 Configuring Application Character Set and Collation

For applications that store data using the default MySQL character set and collation (latin1, latin1_swedish_ci), no special configuration should be needed. If applications require data storage using a different character set or collation, you can configure character set information several ways:

- Specify character settings per database. For example, applications that use one database might use the default of latin1, whereas applications that use another database might use sjis.
- Specify character settings at server startup. This causes the server to use the given settings for all applications that do not make other arrangements.
- Specify character settings at configuration time, if you build MySQL from source. This causes the server to use the given settings as the defaults for all applications, without having to specify them at server startup.

When different applications require different character settings, the per-database technique provides a good deal of flexibility. If most or all applications use the same character set, specifying character settings at server startup or configuration time may be most convenient.

For the per-database or server-startup techniques, the settings control the character set for data storage. Applications must also tell the server which character set to use for client/server communications, as described in the following instructions.

The examples shown here assume use of the utf8 character set and utf8_general_ci collation in particular contexts as an alternative to the defaults of latin1 and latin1_swedish_ci.

- **Specify character settings per database.** To create a database such that its tables will use a given default character set and collation for data storage, use a `CREATE DATABASE` statement like this:

```
CREATE DATABASE mydb
    CHARACTER SET utf8
    COLLATE utf8_general_ci;
```

Tables created in the database will use utf8 and utf8_general_ci by default for any character columns.

Applications that use the database should also configure their connection to the server each time they connect. This can be done by executing a `SET NAMES 'utf8'` statement after connecting. The statement can be used regardless of connection method (the mysql client, PHP scripts, and so forth).

In some cases, it may be possible to configure the connection to use the desired character set some other way. For example, to connect using mysql, you can specify the `--default-character-set=utf8` command-line option to achieve the same effect as `SET NAMES 'utf8'`.

For more information about configuring client connections, see Section 10.4, “Connection Character Sets and Collations”. 
Note

If you use `ALTER DATABASE` to change the database default character set or collation, existing stored routines in the database that use those defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Statements".)

- **Specify character settings at server startup.** To select a character set and collation at server startup, use the `--character-set-server` and `--collation-server` options. For example, to specify the options in an option file, include these lines:

  ```
  [mysqld]
  character-set-server=utf8
  collation-server=utf8_general_ci
  ```

  These settings apply server-wide and apply as the defaults for databases created by any application, and for tables created in those databases.

  It is still necessary for applications to configure their connection using `SET NAMES` or equivalent after they connect, as described previously. You might be tempted to start the server with the `--init_connect="SET NAMES 'utf8'"` option to cause `SET NAMES` to be executed automatically for each client that connects. However, this may yield inconsistent results because the `init_connect` value is not executed for users who have the `SUPER` privilege.

- **Specify character settings at MySQL configuration time.** To select a character set and collation if you configure and build MySQL from source, use the `DEFAULT_CHARSET` and `DEFAULT_COLLATION` `CMake` options:

  ```
  cmake . -DDEFAULT_CHARSET=utf8
  -DDEFAULT_COLLATION=utf8_general_ci
  ```

  The resulting server uses `utf8` and `utf8_general_ci` as the default for databases and tables and for client connections. It is unnecessary to use `--character-set-server` and `--collation-server` to specify those defaults at server startup. It is also unnecessary for applications to configure their connection using `SET NAMES` or equivalent after they connect to the server.

  Regardless of how you configure the MySQL character set for application use, you must also consider the environment within which those applications execute. For example, if you will send statements using UTF-8 text taken from a file that you create in an editor, you should edit the file with the locale of your environment set to UTF-8 so that the file encoding is correct and so that the operating system handles it correctly. If you use the `mysql` client from within a terminal window, the window must be configured to use UTF-8 or characters may not display properly. For a script that executes in a Web environment, the script must handle character encoding properly for its interaction with the MySQL server, and it must generate pages that correctly indicate the encoding so that browsers know how to display the content of the pages. For example, you can include this `<meta>` tag within your `<head>` element:

  ```
  <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
  ```

10.6 Error Message Character Set

This section describes how the MySQL server uses character sets for constructing error messages. For information about the language of error messages (rather than the character set), see Section 10.12, “Setting the Error Message Language”. For general information about configuring error logging, see Section 5.4.2, “The Error Log”.

1107
Character Set for Error Message Construction

The server constructs error messages as follows:

- The message template uses UTF-8 (utf8mb3).
- Parameters in the message template are replaced with values that apply to a specific error occurrence:
  - Identifiers such as table or column names use UTF-8 internally so they are copied as is.
  - Character (nonbinary) string values are converted from their character set to UTF-8.
  - Binary string values are copied as is for bytes in the range 0x20 to 0x7E, and using \x hexadecimal encoding for bytes outside that range. For example, if a duplicate-key error occurs for an attempt to insert 0x41CF9F into a VARBINARY unique column, the resulting error message uses UTF-8 with some bytes hexadecimal encoded:

  Duplicate entry 'A\xC3\x9F' for key 1

Character Set for Error Message Disposition

An error message, once constructed, can be written by the server to the error log or sent to clients:

- If the server writes the error message to the error log, it writes it in UTF-8, as constructed, without conversion to another character set.
- If the server sends the error message to a client program, the server converts it from UTF-8 to the character set specified by the character_set_results system variable. If character_set_results has a value of NULL or binary, no conversion occurs. No conversion occurs if the variable value is utf8mb3 or utf8mb4, either, because those character sets have a repertoire that includes all UTF-8 characters used in message construction.

If characters cannot be represented in character_set_results, some encoding may occur during the conversion. The encoding uses Unicode code point values:

- Characters in the Basic Multilingual Plane (BMP) range (0x0000 to 0xFFFF) are written using \nnnn notation.
- Characters outside the BMP range (0x10000 to 0x10FFFF) are written using \+nnnnnn notation.

Clients can set character_set_results to control the character set in which they receive error messages. The variable can be set directly, or indirectly by means such as SET NAMES. For more information about character_set_results, see Section 10.4, “Connection Character Sets and Collations”.

10.7 Column Character Set Conversion

To convert a binary or nonbinary string column to use a particular character set, use ALTER TABLE. For successful conversion to occur, one of the following conditions must apply:

- If the column has a binary data type (BINARY, VARBINARY, BLOB), all the values that it contains must be encoded using a single character set (the character set you're converting the column to). If you use a
binary column to store information in multiple character sets, MySQL has no way to know which values use which character set and cannot convert the data properly.

- If the column has a nonbinary data type (CHAR, VARCHAR, TEXT), its contents should be encoded in the column character set, not some other character set. If the contents are encoded in a different character set, you can convert the column to use a binary data type first, and then to a nonbinary column with the desired character set.

Suppose that a table \( t \) has a binary column named \( \text{col1} \) defined as \VARBINARY(50). Assuming that the information in the column is encoded using a single character set, you can convert it to a nonbinary column that has that character set. For example, if \( \text{col1} \) contains binary data representing characters in the \text{greek} character set, you can convert it as follows:

\[
\text{ALTER TABLE } t \text{ MODIFY col1 VARCHAR(50) CHARACTER SET greek;}
\]

If your original column has a type of \BINARY(50), you could convert it to \CHAR(50), but the resulting values will be padded with 0x00 bytes at the end, which may be undesirable. To remove these bytes, use the \TRIM() function:

\[
\text{UPDATE } t \text{ SET col1 = TRIM(TRAILING 0x00 FROM col1;}
\]

Suppose that table \( t \) has a nonbinary column named \( \text{col1} \) defined as \CHAR(50) \ CHARACTER SET \latin1 but you want to convert it to use \utf8 so that you can store values from many languages. The following statement accomplishes this:

\[
\text{ALTER TABLE } t \text{ MODIFY col1 CHAR(50) CHARACTER SET utf8;}
\]

Conversion may be lossy if the column contains characters that are not in both character sets.

A special case occurs if you have old tables from before MySQL 4.1 where a nonbinary column contains values that actually are encoded in a character set different from the server's default character set. For example, an application might have stored \text{sjis} values in a column, even though MySQL's default character set was different. It is possible to convert the column to use the proper character set but an additional step is required. Suppose that the server's default character set was \latin1 and \text{col1} is defined as \CHAR(50) but its contents are \text{sjis} values. The first step is to convert the column to a binary data type, which removes the existing character set information without performing any character conversion:

\[
\text{ALTER TABLE } t \text{ MODIFY col1 BLOB;}
\]

The next step is to convert the column to a nonbinary data type with the proper character set:

\[
\text{ALTER TABLE } t \text{ MODIFY col1 CHAR(50) CHARACTER SET sjis;}
\]

This procedure requires that the table not have been modified already with statements such as \INSERT or \UPDATE after an upgrade to MySQL 4.1 or higher. In that case, MySQL would store new values in the column using \latin1, and the column will contain a mix of \text{sjis} and \latin1 values and cannot be converted properly.

If you specified attributes when creating a column initially, you should also specify them when altering the table with \ALTER TABLE. For example, if you specified \NOT NULL and an explicit \DEFAULT value, you should also provide them in the \ALTER TABLE statement. Otherwise, the resulting column definition will not include those attributes.

To convert all character columns in a table, the \ALTER TABLE ... CONVERT TO CHARACTER SET \text{charset} statement may be useful. See Section 13.1.7, "ALTER TABLE Statement".
10.8 Collation Issues

The following sections discuss various aspects of character set collations.

10.8.1 Using COLLATE in SQL Statements

With the `COLLATE` clause, you can override whatever the default collation is for a comparison. `COLLATE` may be used in various parts of SQL statements. Here are some examples:

- **With `ORDER BY`:**

  ```sql
  SELECT k
  FROM t1
  ORDER BY k COLLATE latin1_german2_ci;
  ```

- **With `AS`:**

  ```sql
  SELECT k COLLATE latin1_german2_ci AS k1
  FROM t1
  ORDER BY k1;
  ```

- **With `GROUP BY`:**

  ```sql
  SELECT k
  FROM t1
  GROUP BY k COLLATE latin1_german2_ci;
  ```

- **With aggregate functions:**

  ```sql
  SELECT MAX(k COLLATE latin1_german2_ci)
  FROM t1;
  ```

- **With `DISTINCT`:**

  ```sql
  SELECT DISTINCT k COLLATE latin1_german2_ci
  FROM t1;
  ```

- **With `WHERE`:**

  ```sql
  SELECT *
  FROM t1
  WHERE _latin1 'Müller' COLLATE latin1_german2_ci = k;
  ```

  ```sql
  SELECT *
  FROM t1
  WHERE k LIKE _latin1 'Müller' COLLATE latin1_german2_ci;
  ```

- **With `HAVING`:**

  ```sql
  SELECT k
  FROM t1
  GROUP BY k
  HAVING k = _latin1 'Müller' COLLATE latin1_german2_ci;
  ```

10.8.2 COLLATE Clause Precedence

The `COLLATE` clause has high precedence (higher than `||`), so the following two expressions are equivalent:

```sql
x || y COLLATE z
x || (y COLLATE z)
```
10.8.3 Character Set and Collation Compatibility

Each character set has one or more collations, but each collation is associated with one and only one character set. Therefore, the following statement causes an error message because the `latin2_bin` collation is not legal with the `latin1` character set:

```sql
mysql> SELECT _latin1 'x' COLLATE latin2_bin;
ERROR 1253 (42000): COLLATION 'latin2_bin' is not valid for CHARACTER SET 'latin1'
```

10.8.4 Collation Coercibility in Expressions

In the great majority of statements, it is obvious what collation MySQL uses to resolve a comparison operation. For example, in the following cases, it should be clear that the collation is the collation of column `x`:

- `SELECT x FROM T ORDER BY x;`
- `SELECT x FROM T WHERE x = x;`
- `SELECT DISTINCT x FROM T;`

However, with multiple operands, there can be ambiguity. For example:

```sql
SELECT x FROM T WHERE x = 'Y';
```

Should the comparison use the collation of the column `x`, or of the string literal `'Y'`? Both `x` and `'Y'` have collations, so which collation takes precedence?

A mix of collations may also occur in contexts other than comparison. For example, a multiple-argument concatenation operation such as `CONCAT(x, 'Y')` combines its arguments to produce a single string. What collation should the result have?

To resolve questions like these, MySQL checks whether the collation of one item can be coerced to the collation of the other. MySQL assigns coercibility values as follows:

- An explicit `COLLATE` clause has a coercibility of 0 (not coercible at all).
- The concatenation of two strings with different collations has a coercibility of 1.
- The collation of a column or a stored routine parameter or local variable has a coercibility of 2.
- A “system constant” (the string returned by functions such as `USER()` or `VERSION()`) has a coercibility of 3.
- The collation of a literal has a coercibility of 4.
- The collation of a numeric or temporal value has a coercibility of 5.
- `NULL` or an expression that is derived from `NULL` has a coercibility of 6.

MySQL uses coercibility values with the following rules to resolve ambiguities:

- Use the collation with the lowest coercibility value.
- If both sides have the same coercibility, then:
  - If both sides are Unicode, or both sides are not Unicode, it is an error.
  - If one of the sides has a Unicode character set, and another side has a non-Unicode character set, the side with Unicode character set wins, and automatic character set conversion is applied to the non-Unicode side. For example, the following statement does not return an error:
The binary Collation Compared to _bin Collations

SELECT CONCAT(utf8_column, latin1_column) FROM t1;

It returns a result that has a character set of utf8 and the same collation as utf8_column. Values of latin1_column are automatically converted to utf8 before concatenating.

- For an operation with operands from the same character set but that mix a _bin collation and a _ci or _cs collation, the _bin collation is used. This is similar to how operations that mix nonbinary and binary strings evaluate the operands as binary strings, except that it is for collations rather than data types.

Although automatic conversion is not in the SQL standard, the standard does say that every character set is (in terms of supported characters) a "subset" of Unicode. Because it is a well-known principle that "what applies to a superset can apply to a subset," we believe that a collation for Unicode can apply for comparisons with non-Unicode strings.

The following table illustrates some applications of the preceding rules.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Collation Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>column1 = 'A'</td>
<td>Use collation of column1</td>
</tr>
<tr>
<td>column1 = 'A' COLLATE x</td>
<td>Use collation of 'A' COLLATE x</td>
</tr>
<tr>
<td>column1 COLLATE x = 'A' COLLATE y</td>
<td>Error</td>
</tr>
</tbody>
</table>

To determine the coercibility of a string expression, use the COERCIBILITY() function (see Section 12.15, "Information Functions"):

mysql> SELECT COERCIBILITY('A' COLLATE latin1_swedish_ci);
-> 0
mysql> SELECT COERCIBILITY(VERSION());
-> 3
mysql> SELECT COERCIBILITY('A');
-> 4
mysql> SELECT COERCIBILITY(1000);
-> 5

For implicit conversion of a numeric or temporal value to a string, such as occurs for the argument 1 in the expression CONCAT(1, 'abc'), the result is a character (nonbinary) string that has a character set and collation determined by the character_set_connection and collation_connection system variables. See Section 12.2, "Type Conversion in Expression Evaluation".

10.8.5 The binary Collation Compared to _bin Collations

This section describes how the binary collation for binary strings compares to _bin collations for nonbinary strings.

Binary strings (as stored using the BINARY, VARBINARY, and BLOB data types) have a character set and collation named binary. Binary strings are sequences of bytes and the numeric values of those bytes determine comparison and sort order. See Section 10.10.8, "The Binary Character Set".

Nonbinary strings (as stored using the CHAR, VARCHAR, and TEXT data types) have a character set and collation other than binary. A given nonbinary character set can have several collations, each of which defines a particular comparison and sort order for the characters in the set. One of these is the binary collation, indicated by a _bin suffix in the collation name. For example, the binary collation for utf8 and latin1 is named utf8_bin and latin1_bin, respectively.

The binary collation differs from _bin collations in several respects, discussed in the following sections:
The binary Collation Compared to _bin Collations

• The Unit for Comparison and Sorting
• Character Set Conversion
• Lettercase Conversion
• Trailing Space Handling in Comparisons
• Trailing Space Handling for Inserts and Retrievals

The Unit for Comparison and Sorting

Binary strings are sequences of bytes. For the binary collation, comparison and sorting are based on numeric byte values. Nonbinary strings are sequences of characters, which might be multibyte. Collations for nonbinary strings define an ordering of the character values for comparison and sorting. For _bin collations, this ordering is based on numeric character code values, which is similar to ordering for binary strings except that character code values might be multibyte.

Character Set Conversion

A nonbinary string has a character set and is automatically converted to another character set in many cases, even when the string has a _bin collation:

• When assigning column values to another column that has a different character set:

  UPDATE t1 SET utf8_bin_column=latin1_column;
  INSERT INTO t1 (latin1_column) SELECT utf8_bin_column FROM t2;

• When assigning column values for INSERT or UPDATE using a string literal:

  SET NAMES latin1;
  INSERT INTO t1 (utf8_bin_column) VALUES ('string-in-latin1');

• When sending results from the server to a client:

  SET NAMES latin1;
  SELECT utf8_bin_column FROM t2;

For binary string columns, no conversion occurs. For cases similar to those preceding, the string value is copied byte-wise.

Lettercase Conversion

Collations for nonbinary character sets provide information about lettercase of characters, so characters in a nonbinary string can be converted from one lettercase to another, even for _bin collations that ignore lettercase for ordering:

```
mysql> SET NAMES utf8mb4 COLLATE utf8mb4_bin;
mysql> SELECT LOWER('aA'), UPPER('zZ');
+-------------+-------------+
| LOWER('aA') | UPPER('zZ') |
| aa          | ZZ          |
+-------------+-------------+
```

The concept of lettercase does not apply to bytes in a binary string. To perform lettercase conversion, the string must first be converted to a nonbinary string using a character set appropriate for the data stored in the string:

```
mysql> SET NAMES binary;
mysql> SELECT LOWER('aA'), LOWER(CONVERT('aA' USING utf8mb4));
```
Examples of the Effect of Collation

Trailing Space Handling in Comparisons

Nonbinary strings have PAD SPACE behavior for all collations, including _bin collations. Trailing spaces are insignificant in comparisons:

```
mysql> SET NAMES utf8 COLLATE utf8_bin;
mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          1  |
+------------+
```

For binary strings, all characters are significant in comparisons, including trailing spaces:

```
mysql> SET NAMES binary;
mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          0  |
+------------+
```

Trailing Space Handling for Inserts and Retrievals

CHAR(N) columns store nonbinary strings N characters long. For inserts, values shorter than N characters are extended with spaces. For retrievals, trailing spaces are removed.

BINARY(N) columns store binary strings N bytes long. For inserts, values shorter than N bytes are extended with \0x00 bytes. For retrievals, nothing is removed; a value of the declared length is always returned.

```
mysql> CREATE TABLE t1 (a CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin,
                         b BINARY(10));
mysql> INSERT INTO t1 VALUES ('x','x');
mysql> INSERT INTO t1 VALUES ('x ','x ');;
mysql> SELECT a, b, HEX(a), HEX(b) FROM t1;
+------+------------+--------+----------------------+
| a    | b           | HEX(a) | HEX(b)               |
+------+------------+--------+----------------------+
| x    | x           | 78     | 78000000000000000000 |
| x    | x           | 78     | 78200000000000000000 |
+------+------------+--------+----------------------+
```

10.8.6 Examples of the Effect of Collation

Example 1: Sorting German Umlauts

Suppose that column X in table T has these latin1 column values:

Muffler
Müller
MX Systems
MySQL

Suppose also that the column values are retrieved using the following statement:
Examples of the Effect of Collation

The following table shows the resulting order of the values if we use `ORDER BY` with different collations.

<table>
<thead>
<tr>
<th><code>latin1_swedish_ci</code></th>
<th><code>latin1_german1_ci</code></th>
<th><code>latin1_german2_ci</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Muffler</td>
<td>Muffler</td>
<td>Müller</td>
</tr>
<tr>
<td>MX Systems</td>
<td>Müller</td>
<td>Muffler</td>
</tr>
<tr>
<td>Müller</td>
<td>MX Systems</td>
<td>MX Systems</td>
</tr>
<tr>
<td>MySQL</td>
<td>MySQL</td>
<td>MySQL</td>
</tr>
</tbody>
</table>

The character that causes the different sort orders in this example is the U with two dots over it (ü), which the Germans call “U-umlaut.”

- The first column shows the result of the `SELECT` using the Swedish/Finnish collating rule, which says that U-umlaut sorts with Y.
- The second column shows the result of the `SELECT` using the German DIN-1 rule, which says that U-umlaut sorts with U.
- The third column shows the result of the `SELECT` using the German DIN-2 rule, which says that U-umlaut sorts with UE.

Example 2: Searching for German Umlauts

Suppose that you have three tables that differ only by the character set and collation used:

```sql
mysql> SET NAMES utf8;
mysql> CREATE TABLE german1 (c CHAR(10)) CHARACTER SET latin1 COLLATE latin1_german1_ci;
mysql> CREATE TABLE german2 (c CHAR(10)) CHARACTER SET latin1 COLLATE latin1_german2_ci;
mysql> CREATE TABLE germanutf8 (c CHAR(10)) CHARACTER SET utf8 COLLATE utf8_unicode_ci;
```

Each table contains two records:

```sql
mysql> INSERT INTO german1 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO german2 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO germanutf8 VALUES ('Bar'), ('Bär');
```

Two of the above collations have an A = Ä equality, and one has no such equality (`latin1_german2_ci`). For that reason, you'll get these results in comparisons:

```sql
mysql> SELECT * FROM german1 WHERE c = 'Bär';
+----+
| c  |
+----+
| Bar|
| Bär|
mysql> SELECT * FROM german2 WHERE c = 'Bär';
+----+
| c  |
+----+
| Bär|
| Bär|
mysql> SELECT * FROM germanutf8 WHERE c = 'Bär';
+----+
| c  |
+----+
```

1115
This is not a bug but rather a consequence of the sorting properties of `latin1_german1_ci` and `utf8_unicode_ci` (the sorting shown is done according to the German DIN 5007 standard).

### 10.8.7 Using Collation in INFORMATION_SCHEMA Searches

String columns in INFORMATION_SCHEMA tables have a collation of `utf8_general_ci`, which is case-insensitive. However, for values that correspond to objects that are represented in the file system, such as databases and tables, searches in INFORMATION_SCHEMA string columns can be case-sensitive or case-insensitive, depending on the characteristics of the underlying file system and the value of the `lower_case_table_names` system variable. For example, searches may be case-sensitive if the file system is case-sensitive. This section describes this behavior and how to modify it if necessary; see also Bug #34921.

Suppose that a query searches the SCHEMATA.SCHEMA_NAME column for the `test` database. On Linux, file systems are case-sensitive, so comparisons of SCHEMATA.SCHEMA_NAME with `'test'` match, but comparisons with `'TEST'` do not:

```sql
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    WHERE SCHEMA_NAME = 'TEST';
Empty set (0.00 sec)
```

These results occur with the `lower_case_table_names` system variable set to 0. Changing the value of `lower_case_table_names` to 1 or 2 causes the second query to return the same (nonempty) result as the first query.

On Windows or macOS, file systems are not case-sensitive, so comparisons match both `'test'` and `'TEST'`:

```sql
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    WHERE SCHEMA_NAME = 'TEST';
+-------------+
| TEST        |
+-------------+
```

The value of `lower_case_table_names` makes no difference in this context.

The preceding behavior occurs because the `utf8_general_ci` collation is not used for INFORMATION_SCHEMA queries when searching for values that correspond to objects.
Using Collation in INFORMATION_SCHEMA Searches

represented in the file system. It is a result of file system-scanning optimizations implemented for INFORMATION_SCHEMA searches. For information about these optimizations, see Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”.

If the result of a string operation on an INFORMATION_SCHEMA column differs from expectations, a workaround is to use an explicit COLLATE clause to force a suitable collation (see Section 10.8.1, “Using COLLATE in SQL Statements”). For example, to perform a case-insensitive search, use COLLATE with the INFORMATION_SCHEMA column name:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
```

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'TEST';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
```

In the preceding queries, it is important to apply the COLLATE clause to the INFORMATION_SCHEMA column name. Applying COLLATE to the comparison value has no effect.

You can also use the UPPER() or LOWER() function:

```
WHERE UPPER(SCHEMA_NAME) = 'TEST'
WHERE LOWER(SCHEMA_NAME) = 'test'
```

Although a case-insensitive comparison can be performed even on platforms with case-sensitive file systems, as just shown, it is not necessarily always the right thing to do. On such platforms, it is possible to have multiple objects with names that differ only in lettercase. For example, tables named city, CITY, and City can all exist simultaneously. Consider whether a search should match all such names or just one and write queries accordingly. The first of the following comparisons (with utf8_bin) is case-sensitive; the others are not:

```
WHERE TABLE_NAME COLLATE utf8_bin = 'City'
WHERE TABLE_NAME COLLATE utf8_general_ci = 'city'
WHERE UPPER(TABLE_NAME) = 'CITY'
WHERE LOWER(TABLE_NAME) = 'city'
```

Searches in INFORMATION_SCHEMA string columns for values that refer to INFORMATION_SCHEMA itself do use the utf8_general_ci collation because INFORMATION_SCHEMA is a “virtual” database not represented in the file system. For example, comparisons with SCHEMATA.SCHEMA_NAME match 'information_schema' or 'INFORMATION_SCHEMA' regardless of platform:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
WHERE SCHEMA_NAME = 'information_schema';
+-------------------+
| SCHEMA_NAME       |
+-------------------+
| information_schema |
+-------------------+
```

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
WHERE SCHEMA_NAME = 'INFORMATION_SCHEMA';
+-------------------+
| SCHEMA_NAME       |
+-------------------+
```

1117
10.9 Unicode Support

The Unicode Standard includes characters from the Basic Multilingual Plane (BMP) and supplementary characters that lie outside the BMP. This section describes support for Unicode in MySQL. For information about the Unicode Standard itself, visit the Unicode Consortium website.

BMP characters have these characteristics:

- Their code point values are between 0 and 65535 (or \texttt{U+0000} and \texttt{U+FFFF}).
- They can be encoded in a variable-length encoding using 8, 16, or 24 bits (1 to 3 bytes).
- They can be encoded in a fixed-length encoding using 16 bits (2 bytes).
- They are sufficient for almost all characters in major languages.

Supplementary characters lie outside the BMP:

- Their code point values are between \texttt{U+10000} and \texttt{U+10FFFF}.
- Unicode support for supplementary characters requires character sets that have a range outside BMP characters and therefore take more space than BMP characters (up to 4 bytes per character).

The UTF-8 (Unicode Transformation Format with 8-bit units) method for encoding Unicode data is implemented according to RFC 3629, which describes encoding sequences that take from one to four bytes. The idea of UTF-8 is that various Unicode characters are encoded using byte sequences of different lengths:

- Basic Latin letters, digits, and punctuation signs use one byte.
- Most European and Middle East script letters fit into a 2-byte sequence: extended Latin letters (with tilde, macron, acute, grave and other accents), Cyrillic, Greek, Armenian, Hebrew, Arabic, Syriac, and others.
- Korean, Chinese, and Japanese ideographs use 3-byte or 4-byte sequences.

MySQL supports these Unicode character sets:

- \texttt{utf8mb4}: A UTF-8 encoding of the Unicode character set using one to four bytes per character.
- \texttt{utf8mb3}: A UTF-8 encoding of the Unicode character set using one to three bytes per character.
- \texttt{utf8}: An alias for \texttt{utf8mb3}.
- \texttt{ucs2}: The UCS-2 encoding of the Unicode character set using two bytes per character.
- \texttt{utf16}: The UTF-16 encoding for the Unicode character set using two or four bytes per character. Like \texttt{ucs2} but with an extension for supplementary characters.
- \texttt{utf32}: The UTF-32 encoding for the Unicode character set using four bytes per character.

Table 10.2, “Unicode Character Set General Characteristics”, summarizes the general characteristics of Unicode character sets supported by MySQL.

**Table 10.2 Unicode Character Set General Characteristics**

<table>
<thead>
<tr>
<th>Character Set</th>
<th>Supported Characters</th>
<th>Required Storage Per Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>utf8mb3, utf8</td>
<td>BMP only</td>
<td>1, 2, or 3 bytes</td>
</tr>
</tbody>
</table>

1118
The utf8mb4 Character Set (4-Byte UTF-8 Unicode Encoding)

<table>
<thead>
<tr>
<th>Character Set</th>
<th>Supported Characters</th>
<th>Required Storage Per Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>ucs2</td>
<td>BMP only</td>
<td>2 bytes</td>
</tr>
<tr>
<td>utf8mb4</td>
<td>BMP and supplementary</td>
<td>1, 2, 3, or 4 bytes</td>
</tr>
<tr>
<td>utf16</td>
<td>BMP and supplementary</td>
<td>2 or 4 bytes</td>
</tr>
<tr>
<td>utf32</td>
<td>BMP and supplementary</td>
<td>4 bytes</td>
</tr>
</tbody>
</table>

Characters outside the BMP compare as REPLACEMENT CHARACTER and convert to '?' when converted to a Unicode character set that supports only BMP characters (utf8mb3 or ucs2).

If you use character sets that support supplementary characters and thus are “wider” than the BMP-only utf8mb3 and ucs2 character sets, there are potential incompatibility issues for your applications; see Section 10.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”. That section also describes how to convert tables from the (3-byte) utf8mb3 to the (4-byte) utf8mb4, and what constraints may apply in doing so.

A similar set of collations is available for each Unicode character set. For example, each has a Danish collation, the names of which are utf8mb4_danish_ci, utf8mb3_danish_ci, utf8_danish_ci, ucs2_danish_ci, utf16_danish_ci, and utf32_danish_ci. For information about Unicode collations and their differentiating properties, including collation properties for supplementary characters, see Section 10.10.1, “Unicode Character Sets”.

Although many of the supplementary characters come from East Asian languages, what MySQL 5.5 adds is support for more Japanese and Chinese characters in Unicode character sets, not support for new Japanese and Chinese character sets.

The MySQL implementation of UCS-2, UTF-16, and UTF-32 stores characters in big-endian byte order and does not use a byte order mark (BOM) at the beginning of values. Other database systems might use little-endian byte order or a BOM. In such cases, conversion of values will need to be performed when transferring data between those systems and MySQL.

MySQL uses no BOM for UTF-8 values.

Client applications that communicate with the server using Unicode should set the client character set accordingly (for example, by issuing a `SET NAMES 'utf8mb4'` statement). Some character sets cannot be used as the client character set. Attempting to use them with `SET NAMES` or `SET CHARACTER SET` produces an error. See Impermissible Client Character Sets.

The following sections provide additional detail on the Unicode character sets in MySQL.

## 10.9.1 The utf8mb4 Character Set (4-Byte UTF-8 Unicode Encoding)

The utf8mb4 character set has these characteristics:

- Supports BMP and supplementary characters.
- Requires a maximum of four bytes per multibyte character.

utf8mb4 contrasts with the utf8mb3 character set, which supports only BMP characters and uses a maximum of three bytes per character:

- For a BMP character, utf8mb4 and utf8mb3 have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, utf8mb4 requires four bytes to store it, whereas utf8mb3 cannot store the character at all. When converting utf8mb3 columns to utf8mb4, you need not worry about converting supplementary characters because there will be none.
The utf8mb3 Character Set (3-Byte UTF-8 Unicode Encoding)

utf8mb4 is a superset of utf8mb3, so for an operation such as the following concatenation, the result has character set utf8mb4 and the collation of utf8mb4_col:

```
SELECT CONCAT(utf8mb3_col, utf8mb4_col);
```

Similarly, the following comparison in the WHERE clause works according to the collation of utf8mb4_col:

```
SELECT * FROM utf8mb3_tbl, utf8mb4_tbl
WHERE utf8mb3_tbl.utf8mb3_col = utf8mb4_tbl.utf8mb4_col;
```

For information about data type storage as it relates to multibyte character sets, see String Type Storage Requirements.

10.9.2 The utf8mb3 Character Set (3-Byte UTF-8 Unicode Encoding)

The utf8mb3 character set has these characteristics:

- Supports BMP characters only (no support for supplementary characters)
- Requires a maximum of three bytes per multibyte character.

Applications that use UTF-8 data but require supplementary character support should use utf8mb4 rather than utf8mb3 (see Section 10.9.1, "The utf8mb4 Character Set (4-Byte UTF-8 Unicode Encoding)").

Exactly the same set of characters is available in utf8mb3 and ucs2. That is, they have the same repertoire.

utf8 is an alias for utf8mb3; the character limit is implicit, rather than explicit in the name.

utf8mb3 can be used in CHARACTER SET clauses, and utf8mb3_collation_substring in COLLATE clauses, where collation_substring is bin, czech_ci, danish_ci, esperanto_ci, estonian_ci, and so forth. For example:

```
CREATE TABLE t (s1 CHAR(1) CHARACTER SET utf8mb3;
SELECT * FROM t WHERE s1 COLLATE utf8mb3_general_ci = 'x';
DECLARE x VARCHAR(5) CHARACTER SET utf8mb3 COLLATE utf8mb3_danish_ci;
SELECT CAST('a' AS CHAR CHARACTER SET utf8) COLLATE utf8_czech_ci;
```

MySQL immediately converts instances of utf8mb3 in statements to utf8, so in statements such as SHOW CREATE TABLE or SELECT CHARACTER_SET_NAME FROM INFORMATION_SCHEMA.COLUMNS or SELECT COLLATION_NAME FROM INFORMATION_SCHEMA.COLUMNS, users will see the name utf8 or utf8_collation_substring.

utf8mb3 is also valid in contexts other than CHARACTER_SET clauses. For example:

```
mysqld --character-set-server=utf8mb3
```

There is no utf8mb3 collation corresponding to the utf8 collation for collation names that include a version number to indicate the Unicode Collation Algorithm version on which the collation is based (for example, utf8_unicode_520_ci).

For information about data type storage as it relates to multibyte character sets, see String Type Storage Requirements.

10.9.3 The utf8 Character Set (Alias for utf8mb3)

utf8 is an alias for the utf8mb3 character set. For more information, see Section 10.9.2, “The utf8mb3 Character Set (3-Byte UTF-8 Unicode Encoding)".
10.9.4 The ucs2 Character Set (UCS-2 Unicode Encoding)

In UCS-2, every character is represented by a 2-byte Unicode code with the most significant byte first. For example: \texttt{LATIN CAPITAL LETTER A} has the code \texttt{0x0041} and it is stored as a 2-byte sequence: \texttt{0x00 0x41}. \texttt{CYRILLIC SMALL LETTER YERU} (Unicode \texttt{0x044B}) is stored as a 2-byte sequence: \texttt{0x04 0x4B}. For Unicode characters and their codes, please refer to the Unicode Consortium website.

The ucs2 character set has these characteristics:

- Supports BMP characters only (no support for supplementary characters)
- Uses a fixed-length 16-bit encoding and requires two bytes per character.

10.9.5 The utf16 Character Set (UTF-16 Unicode Encoding)

The utf16 character set is the ucs2 character set with an extension that enables encoding of supplementary characters:

- For a BMP character, utf16 and ucs2 have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, utf16 has a special sequence for representing the character using 32 bits. This is called the "surrogate" mechanism: For a number greater than \texttt{0xffff}, take 10 bits and add them to \texttt{0xd800} and put them in the first 16-bit word, take 10 more bits and add them to \texttt{0xdc00} and put them in the next 16-bit word. Consequently, all supplementary characters require 32 bits, where the first 16 bits are a number between \texttt{0xd800} and \texttt{0xdbff}, and the last 16 bits are a number between \texttt{0xdc00} and \texttt{0xdfff}. Examples are in Section 15.5 Surrogates Area of the Unicode 4.0 document.

Because utf16 supports surrogates and ucs2 does not, there is a validity check that applies only in utf16: You cannot insert a top surrogate without a bottom surrogate, or vice versa. For example:

\begin{verbatim}
INSERT INTO t (ucs2_column) VALUES (0xd800); /* legal */
INSERT INTO t (utf16_column)VALUES (0xd800); /* illegal */
\end{verbatim}

There is no validity check for characters that are technically valid but are not true Unicode (that is, characters that Unicode considers to be "unassigned code points" or "private use" characters or even "illegals" like \texttt{0xffff}). For example, since U+F8FF is the Apple Logo, this is legal:

\begin{verbatim}
INSERT INTO t (utf16_column)VALUES (0xf8ff); /* legal */
\end{verbatim}

Such characters cannot be expected to mean the same thing to everyone.

Because MySQL must allow for the worst case (that one character requires four bytes) the maximum length of a utf16 column or index is only half of the maximum length for a ucs2 column or index. For example, the maximum length of a MEMORY table index key is 3072 bytes, so these statements create tables with the longest permitted indexes for ucs2 and utf16 columns:

\begin{verbatim}
CREATE TABLE tf (s1 VARCHAR(1536) CHARACTER SET ucs2) ENGINE=MEMORY;
CREATE INDEX i ON tf (s1);
CREATE TABLE tg (s1 VARCHAR(768) CHARACTER SET utf16) ENGINE=MEMORY;
CREATE INDEX i ON tg (s1);
\end{verbatim}

10.9.6 The utf32 Character Set (UTF-32 Unicode Encoding)

The utf32 character set is fixed length (like ucs2 and unlike utf16). utf32 uses 32 bits for every character, unlike ucs2 (which uses 16 bits for every character), and unlike utf16 (which uses 16 bits for some characters and 32 bits for others).
Converting Between 3-Byte and 4-Byte Unicode Character Sets

utf32 takes twice as much space as ucs2 and more space than utf16, but utf32 has the same advantage as ucs2 that it is predictable for storage: The required number of bytes for utf32 equals the number of characters times 4. Also, unlike utf16, there are no tricks for encoding in utf32, so the stored value equals the code value.

To demonstrate how the latter advantage is useful, here is an example that shows how to determine a utf8mb4 value given the utf32 code value:

```sql
/* Assume code value = 100cc LINEAR B WHEELED CHARIOT */
CREATE TABLE tmp (utf32_col CHAR(1) CHARACTER SET utf32,
    utf8mb4_col CHAR(1) CHARACTER SET utf8mb4);
INSERT INTO tmp VALUES (0x000100cc,NULL);
UPDATE tmp SET utf8mb4_col = utf32_col;
SELECT HEX(utf32_col),HEX(utf8mb4_col) FROM tmp;
```

MySQL is very forgiving about additions of unassigned Unicode characters or private-use-area characters. There is in fact only one validity check for utf32: No code value may be greater than 0x10ffff. For example, this is illegal:

```sql
INSERT INTO t (utf32_column) VALUES (0x110000); /* illegal */
```

### 10.9.7 Converting Between 3-Byte and 4-Byte Unicode Character Sets

This section describes issues that you may face when converting character data between the utf8mb3 and utf8mb4 character sets.

**Note**

This discussion focuses primarily on converting between utf8mb3 and utf8mb4, but similar principles apply to converting between the ucs2 character set and character sets such as utf16 or utf32.

The utf8mb3 and utf8mb4 character sets differ as follows:

- **utf8mb3** supports only characters in the Basic Multilingual Plane (BMP). utf8mb4 additionally supports supplementary characters that lie outside the BMP.
- **utf8mb3** uses a maximum of three bytes per character. utf8mb4 uses a maximum of four bytes per character.

**Note**

This discussion refers to the utf8mb3 and utf8mb4 character set names to be explicit about referring to 3-byte and 4-byte UTF-8 character set data. The exception is that in table definitions, utf8 is used because MySQL converts instances of utf8mb3 specified in such definitions to utf8, which is an alias for utf8mb3.

One advantage of converting from utf8mb3 to utf8mb4 is that this enables applications to use supplementary characters. One tradeoff is that this may increase data storage space requirements.

In terms of table content, conversion from utf8mb3 to utf8mb4 presents no problems:

- For a BMP character, utf8mb4 and utf8mb3 have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, utf8mb4 requires four bytes to store it, whereas utf8mb3 cannot store the character at all. When converting utf8mb3 columns to utf8mb4, you need not worry about converting supplementary characters because there will be none.
In terms of table structure, these are the primary potential incompatibilities:

- For the variable-length character data types (VARCHAR and the TEXT types), the maximum permitted length in characters is less for utf8mb4 columns than for utf8mb3 columns.

- For all character data types (CHAR, VARCHAR, and the TEXT types), the maximum number of characters that can be indexed is less for utf8mb4 columns than for utf8mb3 columns.

Consequently, to convert tables from utf8mb3 to utf8mb4, it may be necessary to change some column or index definitions.

Tables can be converted from utf8mb3 to utf8mb4 by using ALTER TABLE. Suppose that a table has this definition:

```sql
CREATE TABLE t1 (  
  col1 CHAR(10) CHARACTER SET utf8 COLLATE utf8_unicode_ci NOT NULL,  
  col2 CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin NOT NULL  
) CHARACTER SET utf8;
```

The following statement converts t1 to use utf8mb4:

```sql
ALTER TABLE t1  
DEFAULT CHARACTER SET utf8mb4,  
MODIFY col1 CHAR(10)  
  CHARACTER SET utf8mb4 COLLATE utf8mb4_unicode_ci NOT NULL,  
MODIFY col2 CHAR(10)  
  CHARACTER SET utf8mb4 COLLATE utf8mb4_bin NOT NULL;
```

The catch when converting from utf8mb3 to utf8mb4 is that the maximum length of a column or index key is unchanged in terms of bytes. Therefore, it is smaller in terms of characters because the maximum length of a character is four bytes instead of three. For the CHAR, VARCHAR, and TEXT data types, watch for these issues when converting your MySQL tables:

- Check all definitions of utf8mb3 columns and make sure they will not exceed the maximum length for the storage engine.
- Check all indexes on utf8mb3 columns and make sure they will not exceed the maximum length for the storage engine. Sometimes the maximum can change due to storage engine enhancements.

If the preceding conditions apply, you must either reduce the defined length of columns or indexes, or continue to use utf8mb3 rather than utf8mb4.

Here are some examples where structural changes may be needed:

- A TINYTEXT column can hold up to 255 bytes, so it can hold up to 85 3-byte or 63 4-byte characters. Suppose that you have a TINYTEXT column that uses utf8mb3 but must be able to contain more than 63 characters. You cannot convert it to utf8mb4 unless you also change the data type to a longer type such as TEXT.

  Similarly, a very long VARCHAR column may need to be changed to one of the longer TEXT types if you want to convert it from utf8mb3 to utf8mb4.

- InnoDB has a maximum index length of 767 bytes, so for utf8mb3 or utf8mb4 columns, you can index a maximum of 255 or 191 characters, respectively. If you currently have utf8mb3 columns with indexes longer than 191 characters, you will need to index a smaller number of characters. In an InnoDB table, these column and index definitions are legal:

```sql
  coll VARCHAR(500) CHARACTER SET utf8, INDEX (coll(255))
```

To use utf8mb4 instead, the index must be smaller:
The preceding types of changes are most likely to be required only if you have very long columns or indexes. Otherwise, you should be able to convert your tables from utf8mb3 to utf8mb4 without problems, using ALTER TABLE as described previously.

The following items summarize other potential incompatibilities:

- **SET NAMES 'utf8mb4'** causes use of the 4-byte character set for connection character sets. As long as no 4-byte characters are sent from the server, there should be no problems. Otherwise, applications that expect to receive a maximum of three bytes per character may have problems. Conversely, applications that expect to send 4-byte characters must ensure that the server understands them.

- For replication, if character sets that support supplementary characters are to be used on the master, all slaves must understand them as well.

Also, keep in mind the general principle that if a table has different definitions on the master and slave, this can lead to unexpected results. For example, the differences in maximum index key length make it risky to use utf8mb3 on the master and utf8mb4 on the slave.

If you have converted to utf8mb4, utf16, or utf32, and then decide to convert back to utf8mb3 or ucs2 (for example, to downgrade to an older version of MySQL), these considerations apply:

- utf8mb3 and ucs2 data should present no problems.

- The server must be recent enough to recognize definitions referring to the character set from which you are converting.

- For object definitions that refer to the utf8mb4 character set, you can dump them with mysqldump prior to downgrading, edit the dump file to change instances of utf8mb4 to utf8, and reload the file in the older server, as long as there are no 4-byte characters in the data. The older server will see utf8 in the dump file object definitions and create new objects that use the (3-byte) utf8 character set.

## 10.10 Supported Character Sets and Collations

This section indicates which character sets MySQL supports. There is one subsection for each group of related character sets. For each character set, the permissible collations are listed.

To list the available character sets and their default collations, use the SHOW CHARACTER SET statement or query the INFORMATION_SCHEMA CHARACTER SETS table. For example:

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese   | big5_chinese_ci     | 2      |
| dec8     | DEC West European           | dec8_swedish_ci     | 1      |
| cp850    | DOS West European           | cp850_general_ci    | 1      |
| hp8      | HP West European            | hp8_english_ci      | 1      |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    | 1      |
| latin1   | cp1252 West European        | latin1_swedish_ci   | 1      |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   | 1      |
| swe7     | 7bit Swedish                | swe7_swedish_ci     | 1      |
| ascii    | US ASCII                    | ascii_general_ci    | 1      |
| ujis     | EUC-JP Japanese             | ujis_japanese_ci    | 3      |
| sjis     | Shift-JIS Japanese          | sjis_japanese_ci    | 2      |
| hebrew   | ISO 8859-8 Hebrew           | hebrew_general_ci   | 1      |
| tis620   | TIS620 Thai                  | tis620_thai_ci      | 1      |
| euckr    | EUC-KR Korean               | euckr_korean_ci     | 2      |
```
In cases where a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing the wrong collation, it can be helpful to perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

### 10.10.1 Unicode Character Sets

This section describes the collations available for Unicode character sets and their differentiating properties. For general information about Unicode, see Section 10.9, “Unicode Support”.

MySQL supports multiple Unicode character sets:

- **utf8mb4**: A UTF-8 encoding of the Unicode character set using one to four bytes per character.
- **utf8mb3**: A UTF-8 encoding of the Unicode character set using one to three bytes per character.
- **utf8**: An alias for **utf8mb3**.
- **ucs2**: The UCS-2 encoding of the Unicode character set using two bytes per character.
- **utf16**: The UTF-16 encoding for the Unicode character set using two or four bytes per character. Like **ucs2** but with an extension for supplementary characters.
- **utf32**: The UTF-32 encoding for the Unicode character set using four bytes per character.

**utf8mb4**, **utf16**, and **utf32** support Basic Multilingual Plane (BMP) characters and supplementary characters that lie outside the BMP. **utf8** and **ucs2** support only BMP characters.

Most Unicode character sets have a general collation (indicated by _general in the name or by the absence of a language specifier), a binary collation (indicated by _bin in the name), and several language-specific collations (indicated by language specifiers). For example, for **utf8mb4**, **utf8mb4_general_ci** and **utf8mb4_bin** are its general and binary collations, and **utf8mb4_danish_ci** is one of its language-specific collations.

- **Unicode Collation Algorithm (UCA) Versions**
Unicode Character Sets

- Language-Specific Collations
- _general_ci Versus _unicode_ci Collations
- Character Collating Weights
- Miscellaneous Information

Unicode Collation Algorithm (UCA) Versions

MySQL implements the xxx_unicode_ci collations according to the Unicode Collation Algorithm (UCA) described at http://www.unicode.org/reports/tr10/. The collation uses the version-4.0.0 UCA weight keys: http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt. The xxx_unicode_ci collations have only partial support for the Unicode Collation Algorithm. Some characters are not supported, and combining marks are not fully supported. This affects primarily Vietnamese, Yoruba, and some smaller languages such as Navajo. A combined character is considered different from the same character written with a single unicode character in string comparisons, and the two characters are considered to have a different length (for example, as returned by the CHAR_LENGTH() function or in result set metadata).

Language-Specific Collations

MySQL implements language-specific Unicode collations if the ordering based only on the Unicode Collation Algorithm (UCA) does not work well for a language. Language-specific collations are UCA-based, with additional language tailoring rules. Examples of such rules appear later in this section. For questions about particular language orderings, unicode.org provides Common Locale Data Repository (CLDR) collation charts at http://www.unicode.org/cldr/charts/30/collation/index.html.

A language name shown in the following table indicates a language-specific collation. Unicode character sets may include collations for one or more of these languages.

Table 10.3 Unicode Collation Language Specifiers

<table>
<thead>
<tr>
<th>Language</th>
<th>Language Specifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical Latin</td>
<td>roman</td>
</tr>
<tr>
<td>Czech</td>
<td>czech</td>
</tr>
<tr>
<td>Danish</td>
<td>danish</td>
</tr>
<tr>
<td>Esperanto</td>
<td>esperanto</td>
</tr>
<tr>
<td>Estonian</td>
<td>estonian</td>
</tr>
<tr>
<td>Hungarian</td>
<td>hungarian</td>
</tr>
<tr>
<td>Icelandic</td>
<td>icelandic</td>
</tr>
<tr>
<td>Latvian</td>
<td>latvian</td>
</tr>
<tr>
<td>Lithuanian</td>
<td>lithuanian</td>
</tr>
<tr>
<td>Persian</td>
<td>persian</td>
</tr>
<tr>
<td>Polish</td>
<td>polish</td>
</tr>
<tr>
<td>Romanian</td>
<td>romanian</td>
</tr>
<tr>
<td>Sinhala</td>
<td>sinhala</td>
</tr>
<tr>
<td>Slovak</td>
<td>slovak</td>
</tr>
<tr>
<td>Slovenian</td>
<td>slovenian</td>
</tr>
<tr>
<td>Modern Spanish</td>
<td>spanish</td>
</tr>
<tr>
<td>Traditional Spanish</td>
<td>spanish2</td>
</tr>
<tr>
<td>Language</td>
<td>Language Specifier</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Swedish</td>
<td>swedish</td>
</tr>
<tr>
<td>Turkish</td>
<td>turkish</td>
</tr>
</tbody>
</table>

Danish collations may also be used for Norwegian.

For Classical Latin collations, I and J compare as equal, and U and V compare as equal.

Spanish collations are available for modern and traditional Spanish. For both, ň (n-tilde) is a separate letter between n and o. In addition, for traditional Spanish, ch is a separate letter between c and d, and ll is a separate letter between l and m.

Traditional Spanish collations may also be used for Asturian and Galician.

Swedish collations include Swedish rules. For example, in Swedish, the following relationship holds, which is not something expected by a German or French speaker:

\[ \ddot{U} = Y < \ddot{O} \]

### _general_ci Versus _unicode_ci Collations

For any Unicode character set, operations performed using the `xxx_general_ci` collation are faster than those for the `xxx_unicode_ci` collation. For example, comparisons for the `utf8_general_ci` collation are faster, but slightly less correct, than comparisons for `utf8_unicode_ci`. The reason is that `utf8_unicode_ci` supports mappings such as expansions; that is, when one character compares as equal to combinations of other characters. For example, ß is equal to ss in German and some other languages. `utf8_unicode_ci` also supports contractions and ignorable characters. `utf8_general_ci` is a legacy collation that does not support expansions, contractions, or ignorable characters. It can make only one-to-one comparisons between characters.

To further illustrate, the following equalities hold in both `utf8_general_ci` and `utf8_unicode_ci` (for the effect of this in comparisons or searches, see Section 10.8.6, “Examples of the Effect of Collation”):

| Ä = A   |
| Ö = O   |
| Ü = U   |

A difference between the collations is that this is true for `utf8_general_ci`:

\[ ß = s \]

Whereas this is true for `utf8_unicode_ci`, which supports the German DIN-1 ordering (also known as dictionary order):

\[ ß = ss \]

MySQL implements `utf8` language-specific collations if the ordering with `utf8_unicode_ci` does not work well for a language. For example, `utf8_unicode_ci` works fine for German dictionary order and French, so there is no need to create special `utf8` collations.

`utf8_general_ci` also is satisfactory for both German and French, except that ß is equal to s, and not to ss. If this is acceptable for your application, you should use `utf8_general_ci` because it is faster. Otherwise, use `utf8_unicode_ci` because it is more accurate.

### Character Collating Weights

For all Unicode collations except the `_bin` (binary) collations, MySQL performs a table lookup to find a character's collating weight. If a character is not in the table (for example, because it is a “new” character), collating weight determination becomes more complex:
Unicode Character Sets

- For BMP characters in general collations (xxx_general_ci), the weight is the code point.

- For BMP characters in UCA collations (for example, xxx_unicode_ci and language-specific collations), the following algorithm applies:

```c
if (code >= 0x3400 && code <= 0x4DB5)
    base= 0xFB80; /* CJK Ideograph Extension */
else if (code >= 0x4E00 && code <= 0x9FA5)
    base= 0xFB40; /* CJK Ideograph */
else
    base= 0xFBC0; /* All other characters */

aaaa= base +  (code >> 15);
bbbb= (code & 0x7FFF) | 0x8000;
```

The result is a sequence of two collating elements, aaaa followed by bbbb.

Thus, U+04cf CYRILLIC SMALL LETTER PALOCHKA currently is, with all UCA collations, greater than U+04c0 CYRILLIC LETTER PALOCHKA. Eventually, after further collation tuning, all palochkas will sort together.

- For supplementary characters in general collations, the weight is the weight for 0xfffd REPLACEMENT CHARACTER. For supplementary characters in UCA 4.0.0 collations, their collating weight is 0xfffd. That is, to MySQL, all supplementary characters are equal to each other, and greater than almost all BMP characters.

An example with Deseret characters and COUNT(DISTINCT):

```sql
CREATE TABLE t (s1 VARCHAR(5) CHARACTER SET utf32 COLLATE utf32_unicode_ci);
INSERT INTO t VALUES (0xfffd);   /* REPLACEMENT CHARACTER */
INSERT INTO t VALUES (0x010412); /* DESERET CAPITAL LETTER BEE */
INSERT INTO t VALUES (0x010413); /* DESERET CAPITAL LETTER TEE */
SELECT COUNT(DISTINCT s1) FROM t;
```

The result is 2 because in the MySQL xxx_unicode_ci collations, the replacement character has a weight of 0x0dc6, whereas Deseret Bee and Deseret Tee both have a weight of 0xfffd. (Were the utf32_general_ci collation used instead, the result is 1 because all three characters have a weight of 0xfffd in that collation.)

The rule that all supplementary characters are equal to each other is nonoptimal but is not expected to cause trouble. These characters are very rare, so it is very rare that a multi-character string consists entirely of supplementary characters. In Japan, since the supplementary characters are obscure Kanji ideographs, the typical user does not care what order they are in, anyway. If you really want rows sorted by the MySQL rule and secondarily by code point value, it is easy:

```sql
ORDER BY s1 COLLATE utf32_unicode_ci, s1 COLLATE utf32_bin
```

There is a difference between "ordering by the character's code value" and "ordering by the character's binary representation," a difference that appears only with utf16_bin, because of surrogates.

Suppose that utf16_bin (the binary collation for utf16) was a binary comparison “byte by byte” rather than “character by character.” If that were so, the order of characters in utf16_bin would differ from the order in utf8_bin. For example, the following chart shows two rare characters. The first character is in the range E000-FFFF, so it is greater than a surrogate but less than a supplementary. The second character is a supplementary.

<table>
<thead>
<tr>
<th>Code point</th>
<th>Character</th>
<th>utf8</th>
<th>utf16</th>
</tr>
</thead>
<tbody>
<tr>
<td>0FF9D</td>
<td>HALFWIDTH KATAKANA LETTER N</td>
<td>EF BE 9D</td>
<td>FF 9D</td>
</tr>
<tr>
<td>10384</td>
<td>UGARITIC LETTER DELTA</td>
<td>F0 90 8E 84</td>
<td>D8 00 DF 84</td>
</tr>
</tbody>
</table>
The two characters in the chart are in order by code point value because $0xff9d < 0x10384$. And they are in order by utf8 value because $0xef < 0xf0$. But they are not in order by utf16 value, if we use byte-by-byte comparison, because $0xff > 0xd8$.

So MySQL’s utf16_bin collation is not “byte by byte.” It is “by code point.” When MySQL sees a supplementary-character encoding in utf16, it converts to the character’s code-point value, and then compares. Therefore, utf8_bin and utf16_bin are the same ordering. This is consistent with the SQL:2008 standard requirement for a UCS_BASIC collation: “UCS_BASIC is a collation in which the ordering is determined entirely by the Unicode scalar values of the characters in the strings being sorted. It is applicable to the UCS character repertoire. Since every character repertoire is a subset of the UCS repertoire, the UCS_BASIC collation is potentially applicable to every character set. NOTE 11: The Unicode scalar value of a character is its code point treated as an unsigned integer.”

If the character set is ucs2, comparison is byte-by-byte, but ucs2 strings should not contain surrogates, anyway.

**Miscellaneous Information**

The xxx_general_mysql500_ci collations were added in MySQL 5.5.21. They preserve the pre-5.1.24 ordering of the original xxx_general_ci collations and permit upgrades for tables created before MySQL 5.1.24 (Bug #27877).

**10.10.2 West European Character Sets**

Western European character sets cover most West European languages, such as French, Spanish, Catalan, Basque, Portuguese, Italian, Albanian, Dutch, German, Danish, Swedish, Norwegian, Finnish, Faroese, Icelandic, Irish, Scottish, and English.

- **ascii** (US ASCII) collations:
  - ascii_bin
  - ascii_general_ci (default)
- **cp850** (DOS West European) collations:
  - cp850_bin
  - cp850_general_ci (default)
- **dec8** (DEC Western European) collations:
  - dec8_bin
  - dec8_swedish_ci (default)
- **hp8** (HP Western European) collations:
  - hp8_bin
  - hp8_english_ci (default)
- **latin1** (cp1252 West European) collations:
  - latin1_bin
  - latin1_danish_ci
Central European Character Sets

- latin1_general_ci
- latin1_general_cs
- latin1_german1_ci
- latin1_german2_ci
- latin1_spanish_ci
- latin1_swedish_ci (default)

`latin1` is the default character set. MySQL's `latin1` is the same as the Windows `cp1252` character set. This means it is the same as the official ISO 8859-1 or IANA (Internet Assigned Numbers Authority) `latin1`, except that IANA `latin1` treats the code points between 0x80 and 0x9f as "undefined," whereas `cp1252`, and therefore MySQL's `latin1`, assign characters for those positions. For example, 0x80 is the Euro sign. For the "undefined" entries in `cp1252`, MySQL translates 0x81 to Unicode 0x0081, 0x8d to 0x008d, 0x8f to 0x0090, 0x90 to 0x0090, and 0x9d to 0x0090.

The `latin1_swedish_ci` collation is the default that probably is used by the majority of MySQL customers. Although it is frequently said that it is based on the Swedish/Finnish collation rules, there are Swedes and Finns who disagree with this statement.

The `latin1_german1_ci` and `latin1_german2_ci` collations are based on the DIN-1 and DIN-2 standards, where DIN stands for Deutsches Institut für Normung (the German equivalent of ANSI). DIN-1 is called the "dictionary collation" and DIN-2 is called the "phone book collation." For an example of the effect this has in comparisons or when doing searches, see Section 10.8.6, "Examples of the Effect of Collation".

- `latin1_german1_ci` (dictionary) rules:

<table>
<thead>
<tr>
<th>Ä</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ö</td>
<td>O</td>
</tr>
<tr>
<td>Ü</td>
<td>U</td>
</tr>
<tr>
<td>ß</td>
<td>s</td>
</tr>
</tbody>
</table>

- `latin1_german2_ci` (phone-book) rules:

<table>
<thead>
<tr>
<th>Ä</th>
<th>AE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ö</td>
<td>OE</td>
</tr>
<tr>
<td>Ü</td>
<td>UE</td>
</tr>
<tr>
<td>ß</td>
<td>SS</td>
</tr>
</tbody>
</table>

In the `latin1_spanish_ci` collation, ñ (n-tilde) is a separate letter between n and o.

- macroman (Mac West European) collations:
  - macroman_bin
  - macroman_general_ci (default)

- swe7 (7bit Swedish) collations:
  - swe7_bin
  - swe7_swedish_ci (default)

10.10.3 Central European Character Sets
MySQL provides some support for character sets used in the Czech Republic, Slovakia, Hungary, Romania, Slovenia, Croatia, Poland, and Serbia (Latin).

- **cp1250** (Windows Central European) collations:
  - cp1250_bin
  - cp1250_croatian_ci
  - cp1250_czech_cs
  - cp1250_general_ci (default)
  - cp1250_polish_ci

- **cp852** (DOS Central European) collations:
  - cp852_bin
  - cp852_general_ci (default)

- **keybcs2** (DOS Kamenicky Czech-Slovak) collations:
  - keybcs2_bin
  - keybcs2_general_ci (default)

- **latin2** (ISO 8859-2 Central European) collations:
  - latin2_bin
  - latin2_croatian_ci
  - latin2_czech_cs
  - latin2_general_ci (default)
  - latin2_hungarian_ci

- **macce** (Mac Central European) collations:
  - macce_bin
  - macce_general_ci (default)

### 10.10.4 South European and Middle East Character Sets

South European and Middle Eastern character sets supported by MySQL include Armenian, Arabic, Georgian, Greek, Hebrew, and Turkish.

- **armscii8** (ARMSCEII-8 Armenian) collations:
  - armscii8_bin
  - armscii8_general_ci (default)

- **cp1256** (Windows Arabic) collations:
10.10.5 Baltic Character Sets

The Baltic character sets cover Estonian, Latvian, and Lithuanian languages.

- \texttt{cp1257} (Windows Baltic) collations:
  - \texttt{cp1257_bin}
  - \texttt{cp1257_general_ci} (default)
  - \texttt{cp1257_lithuanian_ci}

- \texttt{latin7} (ISO 8859-13 Baltic) collations:
  - \texttt{latin7_bin}
  - \texttt{latin7_estonian_cs}
  - \texttt{latin7_general_ci} (default)
  - \texttt{latin7_general_cs}

10.10.6 Cyrillic Character Sets

The Cyrillic character sets and collations are for use with Belarusian, Bulgarian, Russian, Ukrainian, and Serbian (Cyrillic) languages.

- \texttt{cp1251} (Windows Cyrillic) collations:
  - \texttt{cp1251_bin}
Asian Character Sets

- `cp1251_bulgarian_ci`
- `cp1251_general_ci` (default)
- `cp1251_general_cs`
- `cp1251_ukrainian_ci`

- `cp866` (DOS Russian) collations:
  - `cp866_bin`
  - `cp866_general_ci` (default)

- `koi8r` (KOI8-R Relcom Russian) collations:
  - `koi8r_bin`
  - `koi8r_general_ci` (default)

- `koi8u` (KOI8-U Ukrainian) collations:
  - `koi8u_bin`
  - `koi8u_general_ci` (default)

### 10.10.7 Asian Character Sets

The Asian character sets that we support include Chinese, Japanese, Korean, and Thai. These can be complicated. For example, the Chinese sets must allow for thousands of different characters. See Section 10.10.7.1, “The cp932 Character Set”, for additional information about the `cp932` and `sjis` character sets.

For answers to some common questions and problems relating support for Asian character sets in MySQL, see Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”.

- `big5` (Big5 Traditional Chinese) collations:
  - `big5_bin`
  - `big5_chinese_ci` (default)

- `cp932` (SJIS for Windows Japanese) collations:
  - `cp932_bin`
  - `cp932_japanese_ci` (default)

- `eucjpms` (UJIS for Windows Japanese) collations:
  - `eucjpms_bin`
  - `eucjpms_japanese_ci` (default)

- `euckr` (EUC-KR Korean) collations:
  - `euckr_bin`
Asian Character Sets

- *euckr_korean_ci* (default)
- *gb2312* (GB2312 Simplified Chinese) collations:
  - *gb2312_bin*
  - *gb2312_chinese_ci* (default)
- *gbk* (GBK Simplified Chinese) collations:
  - *gbk_bin*
  - *gbk_chinese_ci* (default)
- *sjis* (Shift-JIS Japanese) collations:
  - *sjis_bin*
  - *sjis_japanese_ci* (default)
- *tis620* (TIS620 Thai) collations:
  - *tis620_bin*
  - *tis620_thai_ci* (default)
- *ujis* (EUC-JP Japanese) collations:
  - *ujis_bin*
  - *ujis_japanese_ci* (default)

The *big5_chinese_ci* collation sorts on number of strokes.

**10.10.7.1 The cp932 Character Set**

**Why is cp932 needed?**

In MySQL, the *sjis* character set corresponds to the *Shift_JIS* character set defined by IANA, which supports JIS X0201 and JIS X0208 characters. (See [http://www.iana.org/assignments/character-sets](http://www.iana.org/assignments/character-sets).

However, the meaning of “SHIFT JIS” as a descriptive term has become very vague and it often includes the extensions to *Shift_JIS* that are defined by various vendors.

For example, “SHIFT JIS” used in Japanese Windows environments is a Microsoft extension of *Shift_JIS* and its exact name is *Microsoft Windows Codepage : 932* or *cp932*. In addition to the characters supported by *Shift_JIS*, *cp932* supports extension characters such as NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.

Many Japanese users have experienced problems using these extension characters. These problems stem from the following factors:

- MySQL automatically converts character sets.
- Character sets are converted using Unicode (*ucs2*).
- The *sjis* character set does not support the conversion of these extension characters.
Asian Character Sets

- There are several conversion rules from so-called “SHIFT JIS” to Unicode, and some characters are converted to Unicode differently depending on the conversion rule. MySQL supports only one of these rules (described later).

The MySQL cp932 character set is designed to solve these problems.

Because MySQL supports character set conversion, it is important to separate IANA Shift_JIS and cp932 into two different character sets because they provide different conversion rules.

**How does cp932 differ from sjis?**

The cp932 character set differs from sjis in the following ways:

- cp932 supports NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.

- Some cp932 characters have two different code points, both of which convert to the same Unicode code point. When converting from Unicode back to cp932, one of the code points must be selected. For this “round trip conversion,” the rule recommended by Microsoft is used. (See [http://support.microsoft.com/kb/170559/EN-US/](http://support.microsoft.com/kb/170559/EN-US/)).

The conversion rule works like this:

- If the character is in both JIS X 0208 and NEC special characters, use the code point of JIS X 0208.

- If the character is in both NEC special characters and IBM selected characters, use the code point of NEC special characters.

- If the character is in both IBM selected characters and NEC selected—IBM extended characters, use the code point of IBM extended characters.

The table shown at [https://msdn.microsoft.com/en-us/goglobal/cc305152.aspx](https://msdn.microsoft.com/en-us/goglobal/cc305152.aspx) provides information about the Unicode values of cp932 characters. For cp932 table entries with characters under which a four-digit number appears, the number represents the corresponding Unicode (ucs2) encoding. For table entries with an underlined two-digit value appears, there is a range of cp932 character values that begin with those two digits. Clicking such a table entry takes you to a page that displays the Unicode value for each of the cp932 characters that begin with those digits.

The following links are of special interest. They correspond to the encodings for the following sets of characters:

- NEC special characters (lead byte 0x87):

- NEC selected—IBM extended characters (lead byte 0xED and 0xEE):

- IBM selected characters (lead byte 0xFA, 0xFB, 0xFC):

- cp932 supports conversion of user-defined characters in combination with eucjpms, and solves the problems with sjis/ujis conversion. For details, please refer to [http://www.sljfaq.org/afaq/encodings.html](http://www.sljfaq.org/afaq/encodings.html).
For some characters, conversion to and from ucs2 is different for sjis and cp932. The following tables illustrate these differences.

Conversion to ucs2:

<table>
<thead>
<tr>
<th>sjis/cp932 Value</th>
<th>sjis -&gt; ucs2 Conversion</th>
<th>cp932 -&gt; ucs2 Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>5C</td>
<td>005C</td>
<td>005C</td>
</tr>
<tr>
<td>7E</td>
<td>007E</td>
<td>007E</td>
</tr>
<tr>
<td>815C</td>
<td>2015</td>
<td>2015</td>
</tr>
<tr>
<td>815F</td>
<td>005C</td>
<td>FF3C</td>
</tr>
<tr>
<td>8160</td>
<td>301C</td>
<td>FF5E</td>
</tr>
<tr>
<td>8161</td>
<td>2016</td>
<td>2225</td>
</tr>
<tr>
<td>817C</td>
<td>2212</td>
<td>FF0D</td>
</tr>
<tr>
<td>8191</td>
<td>00A2</td>
<td>FFE0</td>
</tr>
<tr>
<td>8192</td>
<td>00A3</td>
<td>FFE1</td>
</tr>
<tr>
<td>81CA</td>
<td>00AC</td>
<td>FFE2</td>
</tr>
</tbody>
</table>

Conversion from ucs2:

<table>
<thead>
<tr>
<th>ucs2 value</th>
<th>ucs2 -&gt; sjis Conversion</th>
<th>ucs2 -&gt; cp932 Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>005C</td>
<td>815F</td>
<td>5C</td>
</tr>
<tr>
<td>007E</td>
<td>7E</td>
<td>7E</td>
</tr>
<tr>
<td>00A2</td>
<td>8191</td>
<td>3F</td>
</tr>
<tr>
<td>00A3</td>
<td>8192</td>
<td>3F</td>
</tr>
<tr>
<td>00AC</td>
<td>81CA</td>
<td>3F</td>
</tr>
<tr>
<td>2015</td>
<td>815C</td>
<td>815C</td>
</tr>
<tr>
<td>2016</td>
<td>8161</td>
<td>3F</td>
</tr>
<tr>
<td>2212</td>
<td>817C</td>
<td>3F</td>
</tr>
<tr>
<td>2225</td>
<td>3F</td>
<td>8161</td>
</tr>
<tr>
<td>301C</td>
<td>8160</td>
<td>3F</td>
</tr>
<tr>
<td>FF0D</td>
<td>3F</td>
<td>817C</td>
</tr>
<tr>
<td>FF3C</td>
<td>3F</td>
<td>815F</td>
</tr>
<tr>
<td>FF5E</td>
<td>3F</td>
<td>8160</td>
</tr>
<tr>
<td>FFE0</td>
<td>3F</td>
<td>8191</td>
</tr>
<tr>
<td>FFE1</td>
<td>3F</td>
<td>8192</td>
</tr>
<tr>
<td>FFE2</td>
<td>3F</td>
<td>81CA</td>
</tr>
</tbody>
</table>

Users of any Japanese character sets should be aware that using --character-set-client-handshake (or --skip-character-set-client-handshake) has an important effect. See Section 5.1.6, “Server Command Options”.

10.10.8 The Binary Character Set
The **binary** character set is the character set for binary strings, which are sequences of bytes. The **binary** character set has one collation, also named **binary**. Comparison and sorting are based on numeric byte values, rather than on numeric character code values (which for multibyte characters differ from numeric byte values). For information about the differences between the **binary** collation of the **binary** character set and the **_bin** collations of nonbinary character sets, see Section 10.8.5, “The **binary** Collation Compared to **_bin** Collations”.

For the **binary** character set, the concepts of lettercase and accent equivalence do not apply:

- For single-byte characters stored as binary strings, character and byte boundaries are the same, so lettercase and accent differences are significant in comparisons. That is, the **binary** collation is case-sensitive and accent-sensitive.

  ```
  mysql> SET NAMES 'binary';
  mysql> SELECT CHARSET('abc'), COLLATION('abc');
  +----------------+------------------+
  | CHARSET('abc') | COLLATION('abc') |
  +----------------+------------------+
  | binary         | binary           |
  +----------------+------------------+
  mysql> SELECT 'abc' = 'ABC', 'a' = 'ä';
  +---------------+------------+
  | 'abc' = 'ABC' | 'a' = 'ä'  |
  +---------------+------------+
  |             0 |          0 |
  +---------------+------------+
  ```

- For multibyte characters stored as binary strings, character and byte boundaries differ. Character boundaries are lost, so comparisons that depend on them are not meaningful.

  To perform lettercase conversion of a binary string, first convert it to a nonbinary string using a character set appropriate for the data stored in the string:

  ```
  mysql> SET @str = BINARY 'New York';
  mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING utf8mb4));
  +-----------------+--------------------+
  | LOWER(@str)     | LOWER(CONVERT(@str |
  | New York        | USING utf8mb4))    |
  +-----------------+--------------------+
  ```

To convert a string expression to a binary string, these constructs are equivalent:

- `BINARY expr`
- `CAST(expr AS BINARY)`
- `CONVERT(expr USING BINARY)`

If a value is a character string literal, the **_binary** introducer may be used to designate it as a binary string. For example:

- **_binary** 'a'

The **_binary** introducer is permitted for hexadecimal literals and bit-value literals as well, but unnecessary; such literals are binary strings by default.

For more information about introducers, see Section 10.3.8, “Character Set Introducers”.

### 10.11 Restrictions on Character Sets
• Identifiers are stored in `mysql` database tables (`user`, `db`, and so forth) using `utf8`, but identifiers can contain only characters in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted in identifiers.

• The `ucs2`, `utf16`, and `utf32` character sets have the following restrictions:
  - None of them can be used as the client character set. See "Impermissible Client Character Sets".
  - It is currently not possible to use `LOAD DATA` to load data files that use these character sets.
  - `FULLTEXT` indexes cannot be created on a column that uses any of these character sets. However, you can perform `IN BOOLEAN MODE` searches on the column without an index.
  - The use of `ENCRIPT()` with these character sets is not recommended because the underlying system call expects a string terminated by a zero byte.
  - The `REGEXP` and `RLIKE` operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

### 10.12 Setting the Error Message Language

By default, `mysqld` produces error messages in English, but they can be displayed instead in any of several other languages: Czech, Danish, Dutch, Estonian, French, German, Greek, Hungarian, Italian, Japanese, Korean, Norwegian, Norwegian-ny, Polish, Portuguese, Romanian, Russian, Slovak, Spanish, or Swedish. This applies to messages the server writes to the error log and sends to clients.

To select the language in which the server writes error messages, follow the instructions in this section. For information about changing the character set for error messages (rather than the language), see Section 10.6, "Error Message Character Set". For general information about configuring error logging, see Section 5.4.2, "The Error Log".

The server searches for the error message file using these rules:

• It looks for the file in a directory constructed from two system variable values, `lc_messages_dir` and `lc_messages`, with the latter converted to a language name. Suppose that you start the server using this command:

```bash
mysqld --lc_messages_dir=/usr/share/mysql --lc_messages=fr_FR
```

In this case, `mysqld` maps the locale `fr_FR` to the language `french` and looks for the error file in the `/usr/share/mysql/french` directory.

By default, the language files are located in the `share/mysql/LANGUAGE` directory under the MySQL base directory.

• If the message file cannot be found in the directory constructed as just described, the server ignores the `lc_messages` value and uses only the `lc_messages_dir` value as the location in which to look.

The `lc_messages_dir` system variable can be set only at server startup and has only a global read-only value at runtime. `lc_messages` can be set at server startup and has global and session values that can be modified at runtime. Thus, the error message language can be changed while the server is running, and each client can have its own error message language by setting its session `lc_messages` value to the desired locale name. For example, if the server is using the `fr_FR` locale for error messages, a client can execute this statement to receive error messages in English:
Adding a Character Set

This section discusses the procedure for adding a character set to MySQL. The proper procedure depends on whether the character set is simple or complex:

- If the character set does not need special string collating routines for sorting and does not need multibyte character support, it is simple.
- If the character set needs either of those features, it is complex.

For example, `greek` and `swe7` are simple character sets, whereas `big5` and `czech` are complex character sets.

To use the following instructions, you must have a MySQL source distribution. In the instructions, `MYSET` represents the name of the character set that you want to add.

1. Add a `<charset>` element for `MYSET` to the `sql/share/charsets/Index.xml` file. Use the existing contents in the file as a guide to adding new contents. A partial listing for the `latin1` `<charset>` element follows:

   ```xml
   <charset name="latin1">
     <family>Western</family>
     <description>cp1252 West European</description>
     ...
     <collation name="latin1_swedish_ci" id="8" order="Finnish, Swedish">
       <flag>primary</flag>
       <flag>compiled</flag>
     </collation>
     ...
     <collation name="latin1_bin" id="47" order="Binary">  
       <flag>binary</flag>
       <flag>compiled</flag>
     </collation>
     ...
   </charset>
   
   The `<charset>` element must list all the collations for the character set. These must include at least a binary collation and a default (primary) collation. The default collation is often named using a suffix of `general_ci` (general, case-insensitive). It is possible for the binary collation to be the default collation, but usually they are different. The default collation should have a `primary` flag. The binary collation should have a `binary` flag.

   You must assign a unique ID number to each collation. The range of IDs from 1024 to 2047 is reserved for user-defined collations. To find the maximum of the currently used collation IDs, use this query:

   ```sql
   SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
   ```

2. This step depends on whether you are adding a simple or complex character set. A simple character set requires only a configuration file, whereas a complex character set requires C source file that defines collation functions, multibyte functions, or both.

   For a simple character set, create a configuration file, `MYSET.xml`, that describes the character set properties. Create this file in the `sql/share/charsets` directory. You can use a copy of `latin1.xml` as the basis for this file. The syntax for the file is very simple:

   - Comments are written as ordinary XML comments (`<!-- text -->`).
Adding a Character Set

- Words within `<map>` array elements are separated by arbitrary amounts of whitespace.
- Each word within `<map>` array elements must be a number in hexadecimal format.
- The `<map>` array element for the `<ctype>` element has 257 words. The other `<map>` array elements after that have 256 words. See Section 10.13.1, "Character Definition Arrays".
- For each collation listed in the `<charset>` element for the character set in `Index.xml`, `MYSET.xml` must contain a `<collation>` element that defines the character ordering.

For a complex character set, create a C source file that describes the character set properties and defines the support routines necessary to properly perform operations on the character set:

- Create the file `ctype-MYSET.c` in the `strings` directory. Look at one of the existing `ctype-*.c` files (such as `ctype-big5.c`) to see what needs to be defined. The arrays in your file must have names like `ctype_MYSET`, `to_lower_MYSET`, and so on. These correspond to the arrays for a simple character set. See Section 10.13.1, "Character Definition Arrays".
- For each `<collation>` element listed in the `<charset>` element for the character set in `Index.xml`, the `ctype-MYSET.c` file must provide an implementation of the collation.
- If the character set requires string collating functions, see Section 10.13.2, “String Collating Support for Complex Character Sets”.
- If the character set requires multibyte character support, see Section 10.13.3, “Multi-Byte Character Support for Complex Character Sets”.

3. Modify the configuration information. Use the existing configuration information as a guide to adding information for `MYSYS`. The example here assumes that the character set has default and binary collations, but more lines are needed if `MYSET` has additional collations.
   a. Edit `mysys/charset-def.c`, and “register” the collations for the new character set.
      Add these lines to the "declaration" section:

```c
#ifdef HAVE_CHARSET_MYSET
extern CHARSET_INFO my_charset_MYSET_general_ci;
extern CHARSET_INFO my_charset_MYSET_bin;
#endif
```

Add these lines to the "registration" section:

```c
#ifdef HAVE_CHARSET_MYSET
    add_compiled_collation(&my_charset_MYSET_general_ci);
    add_compiled_collation(&my_charset_MYSET_bin);
#endif
```

b. If the character set uses `ctype-MYSET.c`, edit `strings/CMakeLists.txt` and add `ctype-MYSET.c` to the definition of the `STRINGS_SOURCES` variable.

c. Edit `cmake/character_sets.cmake`:
   i. Add `MYSET` to the value of with `CHARSETS_AVAILABLE` in alphabetic order.
   ii. Add `MYSET` to the value of `CHARSETS_COMPLEX` in alphabetic order. This is needed even for simple character sets, or `CMake` will not recognize `DDEFAULT_CHARSET=MYSET`.

4. Reconfigure, recompile, and test.
10.13.1 Character Definition Arrays

Each simple character set has a configuration file located in the sql/share/charsets directory. For a character set named MYSYS, the file is named MYSET.xml. It uses <map> array elements to list character set properties. <map> elements appear within these elements:

- <ctype> defines attributes for each character.
- <lower> and <upper> list the lowercase and uppercase characters.
- <unicode> maps 8-bit character values to Unicode values.
- <collation> elements indicate character ordering for comparison and sorting, one element per collation. Binary collations need no <map> element because the character codes themselves provide the ordering.

For a complex character set as implemented in a ctype-MYSET.c file in the strings directory, there are corresponding arrays: ctype_MYSET[], to_lower_MYSET[], and so forth. Not every complex character set has all of the arrays. See also the existing ctype-*.*.c files for examples. See the CHARSET_INFO.txt file in the strings directory for additional information.

Most of the arrays are indexed by character value and have 256 elements. The <ctype> array is indexed by character value + 1 and has 257 elements. This is a legacy convention for handling EOF.

<ctype> array elements are bit values. Each element describes the attributes of a single character in the character set. Each attribute is associated with a bitmask, as defined in include/m_ctype.h:

```c
#define _MY_U   01      /* Upper case */
#define _MY_L   02      /* Lower case */
#define _MY_NMR 04      /* Numeral (digit) */
#define _MY_SPC 010     /* Spacing character */
#define _MY_PNT 020     /* Punctuation */
#define _MY_CTR 040     /* Control character */
#define _MY_B   0100    /* Blank */
#define _MY_X   0200    /* heXadecimal digit */
```

The <ctype> value for a given character should be the union of the applicable bitmask values that describe the character. For example, 'A' is an uppercase character (_MY_U) as well as a hexadecimal digit (_MY_X), so its ctype value should be defined like this:

```c
cctype['A'+1] = _MY_U | _MY_X = 01 | 0200 = 0201
```

The bitmask values in m_ctype.h are octal values, but the elements of the <ctype> array in MYSET.xml should be written as hexadecimal values.

The <lower> and <upper> arrays hold the lowercase and uppercase characters corresponding to each member of the character set. For example:

```c
lower['A'] should contain 'a'
upper['a'] should contain 'A'
```

Each <collation> array indicates how characters should be ordered for comparison and sorting purposes. MySQL sorts characters based on the values of this information. In some cases, this is the same as the <upper> array, which means that sorting is case-insensitive. For more complicated sorting rules (for complex character sets), see the discussion of string collating in Section 10.13.2, “String Collating Support for Complex Character Sets”.

10.13.2 String Collating Support for Complex Character Sets
For a simple character set named *MYSET*, sorting rules are specified in the *MYSET.xml* configuration file using `<map>` array elements within `<collation>` elements. If the sorting rules for your language are too complex to be handled with simple arrays, you must define string collating functions in the *ctype-MYSET.c* source file in the *strings* directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the *ctype-* files in the *strings* directory, such as the files for the *big5*, *czech*, *gbk*, *sjis*, and *tis160* character sets. Take a look at the *MY_COLLATION_HANDLER* structures to see how they are used. See also the *CHARSET_INFO.txt* file in the *strings* directory for additional information.

### 10.13.3 Multi-Byte Character Support for Complex Character Sets

If you want to add support for a new character set named *MYSET* that includes multibyte characters, you must use multibyte character functions in the *ctype-MYSET.c* source file in the *strings* directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the *ctype-* files in the *strings* directory, such as the files for the *euc_kr*, *gb2312*, *gbk*, *sjis*, and *ujis* character sets. Take a look at the *MY_CHARSET_HANDLER* structures to see how they are used. See also the *CHARSET_INFO.txt* file in the *strings* directory for additional information.

### 10.14 Adding a Collation to a Character Set

A collation is a set of rules that defines how to compare and sort character strings. Each collation in MySQL belongs to a single character set. Every character set has at least one collation, and most have two or more collations.

A collation orders characters based on weights. Each character in a character set maps to a weight. Characters with equal weights compare as equal, and characters with unequal weights compare according to the relative magnitude of their weights.

MySQL supports several collation implementations, as discussed in Section 10.14.1, “Collation Implementation Types”. Some of these can be added to MySQL without recompiling:

- Simple collations for 8-bit character sets.
- UCA-based collations for Unicode character sets.
- Binary (*xxx_bin*) collations.

The following sections describe how to add collations of the first two types to existing character sets. All existing character sets already have a binary collation, so there is no need here to describe how to add one.

Summary of the procedure for adding a new collation:

1. Choose a collation ID.
2. Add configuration information that names the collation and describes the character-ordering rules.
3. Restart the server.
4. Verify that the collation is present.
The instructions here cover only collations that can be added without recompiling MySQL. To add a collation that does require recompiling (as implemented by means of functions in a C source file), use the instructions in Section 10.13, “Adding a Character Set”. However, instead of adding all the information required for a complete character set, just modify the appropriate files for an existing character set. That is, based on what is already present for the character set’s current collations, add data structures, functions, and configuration information for the new collation.

Note

If you modify an existing collation, that may affect the ordering of rows for indexes on columns that use the collation. In this case, rebuild any such indexes to avoid problems such as incorrect query results. See Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”.

Additional Resources

• The Unicode Collation Algorithm (UCA) specification: http://www.unicode.org/reports/tr10/

• The Locale Data Markup Language (LDML) specification: http://www.unicode.org/reports/tr35/

10.14.1 Collation Implementation Types

MySQL implements several types of collations:

Simple collations for 8-bit character sets

This kind of collation is implemented using an array of 256 weights that defines a one-to-one mapping from character codes to weights. latin1_swedish_ci is an example. It is a case-insensitive collation, so the uppercase and lowercase versions of a character have the same weights and they compare as equal.

```
mysql> SET NAMES 'latin1' COLLATE 'latin1_swedish_ci';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT 'a' = 'A';
+-----------+
| 'a' = 'A' |
+-----------+
| 1         |
+-----------+
1 row in set (0.00 sec)
```

For implementation instructions, see Section 10.14.3, “Adding a Simple Collation to an 8-Bit Character Set”.

Complex collations for 8-bit character sets

This kind of collation is implemented using functions in a C source file that define how to order characters, as described in Section 10.13, “Adding a Character Set”.

Collations for non-Unicode multibyte character sets

For this type of collation, 8-bit (single-byte) and multibyte characters are handled differently. For 8-bit characters, character codes map to weights in case-insensitive fashion. (For example, the single-byte characters ‘a’ and ‘A’ both have a weight of 0x41.) For multibyte characters, there are two types of relationship between character codes and weights:

• Weights equal character codes. sjis_japanese_ci is an example of this kind of collation. The multibyte character ‘ぞ’ has a character code of 0x82C0, and the weight is also 0x82C0.
Choosing a Collation ID

- Character codes map one-to-one to weights, but a code is not necessarily equal to the weight. `gbk_chinese_ci` is an example of this kind of collation. The multibyte character '膰' has a character code of `0x81B0` but a weight of `0xC286`.

For implementation instructions, see Section 10.13, “Adding a Character Set”.

Collations for Unicode multibyte character sets

Some of these collations are based on the Unicode Collation Algorithm (UCA), others are not.

Non-UCA collations have a one-to-one mapping from character code to weight. In MySQL, such collations are case-insensitive and accent-insensitive. `utf8_general_ci` is an example: 'a', 'A', 'À', and 'á' each have different character codes but all have a weight of `0x0041` and compare as equal.

```sql
mysql> SET NAMES 'utf8' COLLATE 'utf8_general_ci';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT 'a' = 'A', 'a' = 'À', 'a' = 'á';
+-----------+-----------+-----------+
<table>
<thead>
<tr>
<th>'a' = 'A'</th>
<th>'a' = 'À'</th>
<th>'a' = 'á'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
+-----------+-----------+-----------+
1 row in set (0.06 sec)
```

UCA-based collations in MySQL have these properties:

- If a character has weights, each weight uses 2 bytes (16 bits).
- A character may have zero weights (or an empty weight). In this case, the character is ignorable. Example: "U+0000 NULL" does not have a weight and is ignorable.
- A character may have one weight. Example: 'a' has a weight of `0x0E33`.
- A character may have many weights. This is an expansion. Example: The German letter 'ß' has a weight of `0x0FEA0FEA`.
- Many characters may have one weight. This is a contraction. Example: 'ch' is a single letter in Czech and has a weight of `0x0EE2`.

A many-characters-to-many-weights mapping is also possible (this is contraction with expansion), but is not supported by MySQL.

For implementation instructions, for a non-UCA collation, see Section 10.13, “Adding a Character Set”. For a UCA collation, see Section 10.14.4, “Adding a UCA Collation to a Unicode Character Set”.

Miscellaneous collations

There are also a few collations that do not fall into any of the previous categories.

### 10.14.2 Choosing a Collation ID

Each collation must have a unique ID. To add a collation, you must choose an ID value that is not currently used. The range of IDs from 1024 to 2047 is reserved for user-defined collations. Before MySQL 5.5, an ID must be chosen from the range 1 to 254. As of MySQL 5.5, the 254 limit is removed for MyISAM tables with the introduction of support for two-byte collation IDs. Two-byte collation ID support for InnoDB tables is not added until MySQL 5.6.

The collation ID that you choose will appear in these contexts:

- The **ID** column of the **INFORMATION_SCHEMA.COLLATIONS** table.
• The \texttt{Id} column of \texttt{SHOW COLLATION} output.

• The \texttt{charsetnr} member of the \texttt{MYSQL\_FIELD} C API data structure.

• The \texttt{number} member of the \texttt{MY\_CHARSET\_INFO} data structure returned by the \texttt{mysql\_get\_character\_set\_info()} C API function.

To determine the largest currently used ID, issue the following statement:

```sql
mysql> SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
```

<table>
<thead>
<tr>
<th>MAX(ID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
</tr>
</tbody>
</table>

To display a list of all currently used IDs, issue this statement:

```sql
mysql> SELECT ID FROM INFORMATION_SCHEMA.COLLATIONS ORDER BY ID;
```

<table>
<thead>
<tr>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>52</td>
</tr>
<tr>
<td>53</td>
</tr>
<tr>
<td>57</td>
</tr>
<tr>
<td>58</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>98</td>
</tr>
<tr>
<td>99</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>129</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>210</td>
</tr>
</tbody>
</table>

Warning

Before upgrading, you should save the configuration files that you change. If you upgrade in place, the process will replace the your modified files.

10.14.3 Adding a Simple Collation to an 8-Bit Character Set

This section describes how to add a simple collation for an 8-bit character set by writing the \texttt{<collation>} elements associated with a \texttt{<charset>} character set description in the MySQL \texttt{Index.xml} file. The procedure described here does not require recompiling MySQL. The example adds a collation named \texttt{latin1\_test\_ci} to the \texttt{latin1} character set.

1. Choose a collation ID, as shown in Section 10.14.2, “Choosing a Collation ID”. The following steps use an ID of 1024.

2. Modify the \texttt{Index.xml} and \texttt{latin1.xml} configuration files. These files are located in the directory named by the \texttt{character\_sets\_dir} system variable. You can check the variable value as follows, although the path name might be different on your system:

```sql
mysql> SHOW VARIABLES LIKE 'character\_sets\_dir';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>character_sets_dir</td>
<td>/user/local/mysql/share/mysql/charsets/</td>
</tr>
</tbody>
</table>

1145
3. Choose a name for the collation and list it in the `Index.xml` file. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. For example:

```xml
<charset name="latin1">
  ...
  <collation name="latin1_test_ci" id="1024"/>
  ...
</charset>
```

4. In the `latin1.xml` configuration file, add a `<collation>` element that names the collation and that contains a `<map>` element that defines a character code-to-weight mapping table for character codes 0 to 255. Each value within the `<map>` element must be a number in hexadecimal format.

```xml
<collation name="latin1_test_ci">
  <map>
  00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
  10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
  20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
  30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
  40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
  50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
  60 61 62 63 64 65 66 67 68 69 6A 6B 6C 6D 6E 6F
  70 71 72 73 74 75 76 77 78 79 7A 7B 7C 7D 7E 7F
  80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
  90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
  A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
  B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
  41 41 41 41 4B 4D 4D 4D 4D 4D 4D 4D 4D 4D 4D 4D
  44 4E 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F
  41 41 41 41 4B 4D 4D 4D 4D 4D 4D 4D 4D 4D 4D 4D
  44 4E 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F
  </map>
</collation>
```

5. Restart the server and use this statement to verify that the collation is present:

```sql
mysql> SHOW COLLATION WHERE Collation = 'latin1_test_ci';
+----------------+---------+------+---------+----------+---------+
| Collation       | Charset | Id   | Default | Compiled | Sortlen |
|----------------+---------+------+---------+----------+---------+
| latin1_test_ci | latin1  | 1024 |         |          |       1 |
+----------------+---------+------+---------+----------+---------+
```

### 10.14.4 Adding a UCA Collation to a Unicode Character Set

This section describes how to add a UCA collation for a Unicode character set by writing the `<collation>` element within a `<charset>` character set description in the MySQL `Index.xml` file. The procedure described here does not require recompiling MySQL. It uses a subset of the Locale Data Markup Language (LDML) specification, which is available at [http://www.unicode.org/reports/tr35/](http://www.unicode.org/reports/tr35/). With this method, you need not define the entire collation. Instead, you begin with an existing “base” collation and describe the new collation in terms of how it differs from the base collation. The following table lists the base collations of the Unicode character sets for which UCA collations can be defined.

<table>
<thead>
<tr>
<th>Character Set</th>
<th>Base Collation</th>
</tr>
</thead>
<tbody>
<tr>
<td>utf8</td>
<td>utf8_unicode_ci</td>
</tr>
<tr>
<td>ucs2</td>
<td>ucs2_unicode_ci</td>
</tr>
</tbody>
</table>
The following sections show how to add a collation that is defined using LDML syntax, and provide a summary of LDML rules supported in MySQL.

10.14.4.1 Defining a UCA Collation Using LDML Syntax

To add a UCA collation for a Unicode character set without recompiling MySQL, use the following procedure. If you are unfamiliar with the LDML rules used to describe the collation's sort characteristics, see Section 10.14.4.2, “LDML Syntax Supported in MySQL”.

The example adds a collation named `utf8_phone_ci` to the `utf8` character set. The collation is designed for a scenario involving a Web application for which users post their names and phone numbers. Phone numbers can be given in very different formats:

```
+7-12345-67
+7-12-345-67
+7 12 345 67
+7 (12) 345 67
+71234567
```

The problem raised by dealing with these kinds of values is that the varying permissible formats make searching for a specific phone number very difficult. The solution is to define a new collation that reorders punctuation characters, making them ignorable.

1. Choose a collation ID, as shown in Section 10.14.2, “Choosing a Collation ID”. The following steps use an ID of 1029.

2. To modify the `Index.xml` configuration file. This file is located in the directory named by the `character_sets_dir` system variable. You can check the variable value as follows, although the path name might be different on your system:

```
mysql> SHOW VARIABLES LIKE 'character_sets_dir';
+--------------------+-----------------------------------------+
| Variable_name      | Value                                   |
+--------------------+-----------------------------------------+
| character_sets_dir | /user/local/mysql/share/mysql/charsets/ |
+--------------------+-----------------------------------------+
```

3. Choose a name for the collation and list it in the `Index.xml` file. In addition, you'll need to provide the collation ordering rules. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. Within the `<collation>` element, provide a `<rules>` element containing the ordering rules:

```
<charset name="utf8">...
  <collation name="utf8_phone_ci" id="1029">
    <rules>
      <reset> </reset>
      <i> </i> <!-- space -->
      <i>(</i> <!-- left parenthesis -->
      <i>)</i> <!-- right parenthesis -->
      <i>+</i> <!-- plus -->
      <i>-</i> <!-- hyphen -->
    </rules>
  </collation>
...</charset>
```
4. If you want a similar collation for other Unicode character sets, add other `<collation>` elements. For example, to define `ucs2_phone_ci`, add a `<collation>` element to the `<charset name="ucs2">` element. Remember that each collation must have its own unique ID.

5. Restart the server and use this statement to verify that the collation is present:

   ```sql
   mysql> SHOW COLLATION WHERE Collation = 'utf8_phone_ci';
   +---------------+---------+------+---------+----------+---------+
   | Collation     | Charset | Id   | Default | Compiled | Sortlen |
   +---------------+---------+------+---------+----------+---------+
   | utf8_phone_ci | utf8    | 1029 |         |          |       8 |
   +---------------+---------+------+---------+----------+---------+
   ```

Now test the collation to make sure that it has the desired properties.

Create a table containing some sample phone numbers using the new collation:

   ```sql
   mysql> CREATE TABLE phonebook (name VARCHAR(64), phone VARCHAR(64) CHARACTER SET utf8 COLLATE utf8_phone_ci);
   Query OK, 0 rows affected (0.09 sec)
   mysql> INSERT INTO phonebook VALUES ('Svoj','+7 912 800 80 02');
   Query OK, 1 row affected (0.00 sec)
   mysql> INSERT INTO phonebook VALUES ('Hf','+7 (912) 800 80 04');
   Query OK, 1 row affected (0.00 sec)
   mysql> INSERT INTO phonebook VALUES ('Bar','+7-912-800-80-01');
   Query OK, 1 row affected (0.00 sec)
   mysql> INSERT INTO phonebook VALUES ('Ramil','(7912) 800 80 03');
   Query OK, 1 row affected (0.00 sec)
   mysql> INSERT INTO phonebook VALUES ('Sanja','+380 (912) 8008005');
   Query OK, 1 row affected (0.00 sec)
   ```

Run some queries to see whether the ignored punctuation characters are in fact ignored for comparison and sorting:

   ```sql
   mysql> SELECT * FROM phonebook ORDER BY phone;
   +------+------------------+
   | name | phone            |
   +------+------------------+
   | Sanja| +380 (912) 8008005|
   | Bar  | +7-912-800-80-01 |
   | Svoj | +7 912 800 80 02 |
   | Ramil| (7912) 800 80 03 |
   | Hf   | +7 (912) 800 80 04|
   +------+------------------+
   5 rows in set (0.00 sec)
   mysql> SELECT * FROM phonebook WHERE phone='+7(912)800-80-01';
   +------+------------------+
   | name | phone            |
   +------+------------------+
   | Bar  | +7-912-800-80-01 |
   +------+------------------+
   1 row in set (0.00 sec)
   mysql> SELECT * FROM phonebook WHERE phone='79128008001';
   +------+------------------+
   | name | phone            |
   +------+------------------+
10.14.4.2 LDML Syntax Supported in MySQL

This section describes the LDML syntax that MySQL recognizes. This is a subset of the syntax described in the LDML specification available at http://www.unicode.org/reports/tr35/, which should be consulted for further information. The rules described here are all supported except that character sorting occurs only at the primary level. Rules that specify differences at secondary or higher sort levels are recognized (and thus can be included in collation definitions) but are treated as equality at the primary level.

Character Representation

Characters named in LDML rules can be written in \unnnn format, where nnnn is the hexadecimal Unicode code point value. Within hexadecimal values, the digits A through F are not case-sensitive; \u00E1 and \u00e1 are equivalent. Basic Latin letters A–Z and a–z can also be written literally (this is a MySQL limitation; the LDML specification permits literal non-Latin1 characters in the rules). Only characters in the Basic Multilingual Plane can be specified. This notation does not apply to characters outside the BMP range of 0000 to FFFF.

The Index.xml file itself should be written using ASCII encoding.

Syntax Rules

LDML has reset rules and shift rules to specify character ordering. Orderings are given as a set of rules that begin with a reset rule that establishes an anchor point, followed by shift rules that indicate how characters sort relative to the anchor point.

- A <reset> rule does not specify any ordering in and of itself. Instead, it “resets” the ordering for subsequent shift rules to cause them to be taken in relation to a given character. Either of the following rules resets subsequent shift rules to be taken in relation to the letter 'A':

  <reset>A</reset>
  <reset>A</reset>

- The <p>, <s>, and <t> shift rules define primary, secondary, and tertiary differences of a character from another character:
  - Use primary differences to distinguish separate letters.
  - Use secondary differences to distinguish accent variations.
  - Use tertiary differences to distinguish lettercase variations.

  Either of these rules specifies a primary shift rule for the 'G' character:

  <p>G</p>
  <p>G</p>
10.15 Character Set Configuration

The MySQL server has a compiled-in default character set and collation. To change these defaults, use the `--character-set-server` and `--collation-server` options when you start the server. See Section 5.1.6, "Server Command Options". The collation must be a legal collation for the default character set. To determine which collations are available for each character set, use the `SHOW COLLATION` statement or query the `INFORMATION_SCHEMA` COLLATIONS table.

If you try to use a character set that is not compiled into your binary, you might run into the following problems:

- If your program uses an incorrect path to determine where the character sets are stored (which is typically the `share/mysql/charsets` or `share/charsets` directory under the MySQL installation directory), this can be fixed by using the `--character-sets-dir` option when you run the program. For example, to specify a directory to be used by MySQL client programs, list it in the `[client]` group of your option file. The examples given here show what the setting might look like for Unix or Windows, respectively:

  [client]
  character-sets-dir=/usr/local/mysql/share/mysql/charsets

  [client]
  character-sets-dir="C:/Program Files/MySQL/MySQL Server 5.5/share/charsets"

- If the character set is a complex character set that cannot be loaded dynamically, you must recompile the program with support for the character set.

  For Unicode character sets, you can define collations without recompiling by using LDML notation. See Section 10.14.4, "Adding a UCA Collation to a Unicode Character Set".

- If the character set is a dynamic character set, but you do not have a configuration file for it, you should install the configuration file for the character set from a new MySQL distribution.

- If your character set index file (`Index.xml`) does not contain the name for the character set, your program displays an error message:

  Character set 'charset_name' is not a compiled character set and is not specified in the '/usr/share/mysql/charsets/Index.xml' file

  To solve this problem, you should either get a new index file or manually add the name of any missing character sets to the current file.

You can force client programs to use specific character set as follows:

```
[client]
default-character-set=charset_name
```

This is normally unnecessary. However, when `character_set_system` differs from `character_set_server` or `character_set_client`, and you input characters manually (as database object identifiers, column values, or both), these may be displayed incorrectly in output from the client or the output itself may be formatted incorrectly. In such cases, starting the mysql client with `--default-character-set-system_character_set`—that is, setting the client character set to match the system character set—should fix the problem.
10.16 MySQL Server Locale Support

The locale indicated by the `lc_time_names` system variable controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()`, and `MONTHNAME()` functions.

`lc_time_names` does not affect the `STR_TO_DATE()` or `GET_FORMAT()` function.

The `lc_time_names` value does not affect the result from `FORMAT()`, but this function takes an optional third parameter that enables a locale to be specified to be used for the result number's decimal point, thousands separator, and grouping between separators. Permissible locale values are the same as the legal values for the `lc_time_names` system variable.

Locale names have language and region subtags listed by IANA (http://www.iana.org/assignments/language-subtag-registry) such as 'ja_JP' or 'pt_BR'. The default value is 'en_US' regardless of your system's locale setting, but you can set the value at server startup, or set the `GLOBAL` value at runtime if you have privileges sufficient to set global system variables; see Section 5.1.8.1, "System Variable Privileges". Any client can examine the value of `lc_time_names` or set its `SESSION` value to affect the locale for its own connection.

```sql
mysql> SET NAMES 'utf8';
Query OK, 0 rows affected (0.09 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
+-----------------+
| en_US           |
+-----------------+
1 row in set (0.00 sec)

mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+-----------------------+-------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
| Friday                | January                 |
+-----------------------+-------------------------+
1 row in set (0.00 sec)

mysql> SELECT DATE_FORMAT('2010-01-01','%W %a %M %b');
+-----------------------------------------+
| DATE_FORMAT('2010-01-01','%W %a %M %b') |
| Friday Fri January Jan                  |
+-----------------------------------------+
1 row in set (0.00 sec)

mysql> SET lc_time_names = 'es_MX';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
|-----------------+
| es_MX           |
|-----------------+
1 row in set (0.00 sec)

mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+-----------------------+-------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
| viernes               | enero                   |
+-----------------------+-------------------------+
1151
The day or month name for each of the affected functions is converted from utf8 to the character set indicated by the character_set_connection system variable.

**lc_time_names** may be set to any of the following locale values. The set of locales supported by MySQL may differ from those supported by your operating system.

<table>
<thead>
<tr>
<th>Locale Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ar_AE</td>
<td>Arabic - United Arab Emirates</td>
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<tr>
<td>ar_BH</td>
<td>Arabic - Bahrain</td>
</tr>
<tr>
<td>ar_DZ</td>
<td>Arabic - Algeria</td>
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<td>Arabic - Qatar</td>
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<td>Arabic - Saudi Arabia</td>
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<td>ar_SD</td>
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1152
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<td>el_GR</td>
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</table>
Chapter 11 Data Types

Table of Contents

11.1 Numeric Data Types .............................................................................................................. 1158
  11.1.1 Numeric Data Type Syntax ......................................................................................... 1158
  11.1.2 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT ................................................................. 1162
  11.1.3 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC ........................................ 1162
  11.1.4 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE ............................... 1163
  11.1.5 Bit-Value Type - BIT ................................................................................................. 1163
  11.1.6 Numeric Type Attributes ......................................................................................... 1163
  11.1.7 Out-of-Range and Overflow Handling ...................................................................... 1164

11.2 Date and Time Data Types ................................................................................................. 1166
  11.2.1 Date and Time Data Type Syntax ............................................................................. 1167
  11.2.2 The DATE, DATETIME, and TIMESTAMP Types ..................................................... 1169
  11.2.3 The TIME Type .......................................................................................................... 1170
  11.2.4 The YEAR Type ......................................................................................................... 1171
  11.2.5 2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR ................................. 1171
  11.2.6 Automatic Initialization and Updating for TIMESTAMP ........................................ 1173
  11.2.7 Fractional Seconds in Time Values ........................................................................... 1176
  11.2.8 Conversion Between Date and Time Types ............................................................. 1176
  11.2.9 2-Digit Years in Dates .............................................................................................. 1177

11.3 String Data Types ................................................................................................................ 1178
  11.3.1 String Data Type Syntax ......................................................................................... 1178
  11.3.2 The CHAR and VARCHAR Types .............................................................................. 1181
  11.3.3 The BINARY and VARBINARY Types ..................................................................... 1183
  11.3.4 The BLOB and TEXT Types ..................................................................................... 1184
  11.3.5 The ENUM Type ...................................................................................................... 1186
  11.3.6 The SET Type .......................................................................................................... 1189

11.4 Spatial Data Types .............................................................................................................. 1191
  11.4.1 Spatial Data Types .................................................................................................... 1193
  11.4.2 The OpenGIS Geometry Model .............................................................................. 1194
  11.4.3 Supported Spatial Data Formats ............................................................................. 1200
  11.4.4 Creating Spatial Columns ....................................................................................... 1202
  11.4.5 Populating Spatial Columns ..................................................................................... 1203
  11.4.6 Fetching Spatial Data ............................................................................................... 1204
  11.4.7 Optimizing Spatial Analysis .................................................................................... 1204
  11.4.8 Creating Spatial Indexes ......................................................................................... 1204
  11.4.9 Using Spatial Indexes .............................................................................................. 1205

11.5 Data Type Default Values .................................................................................................. 1207

11.6 Data Type Storage Requirements ...................................................................................... 1209

11.7 Choosing the Right Type for a Column ............................................................................. 1213

11.8 Using Data Types from Other Database Engines ............................................................. 1213

MySQL supports SQL data types in several categories: numeric types, date and time types, string (character and byte) types, and spatial types. This chapter provides an overview and more detailed description of the properties of the types in each category, and a summary of the data type storage requirements. The initial overviews are intentionally brief. Consult the more detailed descriptions for additional information about particular data types, such as the permissible formats in which you can specify values.
Data type descriptions use these conventions:

- For integer types, $M$ indicates the maximum display width. For floating-point and fixed-point types, $M$ is the total number of digits that can be stored (the precision). For string types, $M$ is the maximum length. The maximum permissible value of $M$ depends on the data type.

- $D$ applies to floating-point and fixed-point types and indicates the number of digits following the decimal point (the scale). The maximum possible value is 30, but should be no greater than $M-2$.

- Square brackets ([ and ]) indicate optional parts of type definitions.

### 11.1 Numeric Data Types

MySQL supports all standard SQL numeric data types. These types include the exact numeric data types (`INTEGER`, `SMALLINT`, `DECIMAL`, and `NUMERIC`), as well as the approximate numeric data types (`FLOAT`, `REAL`, and `DOUBLE PRECISION`). The keyword `INT` is a synonym for `INTEGER`, and the keywords `DEC` and `FIXED` are synonyms for `DECIMAL`. MySQL treats `DOUBLE` as a synonym for `DOUBLE PRECISION` (a nonstandard extension). MySQL also treats `REAL` as a synonym for `DOUBLE PRECISION` (a nonstandard variation), unless the `REAL_AS_FLOAT` SQL mode is enabled.

The `BIT` data type stores bit values and is supported for `MyISAM`, `MEMORY`, `InnoDB`, and `NDBCLUSTER` tables.

For information about how MySQL handles assignment of out-of-range values to columns and overflow during expression evaluation, see Section 11.1.7, “Out-of-Range and Overflow Handling”.

For information about storage requirements of the numeric data types, see Section 11.6, “Data Type Storage Requirements”.

For descriptions of functions that operate on numeric values, see Section 12.5, “Numeric Functions and Operators”. The data type used for the result of a calculation on numeric operands depends on the types of the operands and the operations performed on them. For more information, see Section 12.5.1, “Arithmetic Operators”.

### 11.1.1 Numeric Data Type Syntax

For integer data types, $M$ indicates the maximum display width. The maximum display width is 255. Display width is unrelated to the range of values a type can store, as described in Section 11.1.6, “Numeric Type Attributes”.

For floating-point and fixed-point data types, $M$ is the total number of digits that can be stored.

If you specify `ZEROFILL` for a numeric column, MySQL automatically adds the `UNSIGNED` attribute to the column.

Numeric data types that permit the `UNSIGNED` attribute also permit `SIGNED`. However, these data types are signed by default, so the `SIGNED` attribute has no effect.

`SERIAL` is an alias for `BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE`.

`SERIAL DEFAULT VALUE` in the definition of an integer column is an alias for `NOT NULL AUTO_INCREMENT UNIQUE`.

**Warning**

When you use subtraction between integer values where one is of type `UNSIGNED`, the result is unsigned unless the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled. See Section 12.10, “Cast Functions and Operators”.
Numeric Data Type Syntax

- **BIT[\(M\)]**
  
  A bit-value type. \(M\) indicates the number of bits per value, from 1 to 64. The default is 1 if \(M\) is omitted.

- **TINYINT[\(M\)] [UNSIGNED] [ZEROFILL]**
  
  A very small integer. The signed range is \(-128\) to \(127\). The unsigned range is 0 to 255.

- **BOOL, BOOLEAN**
  
  These types are synonyms for TINYINT(1). A value of zero is considered false. Nonzero values are considered true:

  ```
  mysql> SELECT IF(0, 'true', 'false');
  +------------------------+
  | IF(0, 'true', 'false') |
  +------------------------+
  | false                  |
  +------------------------+
  mysql> SELECT IF(1, 'true', 'false');
  +------------------------+
  | IF(1, 'true', 'false') |
  +------------------------+
  | true                   |
  +------------------------+
  mysql> SELECT IF(2, 'true', 'false');
  +------------------------+
  | IF(2, 'true', 'false') |
  +------------------------+
  | true                   |
  +------------------------+
  
  However, the values TRUE and FALSE are merely aliases for 1 and 0, respectively, as shown here:

  ```
  mysql> SELECT IF(0 = FALSE, 'true', 'false');
  +--------------------------------+
  | IF(0 = FALSE, 'true', 'false') |
  +--------------------------------+
  | true                           |
  +--------------------------------+
  mysql> SELECT IF(1 = TRUE, 'true', 'false');
  +-------------------------------+
  | IF(1 = TRUE, 'true', 'false') |
  +-------------------------------+
  | true                          |
  +-------------------------------+
  mysql> SELECT IF(2 = TRUE, 'true', 'false');
  +-------------------------------+
  | IF(2 = TRUE, 'true', 'false') |
  +-------------------------------+
  | false                         |
  +-------------------------------+
  mysql> SELECT IF(2 = FALSE, 'true', 'false');
  +--------------------------------+
  | IF(2 = FALSE, 'true', 'false') |
  +--------------------------------+
  | false                         |
  +--------------------------------+
  
  The last two statements display the results shown because 2 is equal to neither 1 nor 0.
**Numeric Data Type Syntax**

- **SMALLINT[ (M) ] [UNSIGNED] [ZEROFILL]**
  A small integer. The signed range is $-32768$ to $32767$. The unsigned range is 0 to $65535$.

- **MEDIUMINT[ (M) ] [UNSIGNED] [ZEROFILL]**
  A medium-sized integer. The signed range is $-8388608$ to $8388607$. The unsigned range is 0 to $16777215$.

- **INT[ (M) ] [UNSIGNED] [ZEROFILL]**
  A normal-size integer. The signed range is $-2147483648$ to $2147483647$. The unsigned range is 0 to $4294967295$.

- **INTEGER[ (M) ] [UNSIGNED] [ZEROFILL]**
  This type is a synonym for **INT**.

- **BIGINT[ (M) ] [UNSIGNED] [ZEROFILL]**
  A large integer. The signed range is $-9223372036854775808$ to $9223372036854775807$. The unsigned range is 0 to $18446744073709551615$.

  **SERIAL** is an alias for **BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE**.

Some things you should be aware of with respect to **BIGINT** columns:

- All arithmetic is done using signed **BIGINT** or **DOUBLE** values, so you should not use unsigned big integers larger than $9223372036854775807$ (63 bits) except with bit functions! If you do that, some of the last digits in the result may be wrong because of rounding errors when converting a **BIGINT** value to a **DOUBLE**.

MySQL can handle **BIGINT** in the following cases:

- When using integers to store large unsigned values in a **BIGINT** column.
- In **MIN( col_name )** or **MAX( col_name )**, where **col_name** refers to a **BIGINT** column.
- When using operators (+, −, *, and so on) where both operands are integers.
- You can always store an exact integer value in a **BIGINT** column by storing it using a string. In this case, MySQL performs a string-to-number conversion that involves no intermediate double-precision representation.
- The −, +, and * operators use **BIGINT** arithmetic when both operands are integer values. This means that if you multiply two big integers (or results from functions that return integers), you may get unexpected results when the result is larger than $9223372036854775807$.

- **DECIMAL[ (M,[D]) ] [UNSIGNED] [ZEROFILL]**
  A packed “exact” fixed-point number. **M** is the total number of digits (the precision) and **D** is the number of digits after the decimal point (the scale). The decimal point and (for negative numbers) the − sign are not counted in **M**. If **D** is 0, values have no decimal point or fractional part. The maximum number of digits (**M**)
Numeric Data Type Syntax

for **DECIMAL** is 65. The maximum number of supported decimals (**d**) is 30. If **d** is omitted, the default is 0. If **m** is omitted, the default is 10.

**UNSIGNED**, if specified, disallows negative values.

All basic calculations (+, -, *, /) with **DECIMAL** columns are done with a precision of 65 digits.

- **DEC([**(m[**d**])**])** [**UNSIGNED**] [**ZEROFILL**], **NUMERIC([**(m[**d**])**])** [**UNSIGNED**] [**ZEROFILL**], **FIXED([**(m[**d**])**])** [**UNSIGNED**] [**ZEROFILL**]

These types are synonyms for **DECIMAL**. The **FIXED** synonym is available for compatibility with other database systems.

- **FLOAT([**(m[**d**])**])** [**UNSIGNED**] [**ZEROFILL**]

A small (single-precision) floating-point number. Permissible values are -3.402823466E+38 to -1.175494351E-38, 0, and 1.175494351E-38 to 3.402823466E+38. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

**FLOAT** (**m**, **d**) is a nonstandard MySQL extension.

**UNSIGNED**, if specified, disallows negative values.

Using **FLOAT** might give you some unexpected problems because all calculations in MySQL are done with double precision. See Section B.4.4.7, “Solving Problems with No Matching Rows”.

- **FLOAT**(p) [**UNSIGNED**] [**ZEROFILL**]

A floating-point number. **p** represents the precision in bits, but MySQL uses this value only to determine whether to use **FLOAT** or **DOUBLE** for the resulting data type. If **p** is from 0 to 24, the data type becomes **FLOAT** with no **M** or **D** values. If **p** is from 25 to 53, the data type becomes **DOUBLE** with no **M** or **D** values. The range of the resulting column is the same as for the single-precision **FLOAT** or double-precision **DOUBLE** data types described earlier in this section.

**FLOAT**(p) syntax is provided for ODBC compatibility.

- **DOUBLE([**(m[**d**])**])** [**UNSIGNED**] [**ZEROFILL**]

A normal-size (double-precision) floating-point number. Permissible values are -1.7976931348623157E+308 to -2.2250738585072014E-308, 0, and 2.2250738585072014E-308 to 1.7976931348623157E+308. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

**DOUBLE** (**m**, **d**) is a nonstandard MySQL extension.

**UNSIGNED**, if specified, disallows negative values.
11.1.2 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT

MySQL supports the SQL standard integer types `INTEGER` (or `INT`) and `SMALLINT`. As an extension to the standard, MySQL also supports the integer types `TINYINT`, `MEDIUMINT`, and `BIGINT`. The following table shows the required storage and range for each integer type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Storage (Bytes)</th>
<th>Minimum Value Signed</th>
<th>Minimum Value Unsigned</th>
<th>Maximum Value Signed</th>
<th>Maximum Value Unsigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>TINYINT</td>
<td>1</td>
<td>-128</td>
<td>0</td>
<td>127</td>
<td>255</td>
</tr>
<tr>
<td>SMALLINT</td>
<td>2</td>
<td>-32768</td>
<td>0</td>
<td>32767</td>
<td>65535</td>
</tr>
<tr>
<td>MEDIUMINT</td>
<td>3</td>
<td>-8388608</td>
<td>0</td>
<td>8388607</td>
<td>16777215</td>
</tr>
<tr>
<td>INT</td>
<td>4</td>
<td>-2147483648</td>
<td>0</td>
<td>2147483647</td>
<td>4294967295</td>
</tr>
<tr>
<td>BIGINT</td>
<td>8</td>
<td>-2^{63}</td>
<td>0</td>
<td>2^{63}–1</td>
<td>2^{64}–1</td>
</tr>
</tbody>
</table>

11.1.3 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC

The `DECIMAL` and `NUMERIC` types store exact numeric data values. These types are used when it is important to preserve exact precision, for example with monetary data. In MySQL, `NUMERIC` is implemented as `DECIMAL`, so the following remarks about `DECIMAL` apply equally to `NUMERIC`.

MySQL stores `DECIMAL` values in binary format. See Section 12.19, “Precision Math”.

In a `DECIMAL` column declaration, the precision and scale can be (and usually is) specified. For example:

```sql
salary DECIMAL(5,2)
```

In this example, 5 is the precision and 2 is the scale. The precision represents the number of significant digits that are stored for values, and the scale represents the number of digits that can be stored following the decimal point.

Standard SQL requires that `DECIMAL(5,2)` be able to store any value with five digits and two decimals, so values that can be stored in the `salary` column range from -999.99 to 999.99.

In standard SQL, the syntax `DECIMAL(M)` is equivalent to `DECIMAL(M, 0)`. Similarly, the syntax `DECIMAL` is equivalent to `DECIMAL(M, 0)`, where the implementation is permitted to decide the value of \( M \). MySQL supports both of these variant forms of `DECIMAL` syntax. The default value of \( M \) is 10.

If the scale is 0, `DECIMAL` values contain no decimal point or fractional part.

The maximum number of digits for `DECIMAL` is 65, but the actual range for a given `DECIMAL` column can be constrained by the precision or scale for a given column. When such a column is assigned a value with
Floating-Point Types (Approximate Value) - FLOAT, DOUBLE

more digits following the decimal point than are permitted by the specified scale, the value is converted to that scale. (The precise behavior is operating system-specific, but generally the effect is truncation to the permissible number of digits.)

11.1.4 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE

The FLOAT and DOUBLE types represent approximate numeric data values. MySQL uses four bytes for single-precision values and eight bytes for double-precision values.

For FLOAT, the SQL standard permits an optional specification of the precision (but not the range of the exponent) in bits following the keyword FLOAT in parentheses; that is, FLOAT(p). MySQL also supports this optional precision specification, but the precision value in FLOAT(p) is used only to determine storage size. A precision from 0 to 23 results in a 4-byte single-precision FLOAT column. A precision from 24 to 53 results in an 8-byte double-precision DOUBLE column.

MySQL permits a nonstandard syntax: FLOAT(M,D) or REAL(M,D) or DOUBLE PRECISION(M,D). Here, (M,D) means than values can be stored with up to M digits in total, of which D digits may be after the decimal point. For example, a column defined as FLOAT(7,4) will look like -999.9999 when displayed. MySQL performs rounding when storing values, so if you insert 999.00009 into a FLOAT(7,4) column, the approximate result is 999.0001.

Because floating-point values are approximate and not stored as exact values, attempts to treat them as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. For more information, see Section B.4.4.8, “Problems with Floating-Point Values”.

For maximum portability, code requiring storage of approximate numeric data values should use FLOAT or DOUBLE PRECISION with no specification of precision or number of digits.

11.1.5 Bit-Value Type - BIT

The BIT data type is used to store bit values. A type of BIT(M) enables storage of M-bit values. M can range from 1 to 64.

To specify bit values, b'value' notation can be used. value is a binary value written using zeros and ones. For example, b'111' and b'10000000' represent 7 and 128, respectively. See Section 9.1.5, “Bit-Value Literals”.

If you assign a value to a BIT(M) column that is less than M bits long, the value is padded on the left with zeros. For example, assigning a value of b'101' to a BIT(6) column is, in effect, the same as assigning b'000101'.

NDB Cluster. The maximum combined size of all BIT columns used in a given NDB table must not exceed 4096 bits.

11.1.6 Numeric Type Attributes

MySQL supports an extension for optionally specifying the display width of integer data types in parentheses following the base keyword for the type. For example, INT(4) specifies an INT with a display width of four digits. This optional display width may be used by applications to display integer values having a width less than the width specified for the column by left-padding them with spaces. (That is, this width is present in the metadata returned with result sets. Whether it is used is up to the application.)

The display width does not constrain the range of values that can be stored in the column. Nor does it prevent values wider than the column display width from being displayed correctly. For example, a column
specified as `SMALLINT(3)` has the usual `SMALLINT` range of \(-32768\) to \(32767\), and values outside the range permitted by three digits are displayed in full using more than three digits.

When used in conjunction with the optional (nonstandard) `ZEROFILL` attribute, the default padding of spaces is replaced with zeros. For example, for a column declared as `INT(4) ZEROFILL`, a value of 5 is retrieved as `0005`.

### Note

The `ZEROFILL` attribute is ignored for columns involved in expressions or `UNION` queries.

If you store values larger than the display width in an integer column that has the `ZEROFILL` attribute, you may experience problems when MySQL generates temporary tables for some complicated joins. In these cases, MySQL assumes that the data values fit within the column display width.

All integer types can have an optional (nonstandard) `UNSIGNED` attribute. An unsigned type can be used to permit only nonnegative numbers in a column or when you need a larger upper numeric range for the column. For example, if an `INT` column is `UNSIGNED`, the size of the column’s range is the same but its endpoints shift up, from \(-2147483648\) and \(2147483647\) to \(0\) and \(4294967295\).

Floating-point and fixed-point types also can be `UNSIGNED`. As with integer types, this attribute prevents negative values from being stored in the column. Unlike the integer types, the upper range of column values remains the same.

If you specify `ZEROFILL` for a numeric column, MySQL automatically adds the `UNSIGNED` attribute.

Integer or floating-point data types can have the `AUTO_INCREMENT` attribute. When you insert a value of `NULL` into an indexed `AUTO_INCREMENT` column, the column is set to the next sequence value. Typically this is `value+1`, where `value` is the largest value for the column currently in the table. ( `AUTO_INCREMENT` sequences begin with 1.)

Storing 0 into an `AUTO_INCREMENT` column has the same effect as storing `NULL`, unless the `NO_AUTO_VALUE_ON_ZERO` SQL mode is enabled.

Inserting `NULL` to generate `AUTO_INCREMENT` values requires that the column be declared `NOT NULL`. If the column is declared `NULL`, inserting `NULL` stores a `NULL`. When you insert any other value into an `AUTO_INCREMENT` column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the inserted value.

As of MySQL 5.5.29, negative values for `AUTO_INCREMENT` columns are not supported.

### 11.1.7 Out-of-Range and Overflow Handling

When MySQL stores a value in a numeric column that is outside the permissible range of the column data type, the result depends on the SQL mode in effect at the time:

- If strict SQL mode is enabled, MySQL rejects the out-of-range value with an error, and the insert fails, in accordance with the SQL standard.

- If no restrictive modes are enabled, MySQL clips the value to the appropriate endpoint of the column data type range and stores the resulting value instead.

When an out-of-range value is assigned to an integer column, MySQL stores the value representing the corresponding endpoint of the column data type range.
When a floating-point or fixed-point column is assigned a value that exceeds the range implied by the specified (or default) precision and scale, MySQL stores the value representing the corresponding endpoint of that range.

Suppose that a table `t1` has this definition:

```
CREATE TABLE t1 (i1 TINYINT, i2 TINYINT UNSIGNED);
```

With strict SQL mode enabled, an out of range error occurs:

```sql
mysql> SET sql_mode = 'TRADITIONAL';
mysql> INSERT INTO t1 (i1, i2) VALUES(256, 256);
ERROR 1264 (22003): Out of range value for column 'i1' at row 1
```

With strict SQL mode not enabled, clipping with warnings occurs:

```sql
mysql> SET sql_mode = '';
mysql> INSERT INTO t1 (i1, i2) VALUES(256, 256);
mysql> SHOW WARNINGS;
+---------+------+---------------------------------------------+
| Level   | Code | Message                                     |
|---------+------|---------------------------------------------|
| Warning | 1264 | Out of range value for column 'i1' at row 1 |
| Warning | 1264 | Out of range value for column 'i2' at row 1 |
+---------+------+---------------------------------------------+
mysql> SELECT * FROM t1;
+------+------+
| i1   | i2   |
| 127  | 255  |
+------+------+
```

When strict SQL mode is not enabled, column-assignment conversions that occur due to clipping are reported as warnings for `ALTER TABLE`, `LOAD DATA`, `UPDATE`, and multiple-row `INSERT` statements. In strict mode, these statements fail, and some or all the values are not inserted or changed, depending on whether the table is a transactional table and other factors. For details, see Section 5.1.10, “Server SQL Modes”.

Overflow during numeric expression evaluation results in an error. For example, the largest signed `BIGINT` value is 9223372036854775807, so the following expression produces an error:

```sql
mysql> SELECT 9223372036854775807 + 1;
ERROR 1690 (22003): BIGINT value is out of range in '(9223372036854775807 + 1)'
```

To enable the operation to succeed in this case, convert the value to unsigned:

```sql
mysql> SELECT CAST(9223372036854775807 AS UNSIGNED) + 1;
+---------------------------+
| CAST(9223372036854775807 AS UNSIGNED) + 1 |
| 9223372036854775808       |
+---------------------------+
```

Whether overflow occurs depends on the range of the operands, so another way to handle the preceding expression is to use exact-value arithmetic because `DECIMAL` values have a larger range than integers:

```sql
mysql> SELECT 9223372036854775807.0 + 1;
+---------------------------+
| 9223372036854775807.0 + 1 |
| 9223372036854775808.0     |
+---------------------------+
```
Date and Time Data Types

Subtraction between integer values, where one is of type UNSIGNED, produces an unsigned result by default. If the result would otherwise have been negative, an error results:

```sql
mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
ERROR 1690 (22003): BIGINT UNSIGNED value is out of range in '(cast(0 as unsigned) - 1)'
```

If the NO_UNSIGNED_SUBTRACTION SQL mode is enabled, the result is negative:

```sql
mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+-------------------------+
<table>
<thead>
<tr>
<th>CAST(0 AS UNSIGNED) - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
</tr>
</tbody>
</table>
+-------------------------+
```

If the result of such an operation is used to update an UNSIGNED integer column, the result is clipped to the maximum value for the column type, or clipped to 0 if NO_UNSIGNED_SUBTRACTION is enabled. If strict SQL mode is enabled, an error occurs and the column remains unchanged.

11.2 Date and Time Data Types

The date and time data types for representing temporal values are DATE, TIME, DATETIME, TIMESTAMP, and YEAR. Each temporal type has a range of valid values, as well as a “zero” value that may be used when you specify an invalid value that MySQL cannot represent. The TIMESTAMP type has special automatic updating behavior, described in Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”.

For information about storage requirements of the temporal data types, see Section 11.6, “Data Type Storage Requirements”.

For descriptions of functions that operate on temporal values, see Section 12.6, “Date and Time Functions”.

Keep in mind these general considerations when working with date and time types:

- MySQL retrieves values for a given date or time type in a standard output format, but it attempts to interpret a variety of formats for input values that you supply (for example, when you specify a value to be assigned to or compared to a date or time type). For a description of the permitted formats for date and time types, see Section 9.1.3, “Date and Time Literals”. It is expected that you supply valid values. Unpredictable results may occur if you use values in other formats.

- Although MySQL tries to interpret values in several formats, date parts must always be given in year-month-day order (for example, '98-09-04'), rather than in the month-day-year or day-month-year orders commonly used elsewhere (for example, '09-04-98', '04-09-98'). To convert strings in other orders to year-month-day order, the STR_TO_DATE() function may be useful.

- Dates containing 2-digit year values are ambiguous because the century is unknown. MySQL interprets 2-digit year values using these rules:
  - Year values in the range 00–69 become 2000–2069.
See also Section 11.2.9, “2-Digit Years in Dates”.

1166
• Conversion of values from one temporal type to another occurs according to the rules in Section 11.2.8, “Conversion Between Date and Time Types”.

• MySQL automatically converts a date or time value to a number if the value is used in numeric context and vice versa.

• By default, when MySQL encounters a value for a date or time type that is out of range or otherwise invalid for the type, it converts the value to the “zero” value for that type. The exception is that out-of-range TIME values are clipped to the appropriate endpoint of the TIME range.

• By setting the SQL mode to the appropriate value, you can specify more exactly what kind of dates you want MySQL to support. (See Section 5.1.10, “Server SQL Modes”.) You can get MySQL to accept certain dates, such as '2009-11-31', by enabling the ALLOW_INVALID_DATES SQL mode. This is useful when you want to store a “possibly wrong” value which the user has specified (for example, in a web form) in the database for future processing. Under this mode, MySQL verifies only that the month is in the range from 1 to 12 and that the day is in the range from 1 to 31.

• MySQL permits you to store dates where the day or month and day are zero in a DATE or DATETIME column. This is useful for applications that need to store birthdates for which you may not know the exact date. In this case, you simply store the date as '2009-00-00' or '2009-01-00'. However, with dates such as these, you should not expect to get correct results for functions such as DATE_SUB() or DATE_ADD() that require complete dates. To disallow zero month or day parts in dates, enable the NO_ZERO_IN_DATE SQL mode.

• MySQL permits you to store a “zero” value of '0000-00-00' as a “dummy date.” In some cases, this is more convenient than using NULL values, and uses less data and index space. To disallow '0000-00-00', enable the NO_ZERO_DATE SQL mode.

• “Zero” date or time values used through Connector/ODBC are converted automatically to NULL because ODBC cannot handle such values.

The following table shows the format of the “zero” value for each type. The “zero” values are special, but you can store or refer to them explicitly using the values shown in the table. You can also do this using the values '0' or 0, which are easier to write. For temporal types that include a date part (DATE, DATETIME, and TIMESTAMP), use of these values may produce warning or errors. The precise behavior depends on which, if any, of the strict and NO_ZERO_DATE SQL modes are enabled; see Section 5.1.10, “Server SQL Modes”.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>“Zero” Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>'0000-00-00'</td>
</tr>
<tr>
<td>TIME</td>
<td>'00:00:00'</td>
</tr>
<tr>
<td>DATETIME</td>
<td>'0000-00-00 00:00:00'</td>
</tr>
<tr>
<td>TIMESTAMP</td>
<td>'0000-00-00 00:00:00'</td>
</tr>
<tr>
<td>YEAR</td>
<td>0000</td>
</tr>
</tbody>
</table>

11.2.1 Date and Time Data Type Syntax

The date and time data types for representing temporal values are DATE, TIME, DATETIME, TIMESTAMP, and YEAR.

For the DATE and DATETIME range descriptions, “supported” means that although earlier values might work, there is no guarantee.

• DATE
A date. The supported range is '1000-01-01' to '9999-12-31'. MySQL displays DATE values in 'YYYY-MM-DD' format, but permits assignment of values to DATE columns using either strings or numbers.

- **DATETIME**

A date and time combination. The supported range is '1000-01-01 00:00:00' to '9999-12-31 23:59:59'. MySQL displays DATETIME values in 'YYYY-MM-DD hh:mm:ss' format, but permits assignment of values to DATETIME columns using either strings or numbers.

- **TIMESTAMP**

A timestamp. The range is '1970-01-01 00:00:01' UTC to '2038-01-19 03:14:07' UTC. TIMESTAMP values are stored as the number of seconds since the epoch ('1970-01-01 00:00:00' UTC). A TIMESTAMP cannot represent the value '1970-01-01 00:00:00' because that is equivalent to 0 seconds from the epoch and the value 0 is reserved for representing '0000-00-00 00:00:00', the "zero" TIMESTAMP value.

Unless specified otherwise, the first TIMESTAMP column in a table is defined to be automatically set to the date and time of the most recent modification if not explicitly assigned a value. This makes TIMESTAMP useful for recording the timestamp of an INSERT or UPDATE operation. You can also set any TIMESTAMP column to the current date and time by assigning it a NULL value, unless it has been defined with the NULL attribute to permit NULL values. The automatic initialization and updating to the current date and time can be specified using DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP clauses, as described in Section 11.2.6, "Automatic Initialization and Updating for TIMESTAMP".

- **TIME**

A time. The range is '-838:59:59' to '838:59:59'. MySQL displays TIME values in 'hh:mm:ss' format, but permits assignment of values to TIME columns using either strings or numbers.

- **YEAR[(2|4)]**

A year in 2-digit or 4-digit format. The default is 4-digit format. YEAR(2) or YEAR(4) differ in display format, but have the same range of values. In 4-digit format, values display as 1901 to 2155, or 0000. In 2-digit format, values display as 70 to 69, representing years from 1970 to 2069. MySQL displays YEAR values in YYYY or YY format, but permits assignment of values to YEAR columns using either strings or numbers.

**Note**

The YEAR(2) data type has certain issues that you should consider before choosing to use it. As of MySQL 5.5.27, YEAR(2) is deprecated. For more information, see Section 11.2.5, "2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR".

For additional information about YEAR display format and interpretation of input values, see Section 11.2.4, "The YEAR Type".

The SUM() and AVG() aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:

```
SELECT SEC_TO_TIME(SUM(TIME_TO_SEC(time_col))) FROM tbl_name;
SELECT FROM_DAYS(SUM(TO_DAYS(date_col))) FROM tbl_name;
```
The DATE, DATETIME, and TIMESTAMP Types

11.2.2 The DATE, DATETIME, and TIMESTAMP Types

The DATE, DATETIME, and TIMESTAMP types are related. This section describes their characteristics, how they are similar, and how they differ. MySQL recognizes DATE, DATETIME, and TIMESTAMP values in several formats, described in Section 9.1.3, “Date and Time Literals”. For the DATE and DATETIME range descriptions, “supported” means that although earlier values might work, there is no guarantee.

The DATE type is used for values with a date part but no time part. MySQL retrieves and displays DATE values in 'YYYY-MM-DD' format. The supported range is '1000-01-01' to '9999-12-31'.

The DATETIME type is used for values that contain both date and time parts. MySQL retrieves and displays DATETIME values in 'YYYY-MM-DD hh:mm:ss' format. The supported range is '1000-01-01 00:00:00' to '9999-12-31 23:59:59'.

The TIMESTAMP data type is used for values that contain both date and time parts. TIMESTAMP has a range of '1970-01-01 00:00:01' UTC to '2038-01-19 03:14:07' UTC.

MySQL converts TIMESTAMP values from the current time zone to UTC for storage, and back from UTC to the current time zone for retrieval. (This does not occur for other types such as DATETIME.) By default, the current time zone for each connection is the server's time. The time zone can be set on a per-connection basis. As long as the time zone setting remains constant, you get back the same value you store. If you store a TIMESTAMP value, and then change the time zone and retrieve the value, the retrieved value is different from the value you stored. This occurs because the same time zone was not used for conversion in both directions. The current time zone is available as the value of the time_zone system variable. For more information, see Section 5.1.12, “MySQL Server Time Zone Support”.

The TIMESTAMP data type offers automatic initialization and updating to the current date and time. For more information, see Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”.

A DATETIME or TIMESTAMP value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into DATETIME or TIMESTAMP columns. For information about fractional seconds support in MySQL, see Section 11.2.7, “Fractional Seconds in Time Values”.

Invalid DATE, DATETIME, or TIMESTAMP values are converted to the “zero” value of the appropriate type ('0000-00-00' or '0000-00-00 00:00:00'), if the SQL mode permits this conversion. The precise behavior depends on which if any of strict SQL mode and the NO_ZERO_DATE SQL mode are enabled; see Section 5.1.10, “Server SQL Modes”.

Be aware of certain properties of date value interpretation in MySQL:

- MySQL permits a “relaxed” format for values specified as strings, in which any punctuation character may be used as the delimiter between date parts or time parts. In some cases, this syntax can be deceiving. For example, a value such as '10:11:12' might look like a time value because of the :, but is interpreted as the year '2010-11-12' if used in date context. The value '10:45:15' is converted to '0000-00-00' because '45' is not a valid month.
• The server requires that month and day values be valid, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as '2004-04-31' are converted to '0000-00-00' and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable ALLOW_INVALID_DATES. See Section 5.1.10, "Server SQL Modes", for more information.

• MySQL does not accept TIMESTAMP values that include a zero in the day or month column or values that are not a valid date. The sole exception to this rule is the special "zero" value '0000-00-00 00:00:00', if the SQL mode permits this value. The precise behavior depends on which if any of strict SQL mode and the NO_ZERO_DATE SQL mode are enabled; see Section 5.1.10, "Server SQL Modes".

• CAST() treats a TIMESTAMP value as a string when not selecting from a table. (This is true even if you specify FROM DUAL.) See Section 12.10, "Cast Functions and Operators".

• Dates containing 2-digit year values are ambiguous because the century is unknown. MySQL interprets 2-digit year values using these rules:
  • Year values in the range 00–69 become 2000–2069.
  • Year values in the range 70–99 become 1970–1999.

See also Section 11.2.9, "2-Digit Years in Dates".

Note

The MySQL server can be run with the MAXDB SQL mode enabled. In this case, TIMESTAMP is identical with DATETIME. If this mode is enabled at the time that a table is created, TIMESTAMP columns are created as DATETIME columns. As a result, such columns use DATETIME display format, have the same range of values, and there is no automatic initialization or updating to the current date and time. See Section 5.1.10, "Server SQL Modes".

11.2.3 The TIME Type

MySQL retrieves and displays TIME values in 'hh:mm:ss' format (or 'hhh:mm:ss' format for large hours values). TIME values may range from '-838:59:59' to '838:59:59'. The hours part may be so large because the TIME type can be used not only to represent a time of day (which must be less than 24 hours), but also elapsed time or a time interval between two events (which may be much greater than 24 hours, or even negative).

MySQL recognizes TIME values in several formats, described in Section 9.1.3, "Date and Time Literals". Some of these formats can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into TIME columns. For information about fractional seconds support in MySQL, see Section 11.2.7, "Fractional Seconds in Time Values".

Be careful about assigning abbreviated values to a TIME column. MySQL interprets abbreviated TIME values with colons as time of the day. That is, '11:12' means '11:12:00', not '00:11:12'. MySQL interprets abbreviated values without colons using the assumption that the two rightmost digits represent seconds (that is, as elapsed time rather than as time of day). For example, you might think of '1112' and 1112 as meaning '11:12:00' (12 minutes after 11 o'clock), but MySQL interprets them as '00:11:12' (11 minutes, 12 seconds). Similarly, '12' and 12 are interpreted as '00:00:12'.

By default, values that lie outside the TIME range but are otherwise valid are clipped to the closest endpoint of the range. For example, '-850:00:00' and '850:00:00' are converted to '-838:59:59' and '838:59:59'. Invalid TIME values are converted to '00:00:00'. Note that because '00:00:00'
The YEAR Type

is itself a valid TIME value, there is no way to tell, from a value of '00:00:00' stored in a table, whether the original value was specified as '00:00:00' or whether it was invalid.

For more restrictive treatment of invalid TIME values, enable strict SQL mode to cause errors to occur. See Section 5.1.10, "Server SQL Modes".

11.2.4 The YEAR Type

The YEAR type is a 1-byte type used to represent year values. It can be declared as YEAR with an implicit display width of 4 characters, or as YEAR(4) or YEAR(2) with an explicit display width of 4 or 2 characters.

Note

The 2-digit YEAR(2) data type has certain issues that you should consider before choosing to use it. As of MySQL 5.5.27, YEAR(2) is deprecated. For more information, see Section 11.2.5, "2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR".

YEAR/YEAR(4) and YEAR(2) differ in display format, but have the same range of values. For 4-digit format, MySQL displays YEAR values in YYYY format, with a range of 1901 to 2155, and 0000. For 2-digit format, MySQL displays only the last (least significant) 2 digits; for example, 70 (1970 or 2070) or 69 (2069).

YEAR accepts input values in a variety of formats:

- As 4-digit strings in the range '1901' to '2155'.
- As 4-digit numbers in the range 1901 to 2155.
- As 1- or 2-digit strings in the range '0' to '99'. MySQL converts values in the ranges '0' to '69' and '70' to '99' to YEAR values in the ranges 2000 to 2069 and 1970 to 1999.
- As 1- or 2-digit numbers in the range 0 to 99. MySQL converts values in the ranges 1 to 69 and 70 to 99 to YEAR values in the ranges 2001 to 2069 and 1970 to 1999.

Inserting a numeric 0 has different effects for YEAR/YEAR(4) and YEAR(2):

- For YEAR/YEAR(4), the result has a display value of 0000 and an internal value of 0000. To specify zero and have it be interpreted as 2000, specify it as a string '0' or '00'.
- For YEAR(2), the result has a display value of 00 and an internal value of 2000.
- As the result of functions that return a value that is acceptable in YEAR context, such as NOW().

If strict SQL mode is not enabled, MySQL converts invalid YEAR values to 0000. In strict SQL mode, attempting to insert an invalid YEAR value produces an error.

See also Section 11.2.9, "2-Digit Years in Dates".

11.2.5 2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR

This section describes problems that can occur when using the 2-digit YEAR(2) data type and provides information about converting existing YEAR(2) columns to 4-digit year-valued columns, which can be declared as YEAR with an implicit display width of 4 characters, or equivalently as YEAR(4) with an explicit display width.
Although the internal range of values for `YEAR/YEAR(4)` and the deprecated `YEAR(2)` type is the same (1901 to 2155, and 0000), the display width for `YEAR(2)` makes that type inherently ambiguous because displayed values indicate only the last two digits of the internal values and omit the century digits. The result can be a loss of information under certain circumstances. For this reason, avoid using `YEAR(2)` in your applications and use `YEAR/YEAR(4)` wherever you need a year-valued data type. Note that conversion is required at some point because support for `YEAR` data types with display values other than 4, most notably `YEAR(2)`, is reduced as of MySQL 5.6.6 and is removed entirely in MySQL 5.7.

**YEAR(2) Limitations**

Issues with the `YEAR(2)` data type include ambiguity of displayed values, and possible loss of information when values are dumped and reloaded or converted to strings.

- Displayed `YEAR(2)` values can be ambiguous. It is possible for up to three `YEAR(2)` values that have different internal values to have the same displayed value, as the following example demonstrates:

```sql
mysql> CREATE TABLE t (y2 YEAR(2), y4 YEAR);
Query OK, 0 rows affected, 1 warning (0.01 sec)

mysql> INSERT INTO t (y2) VALUES(1912),(2012),(2112);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> UPDATE t SET y4 = y2;
Query OK, 3 rows affected (0.00 sec)
Rows matched: 3  Changed: 3  Warnings: 0

mysql> SELECT * FROM t;
+------+------+
<table>
<thead>
<tr>
<th>y2</th>
<th>y4</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1912</td>
</tr>
<tr>
<td>12</td>
<td>2012</td>
</tr>
<tr>
<td>12</td>
<td>2112</td>
</tr>
</tbody>
</table>
+------+------+
3 rows in set (0.00 sec)
```

- If you use `mysqldump` to dump the table created in the preceding example, the dump file represents all `y2` values using the same 2-digit representation (12). If you reload the table from the dump file, all resulting rows have internal value 2012 and display value 12, thus losing the distinctions between them.

- Conversion of a 2-digit or 4-digit `YEAR` data value to string form uses the data type display width. Suppose that a `YEAR(2)` column and a `YEAR/YEAR(4)` column both contain the value 1970. Assigning each column to a string results in a value of '70' or '1970', respectively. That is, loss of information occurs for conversion from `YEAR(2)` to string.

- Values outside the range from 1970 to 2069 are stored incorrectly when inserted into a `YEAR(2)` column in a CSV table. For example, inserting 2211 results in a display value of 11 but an internal value of 2011.

To avoid these problems, use the 4-digit `YEAR` or `YEAR(4)` data type rather than the 2-digit `YEAR(2)` data type. Suggestions regarding migration strategies appear later in this section.

**Migrating from YEAR(2) to 4-Digit YEAR**

To convert 2-digit `YEAR(2)` columns to 4-digit `YEAR` columns, use `ALTER TABLE`. Suppose that a table `t1` has this definition:

```sql
CREATE TABLE t1 (ycol YEAR(2) NOT NULL DEFAULT '70');
```
Modify the column using `ALTER TABLE` as follows. Remember to include any column attributes such as `NOT NULL` or `DEFAULT`:

```sql
ALTER TABLE t1 MODIFY ycol YEAR NOT NULL DEFAULT '1970';
```

The `ALTER TABLE` statement converts the table without changing `YEAR(2)` values. If the server is a replication master, the `ALTER TABLE` statement replicates to slaves and makes the corresponding table change on each one.

One migration method should be avoided: Do not dump your data with `mysqldump` and reload the dump file after upgrading. That has the potential to change `YEAR(2)` values, as described previously.

A migration from 2-digit `YEAR(2)` columns to 4-digit `YEAR` columns should also involve examining application code for the possibility of changed behavior under conditions such as these:

- Code that expects selecting a `YEAR` column to produce exactly two digits.
- Code that does not account for different handling for inserts of numeric `0`: Inserting `0` into `YEAR(2)` or `YEAR(4)` results in an internal value of `2000` or `0000`, respectively.

### 11.2.6 Automatic Initialization and Updating for TIMESTAMP

**Note**

In older versions of MySQL (prior to 4.1), the properties of the `TIMESTAMP` data type differed significantly in several ways from what is described in this section (see the *MySQL 3.23, 4.0, 4.1 Reference Manual* for details); these include syntax extensions which are deprecated in MySQL 5.1, and no longer supported in MySQL 5.5. This has implications for performing a dump and restore or replicating between MySQL Server versions. If you are using columns that are defined using the old `TIMESTAMP(N)` syntax, see Section 2.11.3, “Changes in MySQL 5.5”, prior to upgrading to MySQL 5.5.

The `TIMESTAMP` data type offers automatic initialization and updating to the current date and time (that is, the current timestamp). You can choose whether to use these properties and which column should have them:

- One `TIMESTAMP` column in a table can have the current timestamp as the default value for initializing the column, as the auto-update value, or both. It is not possible to have the current timestamp be the default value for one column and the auto-update value for another column.
- If the column is auto-initialized, it is set to the current timestamp for inserted rows that specify no value for the column.
- If the column is auto-updated, it is automatically updated to the current timestamp when the value of any other column in the row is changed from its current value. The column remains unchanged if all other columns are set to their current values. To prevent the column from updating when other columns change, explicitly set it to its current value. To update the column even when other columns do not change, explicitly set it to the value it should have (for example, set it to `CURRENT_TIMESTAMP`).

In addition, you can initialize or update any `TIMESTAMP` column to the current date and time by assigning it a `NULL` value, unless it has been defined with the `NULL` attribute to permit `NULL` values.

To specify automatic properties, use the `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` clauses. The order of the clauses does not matter. If both are present in a column definition, either can occur first. Any of the synonyms for `CURRENT_TIMESTAMP` have the same meaning.
Use of `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` is specific to `TIMESTAMP`. The `DEFAULT` clause also can be used to specify a constant (nonautomatic) default value (for example, `DEFAULT 0` or `DEFAULT '2000-01-01 00:00:00'`).

The following examples use `DEFAULT 0`, a default that can produce warnings or errors depending on whether strict SQL mode or the `NO_ZERO_DATE` SQL mode is enabled. Be aware that the `TRADITIONAL` SQL mode includes strict mode and `NO_ZERO_DATE`. See Section 5.1.10, “Server SQL Modes”.

The following rules describe the possibilities for defining the first `TIMESTAMP` column in a table with the current timestamp for both the default and auto-update values, for one but not the other, or for neither:

- **With both `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP`, the column has the current timestamp for its default value and is automatically updated to the current timestamp.**

  ```sql
  CREATE TABLE t1 (
    ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
  );
  ```

- **With neither `DEFAULT CURRENT_TIMESTAMP` nor `ON UPDATE CURRENT_TIMESTAMP`, it is the same as specifying both `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP`.**

  ```sql
  CREATE TABLE t1 (
    ts TIMESTAMP
  );
  ```

- **With a `DEFAULT` clause but no `ON UPDATE CURRENT_TIMESTAMP` clause, the column has the given default value and is not automatically updated to the current timestamp.**

  ```sql
  CREATE TABLE t1 (
    ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP
  );
  ```
  With a constant, the default is the given value. In this case, the column has no automatic properties at all.

  ```sql
  CREATE TABLE t1 (
    ts TIMESTAMP DEFAULT 0
  );
  ```

- **With an `ON UPDATE CURRENT_TIMESTAMP` clause and a constant `DEFAULT` clause, the column is automatically updated to the current timestamp and has the given constant default value.**

  ```sql
  CREATE TABLE t1 (
    ts TIMESTAMP DEFAULT 0 ON UPDATE CURRENT_TIMESTAMP
  );
  ```

- **With an `ON UPDATE CURRENT_TIMESTAMP` clause but no `DEFAULT` clause, the column is automatically updated to the current timestamp. The default is 0 unless the column is defined with the `NULL` attribute, in which case the default is `NULL`.**

  ```sql
  CREATE TABLE t1 (ts TIMESTAMP ON UPDATE CURRENT_TIMESTAMP);
  ```
Automatic Initialization and Updating for TIMESTAMP

It need not be the first TIMESTAMP column in a table that is automatically initialized or updated to the current timestamp. However, to specify automatic initialization or updating for a different TIMESTAMP column, you must suppress the automatic properties for the first one. Then, for the other TIMESTAMP column, the rules for the DEFAULT and ON UPDATE clauses are the same as for the first TIMESTAMP column, except that if you omit both clauses, no automatic initialization or updating occurs.

To suppress automatic properties for the first TIMESTAMP column, do either of the following:

• Define the column with a DEFAULT clause that specifies a constant default value.

• Specify the NULL attribute. This also causes the column to permit NULL values, which means that you cannot assign the current timestamp by setting the column to NULL. Assigning NULL sets the column to NULL.

Consider these table definitions:

```
CREATE TABLE t1 (  
  ts1 TIMESTAMP DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);  
CREATE TABLE t2 (  
  ts1 TIMESTAMP NULL,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);  
CREATE TABLE t3 (  
  ts1 TIMESTAMP NULL DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);  
```

The tables have these properties:

• In each table definition, the first TIMESTAMP column has no automatic initialization or updating.

• The tables differ in how the ts1 column handles NULL values. For t1, ts1 is NOT NULL and assigning it a value of NULL sets it to the current timestamp. For t2 and t3, ts1 permits NULL and assigning it a value of NULL sets it to NULL.

• t2 and t3 differ in the default value for ts1. For t2, ts1 is defined to permit NULL, so the default is also NULL in the absence of an explicit DEFAULT clause. For t3, ts1 permits NULL but has an explicit default of 0.

**TIMESTAMP Initialization and the NULL Attribute**

By default, TIMESTAMP columns are NOT NULL, cannot contain NULL values, and assigning NULL assigns the current timestamp. To permit a TIMESTAMP column to contain NULL, explicitly declare it with the NULL attribute. In this case, the default value also becomes NULL unless overridden with a DEFAULT clause that specifies a different default value. DEFAULT NULL can be used to explicitly specify NULL as the default value. (For a TIMESTAMP column not declared with the NULL attribute, DEFAULT NULL is invalid.) If a TIMESTAMP column permits NULL values, assigning NULL sets it to NULL, not to the current timestamp.

The following table contains several TIMESTAMP columns that permit NULL values:

```
CREATE TABLE t (  
```
A `TIMESTAMP` column that permits `NULL` values does not take on the current timestamp at insert time except under one of the following conditions:

- Its default value is defined as `CURRENT_TIMESTAMP` and no value is specified for the column
- `CURRENT_TIMESTAMP` or any of its synonyms such as `NOW()` is explicitly inserted into the column

In other words, a `TIMESTAMP` column defined to permit `NULL` values auto-initializes only if its definition includes `DEFAULT CURRENT_TIMESTAMP`:

```sql
CREATE TABLE t (ts TIMESTAMP NULL DEFAULT CURRENT_TIMESTAMP);
```

If the `TIMESTAMP` column permits `NULL` values but its definition does not include `DEFAULT CURRENT_TIMESTAMP`, you must explicitly insert a value corresponding to the current date and time. For example:

```sql
CREATE TABLE t1 (ts TIMESTAMP NULL DEFAULT '0000-00-00 00:00:00');
CREATE TABLE t2 (ts TIMESTAMP NULL DEFAULT NULL);
```

To set the `TIMESTAMP` column in either table to the current timestamp at insert time, explicitly assign it that value. For example:

```sql
INSERT INTO t2 VALUES (CURRENT_TIMESTAMP);
INSERT INTO t1 VALUES (NOW());
```

### 11.2.7 Fractional Seconds in Time Values

A trailing fractional seconds part is permissible for temporal values in contexts such as literal values, and in the arguments to or return values from some temporal functions. Example:

```sql
mysql> SELECT MICROSECOND('2010-12-10 14:12:09.019473');
+-------------------------------------------+
| MICROSECOND('2010-12-10 14:12:09.019473') |
+-------------------------------------------+
|                                     19473 |
+-------------------------------------------+
```

However, when MySQL stores a value into a column of any temporal data type, it discards any fractional part and does not store it.

### 11.2.8 Conversion Between Date and Time Types

To some extent, you can convert a value from one temporal type to another. However, there may be some alteration of the value or loss of information. In all cases, conversion between temporal types is subject to the range of valid values for the resulting type. For example, although `DATE`, `DATETIME`, and `TIMESTAMP` values all can be specified using the same set of formats, the types do not all have the same range of values. `TIMESTAMP` values cannot be earlier than 1970 UTC or later than `2038-01-19 03:14:07' UTC. This means that a date such as `1968-01-01`, while valid as a `DATE` or `DATETIME` value, is not valid as a `TIMESTAMP` value and is converted to 0.

Conversion of `DATE` values:

- Conversion to a `DATETIME` or `TIMESTAMP` value adds a time part of `'00:00:00'` because the `DATE` value contains no time information.
• Conversion to a TIME value is not useful; the result is '00:00:00'.

Conversion of DATETIME and TIMESTAMP values:

• Conversion to a DATE value discards the time part because the DATE type contains no time information.
• Conversion to a TIME value discards the date part because the TIME type contains no date information.

Conversion of TIME values:

MySQL converts a time value to a date or date-and-time value by parsing the string value of the time as a date or date-and-time. This is unlikely to be useful. For example, '23:12:31' interpreted as a date becomes '2023-12-31'. Time values not valid as dates become '0000-00-00' or NULL.

Explicit conversion can be used to override implicit conversion. For example, in comparison of DATE and DATETIME values, the DATE value is coerced to the DATETIME type by adding a time part of '00:00:00'. To perform the comparison by ignoring the time part of the DATETIME value instead, use the CAST() function in the following way:

```sql
date_col = CAST(datetime_col AS DATE)
```

Conversion of TIME or DATETIME values to numeric form (for example, by adding +0) results in a double-precision value with a microseconds part of .000000:

```
mysql> SELECT CURTIME(), CURTIME()+0;
+-----------+---------------+
| CURTIME() | CURTIME()+0   |
+-----------+---------------+
| 10:41:36  | 104136.000000 |
+-----------+---------------+
```

```
mysql> SELECT NOW(), NOW()+0;
+---------------------+-----------------------+
| NOW()               | NOW()+0               |
+---------------------+-----------------------+
| 2007-11-30 10:41:47 | 20071130104147.000000 |
+---------------------+-----------------------+
```

11.2.9 2-Digit Years in Dates

Date values with 2-digit years are ambiguous because the century is unknown. Such values must be interpreted into 4-digit form because MySQL stores years internally using 4 digits.

For DATETIME, DATE, and TIMESTAMP types, MySQL interprets dates specified with ambiguous year values using these rules:

• Year values in the range 00–69 become 2000–2069.
• Year values in the range 70–99 become 1970–1999.

For YEAR, the rules are the same, with this exception: A numeric 00 inserted into YEAR(4) results in 0000 rather than 2000. To specify zero for YEAR(4) and have it be interpreted as 2000, specify it as a string '0' or '00'.

Remember that these rules are only heuristics that provide reasonable guesses as to what your data values mean. If the rules used by MySQL do not produce the values you require, you must provide unambiguous input containing 4-digit year values.

ORDER BY properly sorts YEAR values that have 2-digit years.
Some functions like `MIN()` and `MAX()` convert a `YEAR` to a number. This means that a value with a 2-digit year does not work properly with these functions. The fix in this case is to convert the `YEAR` to 4-digit year format.

### 11.3 String Data Types

The string data types are `CHAR`, `VARCHAR`, `BINARY`, `VARBINARY`, `BLOB`, `TEXT`, `ENUM`, and `SET`.

For information about storage requirements of the string data types, see Section 11.6, “Data Type Storage Requirements”.

For descriptions of functions that operate on string values, see Section 12.7, “String Functions and Operators”.

#### 11.3.1 String Data Type Syntax

The string data types are `CHAR`, `VARCHAR`, `BINARY`, `VARBINARY`, `BLOB`, `TEXT`, `ENUM`, and `SET`.

In some cases, MySQL may change a string column to a type different from that given in a `CREATE TABLE` or `ALTER TABLE` statement. See Section 13.1.17.7, “Silent Column Specification Changes”.

For definitions of character string columns (`CHAR`, `VARCHAR`, and the `TEXT` types), MySQL interprets length specifications in character units. For definitions of binary string columns (`BINARY`, `VARBINARY`, and the `BLOB` types), MySQL interprets length specifications in byte units.

Column definitions for character string data types `CHAR`, `VARCHAR`, the `TEXT` types, `ENUM`, `SET`, and any synonyms) can specify the column character set and collation:

- **CHARACTER SET** specifies the character set. If desired, a collation for the character set can be specified with the **COLLATE** attribute, along with any other attributes. For example:

```sql
CREATE TABLE t
(
    c1 VARCHAR(20) CHARACTER SET utf8,
    c2 TEXT CHARACTER SET latin1 COLLATE latin1_general_cs
);
```

This table definition creates a column named `c1` that has a character set of `utf8` with the default collation for that character set, and a column named `c2` that has a character set of `latin1` and a case-sensitive (`_cs`) collation.

The rules for assigning the character set and collation when either or both of **CHARACTER SET** and the **COLLATE** attribute are missing are described in Section 10.3.5, “Column Character Set and Collation”.

**CHARSET** is a synonym for **CHARACTER SET**.

- Specifying the **CHARACTER SET binary** attribute for a character string data type causes the column to be created as the corresponding binary string data type: `CHAR` becomes `BINARY`, `VARCHAR` becomes `VARBINARY`, and `TEXT` becomes `BLOB`. For the `ENUM` and `SET` data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

```sql
CREATE TABLE t
(
    c1 VARCHAR(10) CHARACTER SET binary,
    c2 TEXT CHARACTER SET binary,
    c3 ENUM('a','b','c') CHARACTER SET binary
);
```
The resulting table has this definition:

```sql
CREATE TABLE t
(
  c1 VARBINARY(10),
  c2 BLOB,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

- The `BINARY` attribute is a nonstandard MySQL extension that is shorthand for specifying the binary `_bin` collation of the column character set (or of the table default character set if no column character set is specified). In this case, comparison and sorting are based on numeric character code values. Suppose that you specify a table using this definition:

```sql
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET latin1 BINARY,
  c2 TEXT BINARY
) CHARACTER SET utf8mb4;
```

The resulting table has this definition:

```sql
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET latin1 COLLATE latin1_bin,
  c2 TEXT CHARACTER SET utf8mb4 COLLATE utf8mb4_bin
) CHARACTER SET utf8mb4;
```

- The `ASCII` attribute is shorthand for `CHARACTER SET latin1`.
- The `UNICODE` attribute is shorthand for `CHARACTER SET ucs2`.

Character column comparison and sorting are based on the collation assigned to the column. For the `CHAR, VARCHAR, TEXT, ENUM, and SET` data types, you can declare a column with a binary `_bin` collation or the `BINARY` attribute to cause comparison and sorting to use the underlying character code values rather than a lexical ordering.

For additional information about use of character sets in MySQL, see Chapter 10, Character Sets, Collations, Unicode.

- `[NATIONAL] CHAR[(M)] [CHARACTER SET charset_name] [COLLATE collation_name]`

A fixed-length string that is always right-padded with spaces to the specified length when stored. _M_ represents the column length in characters. The range of _M_ is 0 to 255. If _M_ is omitted, the length is 1.

**Note**

Trailings spaces are removed when `CHAR` values are retrieved unless the `PAD_CHAR_TO_FULL_LENGTH` SQL mode is enabled.

`CHAR` is shorthand for `CHARACTER. NATIONAL CHAR` (or its equivalent short form, `NCHAR`) is the standard SQL way to define that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. Section 10.3.7, “The National Character Set”.

The `CHAR BYTE` data type is an alias for the `BINARY` data type. This is a compatibility feature.

MySQL permits you to create a column of type `CHAR(0)`. This is useful primarily when you must be compliant with old applications that depend on the existence of a column but that do not actually use its value. `CHAR(0)` is also quite nice when you need a column that can take only two values: A column
that is defined as `CHAR(0) NULL` occupies only one bit and can take only the values `NULL` and `'` (the empty string).

- `[NATIONAL] VARCHAR(M) [CHARACTER SET charset_name] [COLLATE collation_name]`

A variable-length string. \( M \) represents the maximum column length in characters. The range of \( M \) is 0 to 65,535. The effective maximum length of a `VARCHAR` is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. For example, `utf8` characters can require up to three bytes per character, so a `VARCHAR` column that uses the `utf8` character set can be declared to be a maximum of 21,844 characters. See Section 8.4.7, “Limits on Table Column Count and Row Size”.

MySQL stores `VARCHAR` values as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A `VARCHAR` column uses one length byte if values require no more than 255 bytes, two length bytes if values may require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

\[ \text{Note} \]

MySQL follows the standard SQL specification, and does *not* remove trailing spaces from `VARCHAR` values.

`VARCHAR` is shorthand for `CHARACTER VARYING`. `NATIONAL VARCHAR` is the standard SQL way to define that a `VARCHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. See Section 10.3.7, “The National Character Set”.

`NVARCHAR` is shorthand for `NATIONAL VARCHAR`.

- `BINARY[()M]`

The `BINARY` type is similar to the `CHAR` type, but stores binary byte strings rather than nonbinary character strings. An optional length \( M \) represents the column length in bytes. If omitted, \( M \) defaults to 1.

- `VARBINARY(M)`

The `VARBINARY` type is similar to the `VARCHAR` type, but stores binary byte strings rather than nonbinary character strings. \( M \) represents the maximum column length in bytes.

- `TINYBLOB`

A `BLOB` column with a maximum length of 255 (\(2^8 - 1\)) bytes. Each `TINYBLOB` value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- `TINYTEXT [CHARACTER SET charset_name] [COLLATE collation_name]`

A `TEXT` column with a maximum length of 255 (\(2^8 - 1\)) characters. The effective maximum length is less if the value contains multibyte characters. Each `TINYTEXT` value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- `BLOB[()M]`

A `BLOB` column with a maximum length of 65,535 (\(2^{16} - 1\)) bytes. Each `BLOB` value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

An optional length \( M \) can be given for this type. If this is done, MySQL creates the column as the smallest `BLOB` type large enough to hold values \( M \) bytes long.

- `TEXT[()M] [CHARACTER SET charset_name] [COLLATE collation_name]`
The CHAR and VARCHAR Types

A **TEXT** column with a maximum length of 65,535 \(2^{16} - 1\) characters. The effective maximum length is less if the value contains multibyte characters. Each **TEXT** value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

An optional length \(M\) can be given for this type. If this is done, MySQL creates the column as the smallest **TEXT** type large enough to hold values \(M\) characters long.

- **MEDIUMBLOB**

  A **BLOB** column with a maximum length of 16,777,215 \(2^{24} - 1\) bytes. Each **MEDIUMBLOB** value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- **MEDIUMTEXT [CHARACTER SET charset_name] [COLLATE collation_name]**

  A **TEXT** column with a maximum length of 16,777,215 \(2^{24} - 1\) characters. The effective maximum length is less if the value contains multibyte characters. Each **MEDIUMTEXT** value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- **LONGBLOB**

  A **BLOB** column with a maximum length of 4,294,967,295 or 4GB \(2^{32} - 1\) bytes. The effective maximum length of **LONGBLOB** columns depends on the configured maximum packet size in the client/server protocol and available memory. Each **LONGBLOB** value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- **LONGTEXT [CHARACTER SET charset_name] [COLLATE collation_name]**

  A **TEXT** column with a maximum length of 4,294,967,295 or 4GB \(2^{32} - 1\) characters. The effective maximum length is less if the value contains multibyte characters. The effective maximum length of **LONGTEXT** columns also depends on the configured maximum packet size in the client/server protocol and available memory. Each **LONGTEXT** value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- **ENUM('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]**

  An enumeration. A string object that can have only one value, chosen from the list of values 'value1', 'value2', ..., NULL or the special '' error value. **ENUM** values are represented internally as integers.

  An **ENUM** column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its **ENUM** and **SET** columns considered as a group. For more information on these limits, see [Limits Imposed by .frm File Structure](#).

- **SET('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]**

  A set. A string object that can have zero or more values, each of which must be chosen from the list of values 'value1', 'value2', ... **SET** values are represented internally as integers.

  A **SET** column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its **ENUM** and **SET** columns considered as a group. For more information on this limit, see [Limits Imposed by .frm File Structure](#).

### 11.3.2 The CHAR and VARCHAR Types

1181
The CHAR and VARCHAR Types

The CHAR and VARCHAR types are similar, but differ in the way they are stored and retrieved. They also differ in maximum length and in whether trailing spaces are retained.

The CHAR and VARCHAR types are declared with a length that indicates the maximum number of characters you want to store. For example, CHAR(30) can hold up to 30 characters.

The length of a CHAR column is fixed to the length that you declare when you create the table. The length can be any value from 0 to 255. When CHAR values are stored, they are right-padded with spaces to the specified length. When CHAR values are retrieved, trailing spaces are removed unless the PAD_CHAR_TO_FULL_LENGTH SQL mode is enabled.

Values in VARCHAR columns are variable-length strings. The length can be specified as a value from 0 to 65,535. The effective maximum length of a VARCHAR is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. See Section 8.4.7, “Limits on Table Column Count and Row Size”.

In contrast to CHAR, VARCHAR values are stored as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A column uses one length byte if values require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

If strict SQL mode is not enabled and you assign a value to a CHAR or VARCHAR column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.10, “Server SQL Modes”.

For VARCHAR columns, truncating values in excess of the column length are truncated prior to insertion and a warning is generated, regardless of the SQL mode in use. For CHAR columns, truncation of excess trailing spaces from inserted values is performed silently regardless of the SQL mode.

VARCHAR values are not padded when they are stored. Trailing spaces are retained when values are stored and retrieved, in conformance with standard SQL.

The following table illustrates the differences between CHAR and VARCHAR by showing the result of storing various string values into CHAR(4) and VARCHAR(4) columns (assuming that the column uses a single-byte character set such as latin1).

<table>
<thead>
<tr>
<th>Value</th>
<th>CHAR(4)</th>
<th>Storage Required</th>
<th>VARCHAR(4)</th>
<th>Storage Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>''</td>
<td>''</td>
<td>4 bytes</td>
<td>''</td>
<td>1 byte</td>
</tr>
<tr>
<td>'ab'</td>
<td>'ab'</td>
<td>4 bytes</td>
<td>'ab'</td>
<td>3 bytes</td>
</tr>
<tr>
<td>'abcd'</td>
<td>'abcd'</td>
<td>4 bytes</td>
<td>'abcd'</td>
<td>5 bytes</td>
</tr>
<tr>
<td>'abcdefgh'</td>
<td>'abcd'</td>
<td>4 bytes</td>
<td>'abcd'</td>
<td>5 bytes</td>
</tr>
</tbody>
</table>

The values shown as stored in the last row of the table apply only when not using strict mode; if MySQL is running in strict mode, values that exceed the column length are not stored, and an error results.

InnoDB encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

If a given value is stored into the CHAR(4) and VARCHAR(4) columns, the values retrieved from the columns are not always the same because trailing spaces are removed from CHAR columns upon retrieval.

The following example illustrates this difference:

```
mysql> CREATE TABLE vc (v VARCHAR(4), c CHAR(4));
Query OK, 0 rows affected (0.01 sec)
```
The BINARY and VARBINARY Types

Values in CHAR and VARCHAR columns are sorted and compared according to the character set collation assigned to the column.

All MySQL collations are of type PAD SPACE. This means that all CHAR, VARCHAR, and TEXT values are compared without regard to any trailing spaces. “Comparison” in this context does not include the LIKE pattern-matching operator, for which trailing spaces are significant. For example:

```
mysql> CREATE TABLE names (myname CHAR(10));
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO names VALUES ('Jones');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT myname = 'Jones', myname = 'Jones  ' FROM names;
+------------------+--------------------+
| myname = 'Jones' | myname = 'Jones  ' |
|                  |                  1 |
+------------------+--------------------+
1 row in set (0.00 sec)

mysql> SELECT myname LIKE 'Jones', myname LIKE 'Jones  ' FROM names;
+---------------------+-----------------------+
| myname LIKE 'Jones' | myname LIKE 'Jones  ' |
|                   1 |                     0 |
+---------------------+-----------------------+
1 row in set (0.00 sec)
```

This is true for all MySQL versions, and is not affected by the server SQL mode.

For more information about MySQL character sets and collations, see Chapter 10, Character Sets, Collations, Unicode. For additional information about storage requirements, see Section 11.6, “Data Type Storage Requirements”.

For those cases where trailing pad characters are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting into the column values that differ only in number of trailing pad characters will result in a duplicate-key error. For example, if a table contains 'a', an attempt to store 'a ' causes a duplicate-key error.

11.3.3 The BINARY and VARBINARY Types

The BINARY and VARBINARY types are similar to CHAR and VARCHAR, except that they store binary strings rather than nonbinary strings. That is, they store byte strings rather than character strings. This means they have the binary character set and collation, and comparison and sorting are based on the numeric values of the bytes in the values.

The permissible maximum length is the same for BINARY and VARBINARY as it is for CHAR and VARCHAR, except that the length for BINARY and VARBINARY is measured in bytes rather than characters.
The BLOB and TEXT Types

The **BINARY** and **VARBINARY** data types are distinct from the **CHAR BINARY** and **VARCHAR BINARY** data types. For the latter types, the **BINARY** attribute does not cause the column to be treated as a binary string column. Instead, it causes the binary (_bin) collation for the column character set (or the table default character set if no column character set is specified) to be used, and the column itself stores nonbinary character strings rather than binary byte strings. For example, if the default character set is **latin1**, **CHAR(5) BINARY** is treated as **CHAR(5) CHARACTER SET latin1 COLLATE latin1_bin**. This differs from **BINARY(5)**, which stores 5-byte binary strings that have the **binary** character set and collation. For information about the differences between the **binary** collation of the **binary** character set and the _bin collations of nonbinary character sets, see Section 10.8.5, “The binary Collation Compared to _bin Collations”.

If strict SQL mode is not enabled and you assign a value to a **BINARY** or **VARBINARY** column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For cases of truncation, to cause an error to occur (rather than a warning) and suppress insertion of the value, use strict SQL mode. See Section 5.1.10, “Server SQL Modes”.

When **BINARY** values are stored, they are right-padded with the pad value to the specified length. The pad value is 0x00 (the zero byte). Values are right-padded with 0x00 for inserts, and no trailing bytes are removed for retrievals. All bytes are significant in comparisons, including **ORDER BY** and **DISTINCT** operations. 0x00 and space differ in comparisons, with 0x00 sorting before space.

Example: For a **BINARY(3)** column, 'a ' becomes 'a \0' when inserted. 'a\0' becomes 'a\0\0' when inserted. Both inserted values remain unchanged for retrievals.

For **VARBINARY**, there is no padding for inserts and no bytes are stripped for retrievals. All bytes are significant in comparisons, including **ORDER BY** and **DISTINCT** operations. 0x00 and space differ in comparisons, with 0x00 sorting before space.

For those cases where trailing pad bytes are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting values into the column that differ only in number of trailing pad bytes results in a duplicate-key error. For example, if a table contains 'a', an attempt to store 'a\0' causes a duplicate-key error.

You should consider the preceding padding and stripping characteristics carefully if you plan to use the **BINARY** data type for storing binary data and you require that the value retrieved be exactly the same as the value stored. The following example illustrates how 0x00-padding of **BINARY** values affects column value comparisons:

```
mysql> CREATE TABLE t (c BINARY(3));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t SET c = 'a';
Query OK, 1 row affected (0.01 sec)

mysql> SELECT HEX(c), c = 'a', c = 'a\0\0' from t;
+--------+---------+-------------+
<table>
<thead>
<tr>
<th>HEX(c)</th>
<th>c = 'a'</th>
<th>c = 'a\0\0'</th>
</tr>
</thead>
<tbody>
<tr>
<td>610000</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
+--------+---------+-------------+
1 row in set (0.09 sec)
```

If the value retrieved must be the same as the value specified for storage with no padding, it might be preferable to use **VARBINARY** or one of the **BLOB** data types instead.

11.3.4 The BLOB and TEXT Types

A **BLOB** is a binary large object that can hold a variable amount of data. The four **BLOB** types are **TINYBLOB**, **BLOB**, **MEDIUMBLOB**, and **LONGBLOB**. These differ only in the maximum length of the
The BLOB and TEXT Types

values they can hold. The four TEXT types are TINYTEXT, TEXT, MEDIUMTEXT, and LONGTEXT. These correspond to the four BLOB types and have the same maximum lengths and storage requirements. See Section 11.6, “Data Type Storage Requirements”.

BLOB values are treated as binary strings (byte strings). They have the binary character set and collation, and comparison and sorting are based on the numeric values of the bytes in column values. TEXT values are treated as nonbinary strings (character strings). They have a character set other than binary, and values are sorted and compared based on the collation of the character set.

If strict SQL mode is not enabled and you assign a value to a BLOB or TEXT column that exceeds the column’s maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.10, “Server SQL Modes”.

Truncation of excess trailing spaces from values to be inserted into TEXT columns always generates a warning, regardless of the SQL mode.

For TEXT and BLOB columns, there is no padding on insert and no bytes are stripped on select.

If a TEXT column is indexed, index entry comparisons are space-padded at the end. This means that, if the index requires unique values, duplicate-key errors will occur for values that differ only in the number of trailing spaces. For example, if a table contains 'a', an attempt to store 'a ' causes a duplicate-key error. This is not true for BLOB columns.

In most respects, you can regard a BLOB column as a VARBINARY column that can be as large as you like. Similarly, you can regard a TEXT column as a VARCHAR column. BLOB and TEXT differ from VARBINARY and VARCHAR in the following ways:

• For indexes on BLOB and TEXT columns, you must specify an index prefix length. For CHAR and VARCHAR, a prefix length is optional. See Section 8.3.4, “Column Indexes”.

• BLOB and TEXT columns cannot have DEFAULT values.

If you use the BINARY attribute with a TEXT data type, the column is assigned the binary (_bin) collation of the column character set.

LONG and LONG VARCHAR map to the MEDIUMTEXT data type. This is a compatibility feature.

MySQL Connector/ODBC defines BLOB values as LONGVARBINARY and TEXT values as LONGVARCHAR.

Because BLOB and TEXT can be extremely long, you might encounter some constraints in using them:

• Only the first max_sort_length bytes of the column are used when sorting. The default value of max_sort_length is 1024. You can make more bytes significant in sorting or grouping by increasing the value of max_sort_length at server startup or runtime. Any client can change the value of its session max_sort_length variable:

```
mysql> SET max_sort_length = 2000;
mysql> SELECT id, comment FROM t
    -> ORDER BY comment;
```

• Instances of BLOB or TEXT columns in the result of a query that is processed using a temporary table causes the server to use a table on disk rather than in memory because the MEMORY storage engine does not support those data types (see Section 8.4.4, “Internal Temporary Table Use in MySQL”). Use of disk incurs a performance penalty, so include BLOB or TEXT columns in the query result only if they are really needed. For example, avoid using SELECT *, which selects all columns.
The ENUM Type

- The maximum size of a BLOB or TEXT object is determined by its type, but the largest value you actually can transmit between the client and server is determined by the amount of available memory and the size of the communications buffers. You can change the message buffer size by changing the value of the max_allowed_packet variable, but you must do so for both the server and your client program. For example, both mysql and mysqldump enable you to change the client-side max_allowed_packet value. See Section 5.1.1, “Configuring the Server”, Section 4.5.1, “mysql — The MySQL Command-Line Client”, and Section 4.5.4, “mysqldump — A Database Backup Program”. You may also want to compare the packet sizes and the size of the data objects you are storing with the storage requirements, see Section 11.6, “Data Type Storage Requirements”

Each BLOB or TEXT value is represented internally by a separately allocated object. This is in contrast to all other data types, for which storage is allocated once per column when the table is opened.

In some cases, it may be desirable to store binary data such as media files in BLOB or TEXT columns. You may find MySQL's string handling functions useful for working with such data. See Section 12.7, “String Functions and Operators”. For security and other reasons, it is usually preferable to do so using application code rather than giving application users the FILE privilege. You can discuss specifics for various languages and platforms in the MySQL Forums (http://forums.mysql.com/).

11.3.5 The ENUM Type

An ENUM is a string object with a value chosen from a list of permitted values that are enumerated explicitly in the column specification at table creation time. It has these advantages:

- Compact data storage in situations where a column has a limited set of possible values. The strings you specify as input values are automatically encoded as numbers. See Section 11.6, “Data Type Storage Requirements” for the storage requirements for ENUM types.

- Readable queries and output. The numbers are translated back to the corresponding strings in query results.

and these potential issues to consider:

- If you make enumeration values that look like numbers, it is easy to mix up the literal values with their internal index numbers, as explained in Enumeration Limitations.

- Using ENUM columns in ORDER BY clauses requires extra care, as explained in Enumeration Sorting.

- Creating and Using ENUM Columns

- Index Values for Enumeration Literals

- Handling of Enumeration Literals

- Empty or NULL Enumeration Values

- Enumeration Sorting

- Enumeration Limitations

Creating and Using ENUM Columns

An enumeration value must be a quoted string literal. For example, you can create a table with an ENUM column like this:

```sql
CREATE TABLE shirts (  
    name VARCHAR(40),
    size ENUM('x-small', 'small', 'medium', 'large', 'x-large')
);```

1186
The ENUM Type

```sql
); INSERT INTO shirts (name, size) VALUES ('dress shirt', 'large'), ('t-shirt', 'medium'), ('polo shirt', 'small');
SELECT name, size FROM shirts WHERE size = 'medium';
+---------+--------+
| name    | size   |
+---------+--------+
| t-shirt | medium |
+---------+--------+
UPDATE shirts SET size = 'small' WHERE size = 'large';
COMMIT;
```

Inserting 1 million rows into this table with a value of 'medium' would require 1 million bytes of storage, as opposed to 6 million bytes if you stored the actual string 'medium' in a VARCHAR column.

**Index Values for Enumeration Literals**

Each enumeration value has an index:

- The elements listed in the column specification are assigned index numbers, beginning with 1.
- The index value of the empty string error value is 0. This means that you can use the following `SELECT` statement to find rows into which invalid ENUM values were assigned:
  ```sql
  mysql> SELECT * FROM tbl_name WHERE enum_col=0;
  ```
- The index of the NULL value is NULL.
- The term “index” here refers to a position within the list of enumeration values. It has nothing to do with table indexes.

For example, a column specified as `ENUM('Mercury', 'Venus', 'Earth')` can have any of the values shown here. The index of each value is also shown.

<table>
<thead>
<tr>
<th>Value</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>''</td>
<td>0</td>
</tr>
<tr>
<td>'Mercury'</td>
<td>1</td>
</tr>
<tr>
<td>'Venus'</td>
<td>2</td>
</tr>
<tr>
<td>'Earth'</td>
<td>3</td>
</tr>
</tbody>
</table>

An ENUM column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its ENUM and SET columns considered as a group. For more information on these limits, see Limits Imposed by .frm File Structure.

If you retrieve an ENUM value in a numeric context, the column value’s index is returned. For example, you can retrieve numeric values from an ENUM column like this:

```sql
mysql> SELECT enum_col+0 FROM tbl_name;
```

Functions such as `SUM()` or `AVG()` that expect a numeric argument cast the argument to a number if necessary. For ENUM values, the index number is used in the calculation.

**Handling of Enumeration Literals**

Trailing spaces are automatically deleted from ENUM member values in the table definition when a table is created.
The ENUM Type

When retrieved, values stored into an **ENUM** column are displayed using the lettercase that was used in the column definition. Note that **ENUM** columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.

If you store a number into an **ENUM** column, the number is treated as the index into the possible values, and the value stored is the enumeration member with that index. (However, this does not work with **LOAD DATA**, which treats all input as strings.) If the numeric value is quoted, it is still interpreted as an index if there is no matching string in the list of enumeration values. For these reasons, it is not advisable to define an **ENUM** column with enumeration values that look like numbers, because this can easily become confusing. For example, the following column has enumeration members with string values of '0', '1', and '2', but numeric index values of 1, 2, and 3:

```
numbers ENUM('0','1','2')
```

If you store 2, it is interpreted as an index value, and becomes '1' (the value with index 2). If you store '2', it matches an enumeration value, so it is stored as '2'. If you store '3', it does not match any enumeration value, so it is treated as an index and becomes '2' (the value with index 3).

```
mysql> INSERT INTO t (numbers) VALUES(2),('2'),('3');
mysql> SELECT * FROM t;
+---------+
| numbers |
+---------+
| 1       |
| 2       |
| 2       |
+---------+
```

To determine all possible values for an **ENUM** column, use **SHOW COLUMNS FROM** `tbl_name` LIKE `enum_col' and parse the **ENUM** definition in the **Type** column of the output.

In the C API, **ENUM** values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 23.7.4, “C API Data Structures”.

**Empty or NULL Enumeration Values**

An enumeration value can also be the empty string ('') or **NULL** under certain circumstances:

- If you insert an invalid value into an **ENUM** (that is, a string not present in the list of permitted values), the empty string is inserted instead as a special error value. This string can be distinguished from a “normal” empty string by the fact that this string has the numeric value 0. See Index Values for Enumeration Literals for details about the numeric indexes for the enumeration values.

  If strict SQL mode is enabled, attempts to insert invalid **ENUM** values result in an error.

- If an **ENUM** column is declared to permit **NULL**, the **NULL** value is a valid value for the column, and the default value is **NULL**. If an **ENUM** column is declared **NOT NULL**, its default value is the first element of the list of permitted values.

**Enumeration Sorting**

**ENUM** values are sorted based on their index numbers, which depend on the order in which the enumeration members were listed in the column specification. For example, 'b' sorts before 'a' for **ENUM('b', 'a')**. The empty string sorts before nonempty strings, and **NULL** values sort before all other enumeration values.

To prevent unexpected results when using the **ORDER BY** clause on an **ENUM** column, use one of these techniques:
The SET Type

- Specify the ENUM list in alphabetic order.
- Make sure that the column is sorted lexically rather than by index number by coding ORDER BY CAST(col AS CHAR) or ORDER BY CONCAT(col).

Enumeration Limitations

An enumeration value cannot be an expression, even one that evaluates to a string value.

For example, this CREATE TABLE statement does not work because the CONCAT function cannot be used to construct an enumeration value:

```sql
CREATE TABLE sizes (  
  size ENUM('small', CONCAT('med','ium'), 'large')
);
```

You also cannot employ a user variable as an enumeration value. This pair of statements do not work:

```sql
SET @mysize = 'medium';
CREATE TABLE sizes (  
  size ENUM('small', @mysize, 'large')
);
```

We strongly recommend that you do not use numbers as enumeration values, because it does not save on storage over the appropriate TINYINT or SMALLINT type, and it is easy to mix up the numbers and the underlying number values (which might not be the same) if you quote the ENUM values incorrectly. If you do use a number as an enumeration value, always enclose it in quotation marks. If the quotation marks are omitted, the number is regarded as an index. See Handling of Enumeration Literals to see how even a quoted number could be mistakenly used as a numeric index value.

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

11.3.6 The SET Type

A SET is a string object that can have zero or more values, each of which must be chosen from a list of permitted values specified when the table is created. SET column values that consist of multiple set members are specified with members separated by commas (,). A consequence of this is that SET member values should not themselves contain commas.

For example, a column specified as SET('one', 'two') NOT NULL can have any of these values:

```
'','
'one',
'two',
'one,two'
```

A SET column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its ENUM and SET columns considered as a group. For more information on this limit, see Limits Imposed by .frm File Structure.

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

Trailing spaces are automatically deleted from SET member values in the table definition when a table is created.

When retrieved, values stored in a SET column are displayed using the lettercase that was used in the column definition. Note that SET columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.
MySQL stores SET values numerically, with the low-order bit of the stored value corresponding to the first set member. If you retrieve a SET value in a numeric context, the value retrieved has bits set corresponding to the set members that make up the column value. For example, you can retrieve numeric values from a SET column like this:

```
mysql> SELECT set_col+0 FROM tbl_name;
```

If a number is stored into a SET column, the bits that are set in the binary representation of the number determine the set members in the column value. For a column specified as SET('a','b','c','d'), the members have the following decimal and binary values.

<table>
<thead>
<tr>
<th>SET Member</th>
<th>Decimal Value</th>
<th>Binary Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>'a'</td>
<td>1</td>
<td>0001</td>
</tr>
<tr>
<td>'b'</td>
<td>2</td>
<td>0010</td>
</tr>
<tr>
<td>'c'</td>
<td>4</td>
<td>0100</td>
</tr>
<tr>
<td>'d'</td>
<td>8</td>
<td>1000</td>
</tr>
</tbody>
</table>

If you assign a value of 9 to this column, that is 1001 in binary, so the first and fourth SET value members 'a' and 'd' are selected and the resulting value is 'a,d'.

For a value containing more than one SET element, it does not matter what order the elements are listed in when you insert the value. It also does not matter how many times a given element is listed in the value. When the value is retrieved later, each element in the value appears once, with elements listed according to the order in which they were specified at table creation time. Suppose that a column is specified as SET('a','b','c','d'):

```
mysql> CREATE TABLE myset (col SET('a', 'b', 'c', 'd'));
```

If you insert the values 'a,d', 'd,a', 'a,d,d', 'a,d,a', and 'd,a,d':

```
mysql> INSERT INTO myset (col) VALUES ('a,d'), ('d,a'), ('a,d,d'), ('a,d,a'), ('d,a,d');
Query OK, 5 rows affected (0.01 sec)
Records: 5  Duplicates: 0  Warnings: 0
```

Then all these values appear as 'a,d' when retrieved:

```
mysql> SELECT col FROM myset;
+------+
<table>
<thead>
<tr>
<th>col</th>
</tr>
</thead>
<tbody>
<tr>
<td>a,d</td>
</tr>
<tr>
<td>a,d</td>
</tr>
<tr>
<td>a,d</td>
</tr>
<tr>
<td>a,d</td>
</tr>
<tr>
<td>a,d</td>
</tr>
</tbody>
</table>
+------+
5 rows in set (0.04 sec)
```

If you set a SET column to an unsupported value, the value is ignored and a warning is issued:

```
mysql> INSERT INTO myset (col) VALUES ('a,d,d,s');
Query OK, 1 row affected, 1 warning (0.03 sec)
```

```
mysql> SHOW WARNINGS;
+---------+------+------------------------------------------+
| Level   | Code | Message                                  |
|---------+------|------------------------------------------+
| Warning | 1265 | Data truncated for column 'col' at row 1 |
+---------+------|------------------------------------------+
```
If strict SQL mode is enabled, attempts to insert invalid `SET` values result in an error.

`SET` values are sorted numerically. `NULL` values sort before non-`NULL` `SET` values.

Functions such as `SUM()` or `AVG()` that expect a numeric argument cast the argument to a number if necessary. For `SET` values, the cast operation causes the numeric value to be used.

Normally, you search for `SET` values using the `FIND_IN_SET()` function or the `LIKE` operator:

```
mysql> SELECT * FROM tbl_name WHERE FIND_IN_SET('value', set_col)>0;
```

```
mysql> SELECT * FROM tbl_name WHERE set_col LIKE '%value%';
```

The first statement finds rows where `set_col` contains the `value` set member. The second is similar, but not the same: It finds rows where `set_col` contains `value` anywhere, even as a substring of another set member.

The following statements also are permitted:

```
mysql> SELECT * FROM tbl_name WHERE set_col & 1;
mysql> SELECT * FROM tbl_name WHERE set_col = 'val1,val2';
```

The first of these statements looks for values containing the first set member. The second looks for an exact match. Be careful with comparisons of the second type. Comparing set values to `'val1,val2'` returns different results than comparing values to `'val2,val1'`. You should specify the values in the same order they are listed in the column definition.

To determine all possible values for a `SET` column, use `SHOW COLUMNS FROM tbl_name LIKE set_col` and parse the `SET` definition in the `Type` column of the output.

In the C API, `SET` values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 23.7.4, “C API Data Structures”.

### 11.4 Spatial Data Types

The [Open Geospatial Consortium](http://www.opengeospatial.org) (OGC) is an international consortium of more than 250 companies, agencies, and universities participating in the development of publicly available conceptual solutions that can be useful with all kinds of applications that manage spatial data.

The Open Geospatial Consortium publishes the [OpenGIS® Implementation Standard for Geographic information - Simple Feature Access - Part 2: SQL Option](http://www.opengeospatial.org/standards/sfs), a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. This specification is available from the OGC website at [http://www.opengeospatial.org/standards/sfs](http://www.opengeospatial.org/standards/sfs).

Following the OGC specification, MySQL implements spatial extensions as a subset of the [SQL with Geometry Types](http://www.opengeospatial.org/standards/sfs) environment. This term refers to an SQL environment that has been extended with a set
of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. The specification describes a set of SQL geometry types, as well as functions on those types to create and analyze geometry values.

MySQL spatial extensions enable the generation, storage, and analysis of geographic features:

- Data types for representing spatial values
- Functions for manipulating spatial values
- Spatial indexing for improved access times to spatial columns

The spatial data types and functions are available for MyISAM, InnoDB, NDB, and ARCHIVE tables. For indexing spatial columns, MyISAM supports both SPATIAL and non-SPATIAL indexes. The other storage engines support non-SPATIAL indexes, as described in Section 13.1.13, “CREATE INDEX Statement”.

A **geographic feature** is anything in the world that has a location. A feature can be:

- An entity. For example, a mountain, a pond, a city.
- A space. For example, town district, the tropics.
- A definable location. For example, a crossroad, as a particular place where two streets intersect.

Some documents use the term **geospatial feature** to refer to geographic features.

**Geometry** is another word that denotes a geographic feature. Originally the word geometry meant measurement of the earth. Another meaning comes from cartography, referring to the geometric features that cartographers use to map the world.

The discussion here considers these terms synonymous: **geographic feature**, **geospatial feature**, **feature**, or **geometry**. The term most commonly used is **geometry**, defined as **a point or an aggregate of points representing anything in the world that has a location**.

The following material covers these topics:

- The spatial data types implemented in MySQL model
- The basis of the spatial extensions in the OpenGIS geometry model
- Data formats for representing spatial data
- How to use spatial data in MySQL
- Use of indexing for spatial data
- MySQL differences from the OpenGIS specification

For information about functions that operate on spatial data, see Section 12.16, “Spatial Analysis Functions”.

**MySQL GIS Conformance and Compatibility**

MySQL does not implement the following GIS features:

- Additional Metadata Views
OpenGIS specifications propose several additional metadata views. For example, a system view named `GEOMETRY_COLUMNS` contains a description of geometry columns, one row for each geometry column in the database.

- The OpenGIS function `Length()` on `LineString` and `MultiLineString` should be called in MySQL as `GLength()`.

The problem is that there is an existing SQL function `Length()` that calculates the length of string values, and sometimes it is not possible to distinguish whether the function is called in a textual or spatial context.

**Additional Resources**


If you have questions or concerns about the use of the spatial extensions to MySQL, you can discuss them in the GIS forum: [https://forums.mysql.com/list.php?23](https://forums.mysql.com/list.php?23).

### 11.4.1 Spatial Data Types

MySQL has spatial data types that correspond to OpenGIS classes. The basis for these types is described in Section 11.4.2, “The OpenGIS Geometry Model”.

Some spatial data types hold single geometry values:

- `GEOMETRY`
- `POINT`
- `LINESTRING`
- `POLYGON`

`GEOMETRY` can store geometry values of any type. The other single-value types (`POINT`, `LINESTRING`, and `POLYGON`) restrict their values to a particular geometry type.

The other spatial data types hold collections of values:

- `MULTIPOINT`
- `MULTILINESTRING`
- `MULTIPOLYGON`
- `GEOMETRYCOLLECTION`

`GEOMETRYCOLLECTION` can store a collection of objects of any type. The other collection types (`MULTIPOINT`, `MULTILINESTRING`, and `MULTIPOLYGON`) restrict collection members to those having a particular geometry type.

Example: To create a table named `geom` that has a column named `g` that can store values of any geometry type, use this statement:
CREATE TABLE geom (g GEOMETRY);

**SPATIAL** indexes can be created on **NOT NULL** spatial columns, so if you plan to index the column, declare it **NOT NULL**:

CREATE TABLE geom (g GEOMETRY NOT NULL);

For other examples showing how to use spatial data types in MySQL, see Section 11.4.4, “Creating Spatial Columns”.

### 11.4.2 The OpenGIS Geometry Model

The set of geometry types proposed by OGC’s **SQL with Geometry Types** environment is based on the **OpenGIS Geometry Model**. In this model, each geometric object has the following general properties:

- It is associated with a spatial reference system, which describes the coordinate space in which the object is defined.
- It belongs to some geometry class.

#### 11.4.2.1 The Geometry Class Hierarchy

The geometry classes define a hierarchy as follows:

- **Geometry** (noninstantiable)
  - **Point** (instantiable)
  - **Curve** (noninstantiable)
    - **LineString** (instantiable)
      - **Line**
      - **LinearRing**
  - **Surface** (noninstantiable)
    - **Polygon** (instantiable)
    - **GeometryCollection** (instantiable)
      - **MultiPoint** (instantiable)
      - **MultiCurve** (noninstantiable)
        - **MultiLineString** (instantiable)
      - **MultiSurface** (noninstantiable)
      - **MultiPolygon** (instantiable)

It is not possible to create objects in noninstantiable classes. It is possible to create objects in instantiable classes. All classes have properties, and instantiable classes may also have assertions (rules that define valid class instances).

**Geometry** is the base class. It is an abstract class. The instantiable subclasses of **Geometry** are restricted to zero-, one-, and two-dimensional geometric objects that exist in two-dimensional coordinate
space. All instantiable geometry classes are defined so that valid instances of a geometry class are
topologically closed (that is, all defined geometries include their boundary).

The base **Geometry** class has subclasses for **Point**, **Curve**, **Surface**, and **GeometryCollection**:

- **Point** represents zero-dimensional objects.
- **Curve** represents one-dimensional objects, and has subclass **LineString**, with sub-subclasses **Line**
  and **LinearRing**.
- **Surface** is designed for two-dimensional objects and has subclass **Polygon**.
- **GeometryCollection** has specialized zero-, one-, and two-dimensional collection classes named
  **MultiPoint**, **MultiLineString**, and **MultiPolygon** for modeling geometries corresponding to
collections of **Points**, **LineStrings**, and **Polygons**, respectively. **MultiCurve** and **MultiSurface**
  are introduced as abstract superclasses that generalize the collection interfaces to handle **Curves** and
  **Surfaces**.

**Geometry**, **Curve**, **Surface**, **MultiCurve**, and **MultiSurface** are defined as noninstantiable classes.
They define a common set of methods for their subclasses and are included for extensibility.

**Point**, **LineString**, **Polygon**, **GeometryCollection**, **MultiPoint**, **MultiLineString**, and
**MultiPolygon** are instantiable classes.

### 11.4.2.2 Geometry Class

**Geometry** is the root class of the hierarchy. It is a noninstantiable class but has a number of properties,
described in the following list, that are common to all geometry values created from any of the **Geometry**
subclasses. Particular subclasses have their own specific properties, described later.

#### Geometry Properties

A geometry value has the following properties:

- **Its type.** Each geometry belongs to one of the instantiable classes in the hierarchy.
- **Its SRID**, or spatial reference identifier. This value identifies the geometry's associated spatial reference
  system that describes the coordinate space in which the geometry object is defined.

  In MySQL, the SRID value is an integer associated with the geometry value. The maximum usable SRID
  value is $2^{32} - 1$. If a larger value is given, only the lower 32 bits are used. All computations are done
  assuming SRID 0, regardless of the actual SRID value. SRID 0 represents an infinite flat Cartesian plane
  with no units assigned to its axes.

  - **Its coordinates** in its spatial reference system, represented as double-precision (8-byte) numbers.
    All nonempty geometries include at least one pair of (X,Y) coordinates. Empty geometries contain no
    coordinates.

  Coordinates are related to the SRID. For example, in different coordinate systems, the distance between
two objects may differ even when objects have the same coordinates, because the distance on the
**planar** coordinate system and the distance on the **geodetic** system (coordinates on the Earth's surface)
are different things.

- **Its interior, boundary, and exterior.**

Every geometry occupies some position in space. The exterior of a geometry is all space not occupied
by the geometry. The interior is the space occupied by the geometry. The boundary is the interface
between the geometry's interior and exterior.
The OpenGIS Geometry Model

- Its MBR (minimum bounding rectangle), or envelope. This is the bounding geometry, formed by the minimum and maximum (X,Y) coordinates:

\[((\text{MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY})\]

- Whether the value is simple or nonsimple. Geometry values of types (LineString, MultiPoint, MultiLineString) are either simple or nonsimple. Each type determines its own assertions for being simple or nonsimple.

- Whether the value is closed or not closed. Geometry values of types (LineString, MultiString) are either closed or not closed. Each type determines its own assertions for being closed or not closed.

- Whether the value is empty or nonempty. A geometry is empty if it does not have any points. Exterior, interior, and boundary of an empty geometry are not defined (that is, they are represented by a NULL value). An empty geometry is defined to be always simple and has an area of 0.

- Its dimension. A geometry can have a dimension of −1, 0, 1, or 2:
  - −1 for an empty geometry.
  - 0 for a geometry with no length and no area.
  - 1 for a geometry with nonzero length and zero area.
  - 2 for a geometry with nonzero area.

  Point objects have a dimension of zero. LineString objects have a dimension of 1. Polygon objects have a dimension of 2. The dimensions of MultiPoint, MultiLineString, and MultiPolygon objects are the same as the dimensions of the elements they consist of.

11.4.2.3 Point Class

A Point is a geometry that represents a single location in coordinate space.

**Point Examples**

- Imagine a large-scale map of the world with many cities. A Point object could represent each city.
- On a city map, a Point object could represent a bus stop.

**Point Properties**

- X-coordinate value.
- Y-coordinate value.
- Point is defined as a zero-dimensional geometry.
- The boundary of a Point is the empty set.

11.4.2.4 Curve Class

A Curve is a one-dimensional geometry, usually represented by a sequence of points. Particular subclasses of Curve define the type of interpolation between points. Curve is a noninstantiable class.

**Curve Properties**

- A Curve has the coordinates of its points.
• A Curve is defined as a one-dimensional geometry.
• A Curve is simple if it does not pass through the same point twice, with the exception that a curve can still be simple if the start and end points are the same.
• A Curve is closed if its start point is equal to its endpoint.
• The boundary of a closed Curve is empty.
• The boundary of a nonclosed Curve consists of its two endpoints.
• A Curve that is simple and closed is a LinearRing.

11.4.2.5 LineString Class

A LineString is a Curve with linear interpolation between points.

LineString Examples
• On a world map, LineString objects could represent rivers.
• In a city map, LineString objects could represent streets.

LineString Properties
• A LineString has coordinates of segments, defined by each consecutive pair of points.
• A LineString is a Line if it consists of exactly two points.
• A LineString is a LinearRing if it is both closed and simple.

11.4.2.6 Surface Class

A Surface is a two-dimensional geometry. It is a noninstantiable class. Its only instantiable subclass is Polygon.

Surface Properties
• A Surface is defined as a two-dimensional geometry.
• The OpenGIS specification defines a simple Surface as a geometry that consists of a single “patch” that is associated with a single exterior boundary and zero or more interior boundaries.
• The boundary of a simple Surface is the set of closed curves corresponding to its exterior and interior boundaries.

11.4.2.7 Polygon Class

A Polygon is a planar Surface representing a multisided geometry. It is defined by a single exterior boundary and zero or more interior boundaries, where each interior boundary defines a hole in the Polygon.

Polygon Examples
• On a region map, Polygon objects could represent forests, districts, and so on.

Polygon Assertions
• The boundary of a Polygon consists of a set of LinearRing objects (that is, LineString objects that are both simple and closed) that make up its exterior and interior boundaries.
- A `Polygon` has no rings that cross. The rings in the boundary of a `Polygon` may intersect at a `Point`, but only as a tangent.

- A `Polygon` has no lines, spikes, or punctures.

- A `Polygon` has an interior that is a connected point set.

- A `Polygon` may have holes. The exterior of a `Polygon` with holes is not connected. Each hole defines a connected component of the exterior.

The preceding assertions make a `Polygon` a simple geometry.

### 11.4.2.8 GeometryCollection Class

A `GeometryCollection` is a geometry that is a collection of zero or more geometries of any class.

All the elements in a geometry collection must be in the same spatial reference system (that is, in the same coordinate system). There are no other constraints on the elements of a geometry collection, although the subclasses of `GeometryCollection` described in the following sections may restrict membership. Restrictions may be based on:

- Element type (for example, a `MultiPoint` may contain only `Point` elements)
- Dimension
- Constraints on the degree of spatial overlap between elements

### 11.4.2.9 MultiPoint Class

A `MultiPoint` is a geometry collection composed of `Point` elements. The points are not connected or ordered in any way.

**MultiPoint Examples**

- On a world map, a `MultiPoint` could represent a chain of small islands.

- On a city map, a `MultiPoint` could represent the outlets for a ticket office.

**MultiPoint Properties**

- A `MultiPoint` is a zero-dimensional geometry.

- A `MultiPoint` is simple if no two of its `Point` values are equal (have identical coordinate values).

- The boundary of a `MultiPoint` is the empty set.

### 11.4.2.10 MultiCurve Class

A `MultiCurve` is a geometry collection composed of `Curve` elements. `MultiCurve` is a noninstantiable class.

**MultiCurve Properties**

- A `MultiCurve` is a one-dimensional geometry.

- A `MultiCurve` is simple if and only if all of its elements are simple; the only intersections between any two elements occur at points that are on the boundaries of both elements.
• A MultiCurve boundary is obtained by applying the “mod 2 union rule” (also known as the “odd-even rule”): A point is in the boundary of a MultiCurve if it is in the boundaries of an odd number of Curve elements.

• A MultiCurve is closed if all of its elements are closed.

• The boundary of a closed MultiCurve is always empty.

11.4.2.11 MultiLineString Class

A MultiLineString is a MultiCurve geometry collection composed of LineString elements.

MultiLineString Examples

• On a region map, a MultiLineString could represent a river system or a highway system.

11.4.2.12 MultiSurface Class

A MultiSurface is a geometry collection composed of surface elements. MultiSurface is a noninstantiable class. Its only instantiable subclass is MultiPolygon.

MultiSurface Assertions

• Surfaces within a MultiSurface have no interiors that intersect.

• Surfaces within a MultiSurface have boundaries that intersect at most at a finite number of points.

11.4.2.13 MultiPolygon Class

A MultiPolygon is a MultiSurface object composed of Polygon elements.

MultiPolygon Examples

• On a region map, a MultiPolygon could represent a system of lakes.

MultiPolygon Assertions

• A MultiPolygon has no two Polygon elements with interiors that intersect.

• A MultiPolygon has no two Polygon elements that cross (crossing is also forbidden by the previous assertion), or that touch at an infinite number of points.

• A MultiPolygon may not have cut lines, spikes, or punctures. A MultiPolygon is a regular, closed point set.

• A MultiPolygon that has more than one Polygon has an interior that is not connected. The number of connected components of the interior of a MultiPolygon is equal to the number of Polygon values in the MultiPolygon.

MultiPolygon Properties

• A MultiPolygon is a two-dimensional geometry.

• A MultiPolygon boundary is a set of closed curves (LineString values) corresponding to the boundaries of its Polygon elements.

• Each Curve in the boundary of the MultiPolygon is in the boundary of exactly one Polygon element.
• Every Curve in the boundary of an Polygon element is in the boundary of the MultiPolygon.

11.4.3 Supported Spatial Data Formats

Two standard spatial data formats are used to represent geometry objects in queries:

• Well-Known Text (WKT) format

• Well-Known Binary (WKB) format

Internally, MySQL stores geometry values in a format that is not identical to either WKT or WKB format. (Internal format is like WKB but with an initial 4 bytes to indicate the SRID.)

There are functions available to convert between different data formats; see Section 12.16.6, “Geometry Format Conversion Functions”.

The following sections describe the spatial data formats MySQL uses:

• Well-Known Text (WKT) Format

• Well-Known Binary (WKB) Format

• Internal Geometry Storage Format

Well-Known Text (WKT) Format

The Well-Known Text (WKT) representation of geometry values is designed for exchanging geometry data in ASCII form. The OpenGIS specification provides a Backus-Naur grammar that specifies the formal production rules for writing WKT values (see Section 11.4, “Spatial Data Types”).

Examples of WKT representations of geometry objects:

• A Point:

```
POINT(15 20)
```

The point coordinates are specified with no separating comma. This differs from the syntax for the SQL Point() function, which requires a comma between the coordinates. Take care to use the syntax appropriate to the context of a given spatial operation. For example, the following statements both use X() to extract the X-coordinate from a Point object. The first produces the object directly using the Point() function. The second uses a WKT representation converted to a Point with GeomFromText().

```
mysql> SELECT X(Point(15, 20));
+------------------+
| X(POINT(15, 20)) |
+------------------+
|               15 |
+------------------+

mysql> SELECT X(GeomFromText('POINT(15 20)'));
+---------------------------------+
| X(GeomFromText('POINT(15 20)')) |
+---------------------------------+
|                              15 |
+---------------------------------+
```

• A LineString with four points:

```
LINESTRING(0 0, 10 10, 20 25, 50 60)
```
The point coordinate pairs are separated by commas.

- A **Polygon** with one exterior ring and one interior ring:
  
  ```
  POLYGON((0 0, 10 0, 10 10, 0 10, 0 0), (5 5, 7 5, 7 7, 5 5, 5 5))
  ```

- A **MultiPoint** with three **Point** values:
  
  ```
  MULTIPONT(0 0, 20 20, 60 60)
  ```

- A **MultiLineString** with two **LineString** values:
  
  ```
  MULTILINESTRING((10 10, 20 20), (15 15, 30 15))
  ```

- A **MultiPolygon** with two **Polygon** values:
  
  ```
  MULTIPOLYGON(((0 0, 10 0, 10 10, 0 10, 0 0)), ((5 5, 7 5, 7 7, 5 5, 5 5)))
  ```

- A **GeometryCollection** consisting of two **Point** values and one **LineString**:
  
  ```
  GEOMETRYCOLLECTION(POINT(10 10), POINT(30 30), LINESTRING(15 15, 20 20))
  ```

**Well-Known Binary (WKB) Format**

The Well-Known Binary (WKB) representation of geometric values is used for exchanging geometry data as binary streams represented by **BLOB** values containing geometric WKB information. This format is defined by the OpenGIS specification (see Section 11.4, “Spatial Data Types”). It is also defined in the ISO SQL/MM Part 3: Spatial standard.

WKB uses 1-byte unsigned integers, 4-byte unsigned integers, and 8-byte double-precision numbers (IEEE 754 format). A byte is eight bits.

For example, a WKB value that corresponds to **POINT(1 -1)** consists of this sequence of 21 bytes, each represented by two hexadecimal digits:

```
0101000000000000000000F03F00000000000F0BF
```

The sequence consists of the components shown in the following table.

**Table 11.2 WKB Components Example**

<table>
<thead>
<tr>
<th>Component</th>
<th>Size</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Byte order</td>
<td>1 byte</td>
<td>01</td>
</tr>
<tr>
<td>WKB type</td>
<td>4 bytes</td>
<td>01000000</td>
</tr>
<tr>
<td>X coordinate</td>
<td>8 bytes</td>
<td>0000000000000000F03F</td>
</tr>
<tr>
<td>Y coordinate</td>
<td>8 bytes</td>
<td>0000000000000000F0BF</td>
</tr>
</tbody>
</table>

Component representation is as follows:

- The byte order indicator is either 1 or 0 to signify little-endian or big-endian storage. The little-endian and big-endian byte orders are also known as Network Data Representation (NDR) and External Data Representation (XDR), respectively.

- The WKB type is a code that indicates the geometry type. MySQL uses values from 1 through 7 to indicate **Point**, **LineString**, **Polygon**, **MultiPoint**, **MultiLineString**, **MultiPolygon**, and **GeometryCollection**.
Creating Spatial Columns

• A **Point** value has X and Y coordinates, each represented as a double-precision value.

WKB values for more complex geometry values have more complex data structures, as detailed in the OpenGIS specification.

**Internal Geometry Storage Format**

MySQL stores geometry values using 4 bytes to indicate the SRID followed by the WKB representation of the value. For a description of WKB format, see **Well-Known Binary (WKB) Format**.

For the WKB part, these MySQL-specific considerations apply:

• The byte-order indicator byte is 1 because MySQL stores geometries as little-ending values.

• MySQL supports geometry types of **Point**, **LineString**, **Polygon**, **MultiPoint**, **MultiLineString**, **MultiPolygon**, and **GeometryCollection**. Other geometry types are not supported.

The **LENGTH()** function returns the space in bytes required for value storage. Example:

```sql
mysql> SET @g = GeomFromText('POINT(1 -1)');
mysql> SELECT LENGTH(@g);
+------------+
| LENGTH(@g) |
+------------+
|         25 |
mysql> SELECT HEX(@g);
+----------------------------------------------------+
| HEX(@g)                                            |
| 000000000101000000000000000000F03F0000000000000F0BF |
+----------------------------------------------------+
```

The value length is 25 bytes, made up of these components (as can be seen from the hexadecimal value):

• 4 bytes for integer SRID (0)

• 1 byte for integer byte order (1 = little-endian)

• 4 bytes for integer type information (1 = **Point**)

• 8 bytes for double-precision X coordinate (1)

• 8 bytes for double-precision Y coordinate (−1)

**11.4.4 Creating Spatial Columns**

MySQL provides a standard way of creating spatial columns for geometry types, for example, with **CREATE TABLE** or **ALTER TABLE**. Spatial columns are supported for **MyISAM**, **InnoDB**, **NDB**, and **ARCHIVE** tables. See also the notes about spatial indexes under Section 11.4.8, “Creating Spatial Indexes”.

• Use the **CREATE TABLE** statement to create a table with a spatial column:

  ```sql
  CREATE TABLE geom (g GEOMETRY);
  ```

• Use the **ALTER TABLE** statement to add or drop a spatial column to or from an existing table:

  ```sql
  ALTER TABLE geom ADD pt POINT;
  ALTER TABLE geom DROP pt;
  ```
11.4.5 Populating Spatial Columns

After you have created spatial columns, you can populate them with spatial data.

Values should be stored in internal geometry format, but you can convert them to that format from either Well-Known Text (WKT) or Well-Known Binary (WKB) format. The following examples demonstrate how to insert geometry values into a table by converting WKT values to internal geometry format:

- Perform the conversion directly in the `INSERT` statement:

```sql
INSERT INTO geom VALUES (GeomFromText('POINT(1 1)'));
SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (GeomFromText(@g));
```

- Perform the conversion prior to the `INSERT`:

```sql
SET @g = GeomFromText('POINT(1 1)');
INSERT INTO geom VALUES (@g);
```

The following examples insert more complex geometries into the table:

```sql
SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (GeomFromText(@g));
SET @g = 'POLYGON((0,10,0,10,0,0),(5,5,7,5,7,5,5))';
INSERT INTO geom VALUES (GeomFromText(@g));
SET @g = 'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0,1,2,3,4))';
INSERT INTO geom VALUES (GeomFromText(@g));
```

The preceding examples use `GeomFromText()` to create geometry values. You can also use type-specific functions:

```sql
SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (PointFromText(@g));
SET @g = 'LINESTRING(0,1,2)';
INSERT INTO geom VALUES (LineStringFromText(@g));
SET @g = 'POLYGON((0,10,0,10,0,0),(5,5,7,5,7,5,5))';
INSERT INTO geom VALUES (PolygonFromText(@g));
SET @g = 'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0,1,2,3,4))';
INSERT INTO geom VALUES (GeomCollFromText(@g));
```

A client application program that wants to use WKB representations of geometry values is responsible for sending correctly formed WKB in queries to the server. There are several ways to satisfy this requirement. For example:

- Inserting a `POINT(1 1)` value with hex literal syntax:

```sql
INSERT INTO geom VALUES (GeomFromWKB(X'01010000000000000000F03F0000000000000F3F'));
```

- An ODBC application can send a WKB representation, binding it to a placeholder using an argument of `BLOB` type:

```sql
INSERT INTO geom VALUES (GeomFromWKB(?))
```

Other programming interfaces may support a similar placeholder mechanism.
11.4.6 Fetching Spatial Data

Geometry values stored in a table can be fetched in internal format. You can also convert them to WKT or WKB format.

- Fetching spatial data in internal format:
  Fetching geometry values using internal format can be useful in table-to-table transfers:
  ```
  CREATE TABLE geom2 (g GEOMETRY) SELECT g FROM geom;
  ```

- Fetching spatial data in WKT format:
  The `AsText()` function converts a geometry from internal format to a WKT string.
  ```
  SELECT AsText(g) FROM geom;
  ```

- Fetching spatial data in WKB format:
  The `AsBinary()` function converts a geometry from internal format to a `BLOB` containing the WKB value.
  ```
  SELECT AsBinary(g) FROM geom;
  ```

11.4.7 Optimizing Spatial Analysis

For `MyISAM` tables, search operations in columns containing spatial data can be optimized using `SPATIAL` indexes. The most typical operations are:

- Point queries that search for all objects that contain a given point
- Region queries that search for all objects that overlap a given region

MySQL uses R-Trees with quadratic splitting for `SPATIAL` indexes on spatial columns. A `SPATIAL` index is built using the minimum bounding rectangle (MBR) of a geometry. For most geometries, the MBR is a minimum rectangle that surrounds the geometries. For a horizontal or a vertical linestring, the MBR is a rectangle degenerated into the linestring. For a point, the MBR is a rectangle degenerated into the point.

It is also possible to create normal indexes on spatial columns. In a non-`SPATIAL` index, you must declare a prefix for any spatial column except for `POINT` columns.

`MyISAM` supports both `SPATIAL` and non-`SPATIAL` indexes. Other storage engines support non-`SPATIAL` indexes, as described in Section 13.1.13, “CREATE INDEX Statement”.

11.4.8 Creating Spatial Indexes

For `MyISAM` tables, MySQL can create spatial indexes using syntax similar to that for creating regular indexes, but using the `SPATIAL` keyword. Columns in spatial indexes must be declared `NOT NULL`. The following examples demonstrate how to create spatial indexes:

- With `CREATE TABLE`:
  ```
  CREATE TABLE geom (g GEOMETRY NOT NULL, SPATIAL INDEX(g)) ENGINE=MyISAM;
  ```

- With `ALTER TABLE`:
Using Spatial Indexes

CREATE TABLE geom (g GEOMETRY NOT NULL) ENGINE=MyISAM;
ALTER TABLE geom ADD SPATIAL INDEX(g);

- With CREATE INDEX:

CREATE TABLE geom (g GEOMETRY NOT NULL) ENGINE=MyISAM;
CREATE SPATIAL INDEX g ON geom (g);

**SPATIAL INDEX** creates an R-tree index. For storage engines that support nonspatial indexing of spatial columns, the engine creates a B-tree index. A B-tree index on spatial values is useful for exact-value lookups, but not for range scans.

For more information on indexing spatial columns, see Section 13.1.13, "CREATE INDEX Statement".

To drop spatial indexes, use **ALTER TABLE or DROP INDEX**:

- With ALTER TABLE:

ALTER TABLE geom DROP INDEX g;

- With DROP INDEX:

DROP INDEX g ON geom;

Example: Suppose that a table **geom** contains more than 32,000 geometries, which are stored in the column **g** of type **GEOMETRY**. The table also has an **AUTO_INCREMENT** column **fid** for storing object ID values.

```
mysql> DESCRIBE geom;
+-------+----------+------+-----+---------+----------------+
| Field | Type     | Null | Key | Default | Extra          |
|-------+----------+------+-----+---------+----------------|
| fid   | int(11)  |      | PRI | NULL    | auto_increment |
| g     | geometry |      |     |         |                |
+-------+----------+------+-----+---------+----------------+
2 rows in set (0.00 sec)
```

```
mysql> SELECT COUNT(*) FROM geom;
+----------+
| count(*) |
+----------+
|    32376 |
+----------+
1 row in set (0.00 sec)
```

To add a spatial index on the column **g**, use this statement:

```
mysql> ALTER TABLE geom ADD SPATIAL INDEX(g) ENGINE=MyISAM;
Query OK, 32376 rows affected (4.05 sec)
Records: 32376  Duplicates: 0  Warnings: 0
```

**11.4.9 Using Spatial Indexes**

The optimizer investigates whether available spatial indexes can be involved in the search for queries that use a function such as **MBRContains()** or **MBRWithin()** in the **WHERE** clause. The following query finds all objects that are in the given rectangle:

```
mysql> SET @poly = -> 'Polygon((30000 15000,
            31000 15000,
            31000 16000,
            30000 16000,
            30000 15000));
```
Using Spatial Indexes

```sql
mysql> SELECT fid, AsText(g) FROM geom WHERE MBRContains(GeomFromText(@poly), g);
+-----+---------------------------------------------------------------+
<table>
<thead>
<tr>
<th>fid</th>
<th>AsText(g)</th>
</tr>
</thead>
</table>
|  21 | LINESTRING(30350.4 15828.8, 30350.6 15845, 30333.8 15845, 30 ...
|  22 | LINESTRING(30350.6 15871.4, 30350.6 15887.8, 30334 15887.8, ...
|  23 | LINESTRING(30350.6 15914.2, 30350.6 15930.4, 30334 15930.4, ...
|  24 | LINESTRING(30290.2 15823, 30290.2 15839.4, 30273.4 15839.4, ...
|  25 | LINESTRING(30291.4 15866.2, 30291.6 15882.4, 30274.8 15882.4, ...
|  26 | LINESTRING(30291.6 15918.2, 30291.6 15934.4, 30275 15934.4, ...
| 249 | LINESTRING(30337.8 15938.6, 30337.8 15946.8, 30320.4 15946.8, ...
|   1 | LINESTRING(30250.4 15129.2, 30248.8 15138.4, 30167 15138.4, 30...
|   2 | LINESTRING(30220.2 15122.8, 30217.2 15136, 30207.6 15136, 30...
|   3 | LINESTRING(30179 15114.4, 30176.6 15129.4, 30167 15129.4, 3016...
|   4 | LINESTRING(30155.2 15121.4, 30140.4 15118.6, 30142 15109, 30...
|   5 | LINESTRING(30192.4 15085, 30177.6 15082.2, 30179.2 15072.4, 30 ...
|   6 | LINESTRING(30244 15087, 30229 15086.2, 30229.4 15076.4, 3024 ...
|   7 | LINESTRING(30200.6 15059.4, 30185.6 15058.6, 30186 15048.8, 30 ...
|  10 | LINESTRING(30179.6 15017.8, 30181 15002.8, 30190.8 15003.6, ...
|  11 | LINESTRING(30154.2 15000.4, 30168.6 15004.8, 30166 15014.2, 30 ...
|  13 | LINESTRING(30105 15065.8, 30108.4 15050.8, 30118 15053, 3011...
|  154 | LINESTRING(30276.2 15143.8, 30261.4 15141, 30263 15131.4, 30 ...| 155 | LINESTRING(30269.8 15084, 30269.4 15093.4, 30258.6 15093, 30 ...
|  157 | LINESTRING(30128.2 15011, 30113.2 15010.2, 30113.6 15000.4, 30...
+-----+---------------------------------------------------------------+
20 rows in set (0.00 sec)
```

Use **EXPLAIN** to check the way this query is executed:

```sql
mysql> SET @poly = 'Polygon((30000 15000, 31000 15000, 31000 16000, 30000 16000, 30000 15000))';
mysql> EXPLAIN SELECT fid, AsText(g) FROM geom WHERE MBRContains(GeomFromText(@poly), g)
+-------------------------------------------------------------------+------------------------------------------------------------------+
| id: 1 | select_type: SIMPLE | table: geom |
|      | type: range |
|      | possible_keys: g |
|      | key: g |
|      | key_len: 32 |
|      | ref: NULL |
|      | rows: 50 |
|      | Extra: Using where |
1 row in set (0.00 sec)
```

Check what would happen without a spatial index:

```sql
mysql> SET @poly = 'Polygon((30000 15000, 31000 15000, 31000 16000, 30000 16000, 30000 15000))';
mysql> EXPLAIN SELECT fid, AsText(g) FROM geom WHERE MBRContains(GeomFromText(@poly), g)
+-------------------------------------------------------------------+------------------------------------------------------------------+
| id: 1 | select_type: SIMPLE | table: geom |
```

Data Type Default Values

Data type specifications can have explicit or implicit default values.

- Handling of Explicit Defaults
- Handling of Implicit Defaults

Handling of Explicit Defaults

A **DEFAULT value** clause in a data type specification explicitly indicates a default value for a column. Examples:

```sql
CREATE TABLE t1 (
    i INT DEFAULT -1,
    c VARCHAR(10) DEFAULT '',
    price DOUBLE(16,2) DEFAULT '0.00'
)
```
**Handling of Implicit Defaults**

**SERIAL DEFAULT VALUE** is a special case. In the definition of an integer column, it is an alias for *NOT NULL AUTO_INCREMENT UNIQUE*.

With one exception, the default value specified in a `DEFAULT` clause must be a literal constant; it cannot be a function or an expression. This means, for example, that you cannot set the default for a date column to be the value of a function such as `NOW()` or `CURRENT_DATE`. The exception is that, for a `TIMESTAMP` column, you can specify `CURRENT_TIMESTAMP` as the default. See Section 11.2.6, "Automatic Initialization and Updating for TIMESTAMP".

The **BLOB** and **TEXT** data types cannot be assigned a default value.

Handling of Implicit Defaults

If a data type specification includes no explicit `DEFAULT` value, MySQL determines the default value as follows:

- If the column can take `NULL` as a value, the column is defined with an explicit `DEFAULT NULL` clause.
- If the column cannot take `NULL` as a value, MySQL defines the column with no explicit `DEFAULT` clause.

Exception: If the column is defined as part of a `PRIMARY KEY` but not explicitly as `NOT NULL`, MySQL creates it as a `NOT NULL` column (because `PRIMARY KEY` columns must be `NOT NULL`), but also assigns it a `DEFAULT` clause using the implicit default value. To prevent this, include an explicit `NOT NULL` in the definition of any `PRIMARY KEY` column.

For data entry into a `NOT NULL` column that has no explicit `DEFAULT` clause, if an `INSERT` or `REPLACE` statement includes no value for the column, or an `UPDATE` statement sets the column to `NULL`, MySQL handles the column according to the SQL mode in effect at the time:

- If strict SQL mode is enabled, an error occurs for transactional tables and the statement is rolled back. For nontransactional tables, an error occurs, but if this happens for the second or subsequent row of a multiple-row statement, the preceding rows will have been inserted.
- If strict mode is not enabled, MySQL sets the column to the implicit default value for the column data type.

Suppose that a table `t` is defined as follows:

```sql
CREATE TABLE t (i INT NOT NULL);
```

In this case, `i` has no explicit default, so in strict mode each of the following statements produce an error and no row is inserted. When not using strict mode, only the third statement produces an error; the implicit default is inserted for the first two statements, but the third fails because `DEFAULT(i)` cannot produce a value:

```sql
INSERT INTO t VALUES();
INSERT INTO t VALUES(DEFAULT);
INSERT INTO t VALUES(DEFAULT(i));
```

See Section 5.1.10, "Server SQL Modes".

For a given table, the `SHOW CREATE TABLE` statement displays which columns have an explicit `DEFAULT` clause.

Implicit defaults are defined as follows:
• For numeric types, the default is 0, with the exception that for integer or floating-point types declared with the AUTO_INCREMENT attribute, the default is the next value in the sequence.

• For date and time types other than TIMESTAMP, the default is the appropriate “zero” value for the type. For the first TIMESTAMP column in a table, the default value is the current date and time. See Section 11.2, "Date and Time Data Types”.

• For string types other than ENUM, the default value is the empty string. For ENUM, the default is the first enumeration value.

11.6 Data Type Storage Requirements

• InnoDB Table Storage Requirements

• NDBCLUSTER Table Storage Requirements

• Numeric Type Storage Requirements

• Date and Time Type Storage Requirements

• String Type Storage Requirements

• Spatial Type Storage Requirements

The storage requirements for data vary, according to the storage engine being used for the table in question. Different storage engines use different methods for recording the raw data and different data types. In addition, some engines may compress the information in a given row, either on a column or entire row basis, making calculation of the storage requirements for a given table or column structure.

However, all storage engines must communicate and exchange information on a given row within a table using the same structure, and this information is consistent, irrespective of the storage engine used to write the information to disk.

This sections includes some guidelines and information for the storage requirements for each data type supported by MySQL, including details for the internal format and the sizes used by storage engines that used a fixed size representation for different types. Information is listed by category or storage engine.

The internal representation of a table has a maximum row size of 65,535 bytes, even if the storage engine is capable of supporting larger rows. This figure excludes BLOB or TEXT columns, which contribute only 9 to 12 bytes toward this size. For BLOB and TEXT data, the information is stored internally in a different area of memory than the row buffer. Different storage engines handle the allocation and storage of this data in different ways, according to the method they use for handling the corresponding types. For more information, see Chapter 15, Alternative Storage Engines, and Section 8.4.7, “Limits on Table Column Count and Row Size”.

InnoDB Table Storage Requirements

See Section 14.14, “InnoDB Row Formats” for information about storage requirements for InnoDB tables.

NDBCLUSTER Table Storage Requirements

Important

For tables using the NDBCLUSTER storage engine, there is the factor of 4-byte alignment to be taken into account when calculating storage requirements. This
Numeric Type Storage Requirements

means that all NDB data storage is done in multiples of 4 bytes. Thus, a column value that would take 15 bytes in a table using a storage engine other than NDB requires 16 bytes in an NDB table. This requirement applies in addition to any other considerations that are discussed in this section. For example, in NDBCLUSTER tables, the TINYINT, SMALLINT, MEDIUMINT, and INTEGER (INT) column types each require 4 bytes storage per record due to the alignment factor.

An exception to this rule is the BIT type, which is not 4-byte aligned. In NDB Cluster tables, a BIT(M) column takes M bits of storage space. However, if a table definition contains 1 or more BIT columns (up to 32 BIT columns), then NDBCLUSTER reserves 4 bytes (32 bits) per row for these. If a table definition contains more than 32 BIT columns (up to 64 such columns), then NDBCLUSTER reserves 8 bytes (that is, 64 bits) per row.

In addition, while a NULL itself does not require any storage space, NDBCLUSTER reserves 4 bytes per row if the table definition contains any columns defined as NULL, up to 32 NULL columns. (If an NDB Cluster table is defined with more than 32 NULL columns up to 64 NULL columns, then 8 bytes per row is reserved.)

When calculating storage requirements for NDB Cluster tables, you must also remember that every table using the NDBCLUSTER storage engine requires a primary key; if no primary key is defined by the user, then a “hidden” primary key will be created by NDB. This hidden primary key consumes 31-35 bytes per table record.

You may find the ndb_size.pl utility to be useful for estimating NDB storage requirements. This Perl script connects to a current MySQL (non-Cluster) database and creates a report on how much space that database would require if it used the NDBCLUSTER storage engine. See Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”, for more information.

### Numeric Type Storage Requirements

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Storage Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>TINYINT</td>
<td>1 byte</td>
</tr>
<tr>
<td>SMALLINT</td>
<td>2 bytes</td>
</tr>
<tr>
<td>MEDIUMINT</td>
<td>3 bytes</td>
</tr>
<tr>
<td>INT, INTEGER</td>
<td>4 bytes</td>
</tr>
<tr>
<td>BIGINT</td>
<td>8 bytes</td>
</tr>
<tr>
<td>FLOAT(p)</td>
<td>4 bytes if 0 &lt;= p &lt;= 24, 8 bytes if 25 &lt;= p &lt;= 53</td>
</tr>
<tr>
<td>FLOAT</td>
<td>4 bytes</td>
</tr>
<tr>
<td>DOUBLE [PRECISION], REAL</td>
<td>8 bytes</td>
</tr>
<tr>
<td>DECIMAL(M, D), NUMERIC(M, D)</td>
<td>Varies; see following discussion</td>
</tr>
<tr>
<td>BIT(M)</td>
<td>approximately (M+7)/8 bytes</td>
</tr>
</tbody>
</table>

Values for DECIMAL (and NUMERIC) columns are represented using a binary format that packs nine decimal (base 10) digits into four bytes. Storage for the integer and fractional parts of each value are determined separately. Each multiple of nine digits requires four bytes, and the “leftover” digits require some fraction of four bytes. The storage required for excess digits is given by the following table.

<table>
<thead>
<tr>
<th>Leftover Digits</th>
<th>Number of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Date and Time Type Storage Requirements

<table>
<thead>
<tr>
<th>Leftover Digits</th>
<th>Number of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

#### String Type Storage Requirements

In the following table, \( M \) represents the declared column length in characters for nonbinary string types and bytes for binary string types. \( L \) represents the actual length in bytes of a given string value.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Storage Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAR((M))</td>
<td>The compact family of InnoDB row formats optimize storage for variable-length character sets. See COMPACT Row Format Storage Characteristics. Otherwise, ( M \times w ) bytes, ( 0 \leq M \leq 255 ), where ( w ) is the number of bytes required for the maximum-length character in the character set.</td>
</tr>
<tr>
<td>BINARY((M))</td>
<td>( M ) bytes, ( 0 \leq M \leq 255 )</td>
</tr>
<tr>
<td>VARCHAR((M)), VARBINARY((M))</td>
<td>( L + 1 ) bytes if column values require ( 0 - 255 ) bytes, ( L + 2 ) bytes if values may require more than ( 255 ) bytes</td>
</tr>
<tr>
<td>TINYBLOB, TINYTEXT</td>
<td>( L + 1 ) bytes, where ( L &lt; 2^8 )</td>
</tr>
<tr>
<td>BLOB, TEXT</td>
<td>( L + 2 ) bytes, where ( L &lt; 2^{16} )</td>
</tr>
<tr>
<td>MEDIUMBLOB, MEDIUMTEXT</td>
<td>( L + 3 ) bytes, where ( L &lt; 2^{24} )</td>
</tr>
<tr>
<td>LONGBLOB, LONGTEXT</td>
<td>( L + 4 ) bytes, where ( L &lt; 2^{32} )</td>
</tr>
<tr>
<td>ENUM('value1', 'value2', ...)</td>
<td>1 or 2 bytes, depending on the number of enumeration values (65,535 values maximum)</td>
</tr>
<tr>
<td>SET('value1', 'value2', ...)</td>
<td>1, 2, 3, 4, or 8 bytes, depending on the number of set members (64 members maximum)</td>
</tr>
</tbody>
</table>

For details about internal representation of temporal values, see MySQL Internals: Important Algorithms and Structures.
Variable-length string types are stored using a length prefix plus data. The length prefix requires from one to four bytes depending on the data type, and the value of the prefix is \( L \) (the byte length of the string). For example, storage for a \texttt{MEDIUMTEXT} value requires \( L \) bytes to store the value plus three bytes to store the length of the value.

To calculate the number of bytes used to store a particular \texttt{CHAR}, \texttt{VARCHAR}, or \texttt{TEXT} column value, you must take into account the character set used for that column and whether the value contains multibyte characters. In particular, when using a \texttt{utf8} Unicode character set, you must keep in mind that not all characters use the same number of bytes. \texttt{utf8mb3} and \texttt{utf8mb4} character sets can require up to three and four bytes per character, respectively. For a breakdown of the storage used for different categories of \texttt{utf8mb3} or \texttt{utf8mb4} characters, see Section 10.9, “Unicode Support”.

\texttt{VARCHAR}, \texttt{VARBINARY}, and the \texttt{BLOB} and \texttt{TEXT} types are variable-length types. For each, the storage requirements depend on these factors:

- The actual length of the column value
- The column's maximum possible length
- The character set used for the column, because some character sets contain multibyte characters

For example, a \texttt{VARCHAR(255)} column can hold a string with a maximum length of 255 characters. Assuming that the column uses the \texttt{latin1} character set (one byte per character), the actual storage required is the length of the string (\( L \)), plus one byte to record the length of the string. For the string 'abcd', \( L \) is 4 and the storage requirement is five bytes. If the same column is instead declared to use the \texttt{ucs2} double-byte character set, the storage requirement is 10 bytes: The length of 'abcd' is eight bytes and the column requires two bytes to store lengths because the maximum length is greater than 255 (up to 510 bytes).

The effective maximum number of \textit{bytes} that can be stored in a \texttt{VARCHAR} or \texttt{VARBINARY} column is subject to the maximum row size of 65,535 bytes, which is shared among all columns. For a \texttt{VARCHAR} column that stores multibyte characters, the effective maximum number of \textit{characters} is less. For example, \texttt{utf8mb3} characters can require up to three bytes per character, so a \texttt{VARCHAR} column that uses the \texttt{utf8mb3} character set can be declared to be a maximum of 21,844 characters. See Section 8.4.7, “Limits on Table Column Count and Row Size”.

\texttt{InnoDB} encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a \texttt{CHAR(255)} column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with \texttt{utf8mb4}.

The \texttt{NDBCLUSTER} storage engine supports variable-width columns. This means that a \texttt{VARCHAR} column in an NDB Cluster table requires the same amount of storage as would any other storage engine, with the exception that such values are 4-byte aligned. Thus, the string 'abcd' stored in a \texttt{VARCHAR(50)} column using the \texttt{latin1} character set requires 8 bytes (rather than 5 bytes for the same column value in a \texttt{MyISAM} table).

\texttt{TEXT} and \texttt{BLOB} columns are implemented differently in the NDB Cluster storage engine, wherein each row in a \texttt{TEXT} column is made up of two separate parts. One of these is of fixed size (256 bytes), and is actually stored in the original table. The other consists of any data in excess of 256 bytes, which is stored in a hidden table. The rows in this second table are always 2000 bytes long. This means that the size of a \texttt{TEXT} column is 256 if \( size \leq 256 \) (where \( size \) represents the size of the row); otherwise, the size is 256 + \( size + (2000 \times \text{(size - 256) \% 2000}) \).

The size of an \texttt{ENUM} object is determined by the number of different enumeration values. One byte is used for enumerations with up to 255 possible values. Two bytes are used for enumerations having between 256 and 65,535 possible values. See Section 11.3.5, “The ENUM Type”.
Spatial Type Storage Requirements

The size of a SET object is determined by the number of different set members. If the set size is $N$, the object occupies $(N+7)/8$ bytes, rounded up to 1, 2, 3, 4, or 8 bytes. A SET can have a maximum of 64 members. See Section 11.3.6, "The SET Type".

Spatial Type Storage Requirements

MySQL stores geometry values using 4 bytes to indicate the SRID followed by the WKB representation of the value. The `LENGTH()` function returns the space in bytes required for value storage.

For descriptions of WKB and internal storage formats for spatial values, see Section 11.4.3, “Supported Spatial Data Formats”.

11.7 Choosing the Right Type for a Column

For optimum storage, you should try to use the most precise type in all cases. For example, if an integer column is used for values in the range from 1 to 99999, `MEDIUMINT UNSIGNED` is the best type. Of the types that represent all the required values, this type uses the least amount of storage.

All basic calculations (+, -, *, and /) with DECIMAL columns are done with precision of 65 decimal (base 10) digits. See Section 11.1.1, “Numeric Data Type Syntax”.

If accuracy is not too important or if speed is the highest priority, the DOUBLE type may be good enough. For high precision, you can always convert to a fixed-point type stored in a BIGINT. This enables you to do all calculations with 64-bit integers and then convert results back to floating-point values as necessary.

PROCEDURE ANALYSE can be used to obtain suggestions for optimal column data types. For more information, see Section 8.4.2.4, “Using PROCEDURE ANALYSE”.

11.8 Using Data Types from Other Database Engines

To facilitate the use of code written for SQL implementations from other vendors, MySQL maps data types as shown in the following table. These mappings make it easier to import table definitions from other database systems into MySQL.

<table>
<thead>
<tr>
<th>Other Vendor Type</th>
<th>MySQL Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOOL</td>
<td>TINYINT</td>
</tr>
<tr>
<td>BOOLEAN</td>
<td>TINYINT</td>
</tr>
<tr>
<td>CHARACTER VARYING(M)</td>
<td>VARCHAR(M)</td>
</tr>
<tr>
<td>FIXED</td>
<td>DECIMAL</td>
</tr>
<tr>
<td>FLOAT4</td>
<td>FLOAT</td>
</tr>
<tr>
<td>FLOAT8</td>
<td>DOUBLE</td>
</tr>
<tr>
<td>INT1</td>
<td>TINYINT</td>
</tr>
<tr>
<td>INT2</td>
<td>SMALLINT</td>
</tr>
<tr>
<td>INT3</td>
<td>MEDIUMINT</td>
</tr>
<tr>
<td>INT4</td>
<td>INT</td>
</tr>
<tr>
<td>INT8</td>
<td>BIGINT</td>
</tr>
<tr>
<td>LONG VARBINARY</td>
<td>MEDIUMBLOB</td>
</tr>
<tr>
<td>LONG VARCHAR</td>
<td>MEDIUMTEXT</td>
</tr>
</tbody>
</table>
Data type mapping occurs at table creation time, after which the original type specifications are discarded. If you create a table with types used by other vendors and then issue a `DESCRIBE tbl_name` statement, MySQL reports the table structure using the equivalent MySQL types. For example:

```sql
mysql> CREATE TABLE t (a BOOL, b FLOAT8, c LONG VARCHAR, d NUMERIC);
Query OK, 0 rows affected (0.00 sec)

mysql> DESCRIBE t;
+----------------+---------------+------|-----+---------+-------+
| Field          | Type          | Null | Key | Default | Extra |
+----------------+---------------+------|-----+---------+-------+
| a              | tinyint(1)    | YES  |     | NULL    |       |
| b              | double        | YES  |     | NULL    |       |
| c              | mediumtext    | YES  |     | NULL    |       |
| d              | decimal(10,0) | YES  |     | NULL    |       |
+----------------+---------------+------|-----+---------+-------+
4 rows in set (0.01 sec)
```
Chapter 12 Functions and Operators

Table of Contents

12.1 Function and Operator Reference .......................................................... 1216
12.2 Type Conversion in Expression Evaluation ............................................. 1225
12.3 Operators ............................................................................................... 1228
  12.3.1 Operator Precedence ........................................................................ 1229
  12.3.2 Comparison Functions and Operators .............................................. 1230
  12.3.3 Logical Operators ........................................................................... 1236
  12.3.4 Assignment Operators .................................................................... 1238
12.4 Control Flow Functions .......................................................................... 1239
12.5 Numeric Functions and Operators ......................................................... 1241
  12.5.1 Arithmetic Operators ....................................................................... 1242
  12.5.2 Mathematical Functions .................................................................. 1244
12.6 Date and Time Functions ......................................................................... 1253
12.7 String Functions and Operators .............................................................. 1273
  12.7.1 String Comparison Functions and Operators .................................... 1285
  12.7.2 Regular Expressions ........................................................................ 1289
  12.7.3 Character Set and Collation of Function Results .............................. 1295
12.8 What Calendar Is Used By MySQL? ......................................................... 1296
12.9 Full-Text Search Functions ..................................................................... 1296
  12.9.1 Natural Language Full-Text Searches .............................................. 1297
  12.9.2 Boolean Full-Text Searches .............................................................. 1301
  12.9.3 Full-Text Searches with Query Expansion ...................................... 1303
  12.9.4 Full-Text Stopwords ........................................................................ 1304
  12.9.5 Full-Text Restrictions ...................................................................... 1306
  12.9.6 Fine-Tuning MySQL Full-Text Search ............................................ 1307
  12.9.7 Adding a Collation for Full-Text Indexing ...................................... 1309
12.10 Cast Functions and Operators ................................................................. 1310
12.11 XML Functions ...................................................................................... 1317
12.12 Bit Functions and Operators .................................................................. 1328
12.13 Encryption and Compression Functions ............................................... 1329
12.14 Locking Functions .................................................................................. 1336
12.15 Information Functions ............................................................................ 1338
12.16 Spatial Analysis Functions ..................................................................... 1348
  12.16.1 Spatial Function Reference .............................................................. 1348
  12.16.2 Argument Handling by Spatial Functions ....................................... 1350
  12.16.3 Functions That Create Geometry Values from WKT Values .......... 1351
  12.16.4 Functions That Create Geometry Values from WKB Values .......... 1351
  12.16.5 MySQL-Specific Functions That Create Geometry Values .......... 1352
  12.16.6 Geometry Format Conversion Functions ....................................... 1353
  12.16.7 Geometry Property Functions ....................................................... 1354
  12.16.8 Spatial Operator Functions .............................................................. 1359
  12.16.9 Functions That Test Spatial Relations Between Geometry Objects ... 1359
12.17 Aggregate (GROUP BY) Functions ......................................................... 1362
  12.17.1 Aggregate (GROUP BY) Function Descriptions ............................. 1362
  12.17.2 GROUP BY Modifiers ..................................................................... 1366
  12.17.3 MySQL Handling of GROUP BY .................................................... 1370
12.18 Miscellaneous Functions ....................................................................... 1371
12.19 Precision Math ....................................................................................... 1375
  12.19.1 Types of Numeric Values ................................................................. 1376
Expressions can be used at several points in SQL statements, such as in the ORDER BY or HAVING clauses of SELECT statements, in the WHERE clause of a SELECT, DELETE, or UPDATE statement, or in SET statements. Expressions can be written using literal values, column values, NULL, built-in functions, stored functions, user-defined functions, and operators. This chapter describes the functions and operators that are permitted for writing expressions in MySQL. Instructions for writing stored functions and user-defined functions are given in Section 20.2, "Using Stored Routines", and Section 24.4, "Adding Functions to MySQL". See Section 9.2.5, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

An expression that contains NULL always produces a NULL value unless otherwise indicated in the documentation for a particular function or operator.

Note
By default, there must be no whitespace between a function name and the parenthesis following it. This helps the MySQL parser distinguish between function calls and references to tables or columns that happen to have the same name as a function. However, spaces around function arguments are permitted.

You can tell the MySQL server to accept spaces after function names by starting it with the --sql-mode=IGNORE_SPACE option. (See Section 5.1.10, "Server SQL Modes".) Individual client programs can request this behavior by using the CLIENT_IGNORE_SPACE option for mysql_real_connect(). In either case, all function names become reserved words.

For the sake of brevity, most examples in this chapter display the output from the mysql program in abbreviated form. Rather than showing examples in this format:

```sql
mysql> SELECT MOD(29,9);
+-----------+
| mod(29,9) |
+-----------+
|         2 |
1 rows in set (0.00 sec)
```

This format is used instead:

```sql
mysql> SELECT MOD(29,9);
-> 2
```

### 12.1 Function and Operator Reference

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;</td>
<td>Bitwise AND</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than operator</td>
</tr>
<tr>
<td>&gt;&gt;</td>
<td>Right shift</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater than or equal operator</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than operator</td>
</tr>
<tr>
<td>&lt;&gt;, !=</td>
<td>Not equal operator</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>&lt;&lt;</code></td>
<td>Left shift</td>
</tr>
<tr>
<td><code>&lt;=</code></td>
<td>Less than or equal operator</td>
</tr>
<tr>
<td><code>&lt;=&gt;</code></td>
<td>NULL-safe equal to operator</td>
</tr>
<tr>
<td><code>%, %MOD</code></td>
<td>Modulo operator</td>
</tr>
<tr>
<td><code>*</code></td>
<td>Multiplication operator</td>
</tr>
<tr>
<td><code>+</code></td>
<td>Addition operator</td>
</tr>
<tr>
<td><code>-</code></td>
<td>Minus operator</td>
</tr>
<tr>
<td><code>-</code></td>
<td>Change the sign of the argument</td>
</tr>
<tr>
<td><code>/</code></td>
<td>Division operator</td>
</tr>
<tr>
<td><code>:=</code></td>
<td>Assign a value</td>
</tr>
<tr>
<td><code>=</code></td>
<td>Equal operator</td>
</tr>
<tr>
<td><code>^</code></td>
<td>Bitwise XOR</td>
</tr>
<tr>
<td><code>ABS()</code></td>
<td>Return the absolute value</td>
</tr>
<tr>
<td><code>ACOS()</code></td>
<td>Return the arc cosine</td>
</tr>
<tr>
<td><code>ADDDATE()</code></td>
<td>Add time values (intervals) to a date value</td>
</tr>
<tr>
<td><code>ADDTIME()</code></td>
<td>Add time</td>
</tr>
<tr>
<td><code>AES_DECRYPT()</code></td>
<td>Decrypt using AES</td>
</tr>
<tr>
<td><code>AES_ENCRYPT()</code></td>
<td>Encrypt using AES</td>
</tr>
<tr>
<td><code>AND, &amp;&amp;</code></td>
<td>Logical AND</td>
</tr>
<tr>
<td><code>Area()</code></td>
<td>Return Polygon or MultiPolygon area</td>
</tr>
<tr>
<td><code>AsBinary(), AsWKB()</code></td>
<td>Convert from internal geometry format to WKB</td>
</tr>
<tr>
<td><code>ASCII()</code></td>
<td>Return numeric value of left-most character</td>
</tr>
<tr>
<td><code>ASIN()</code></td>
<td>Return the arc sine</td>
</tr>
<tr>
<td><code>AsText(), AsWKT()</code></td>
<td>Convert from internal geometry format to WKT</td>
</tr>
<tr>
<td><code>ATAN()</code></td>
<td>Return the arc tangent</td>
</tr>
<tr>
<td><code>ATAN2(), ATAN()</code></td>
<td>Return the arc tangent of the two arguments</td>
</tr>
<tr>
<td><code>AVG()</code></td>
<td>Return the average value of the argument</td>
</tr>
<tr>
<td><code>BENCHMARK()</code></td>
<td>Repeatedly execute an expression</td>
</tr>
<tr>
<td><code>BETWEEN ... AND ...</code></td>
<td>Whether a value is within a range of values</td>
</tr>
<tr>
<td><code>BIN()</code></td>
<td>Return a string containing binary representation of a number</td>
</tr>
<tr>
<td><code>BINARY</code></td>
<td>Cast a string to a binary string</td>
</tr>
<tr>
<td><code>BIT_AND()</code></td>
<td>Return bitwise AND</td>
</tr>
<tr>
<td><code>BIT_COUNT()</code></td>
<td>Return the number of bits that are set</td>
</tr>
<tr>
<td><code>BIT_LENGTH()</code></td>
<td>Return length of argument in bits</td>
</tr>
<tr>
<td><code>BIT_OR()</code></td>
<td>Return bitwise OR</td>
</tr>
<tr>
<td><code>BIT_XOR()</code></td>
<td>Return bitwise XOR</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CASE</td>
<td>Case operator</td>
</tr>
<tr>
<td>CAST()</td>
<td>Cast a value as a certain type</td>
</tr>
<tr>
<td>CEIL()</td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td>CEILING()</td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td>Centroid()</td>
<td>Return centroid as a point</td>
</tr>
<tr>
<td>CHAR()</td>
<td>Return the character for each integer passed</td>
</tr>
<tr>
<td>CHAR_LENGTH()</td>
<td>Return number of characters in argument</td>
</tr>
<tr>
<td>CHARACTER_LENGTH()</td>
<td>Synonym for CHAR_LENGTH()</td>
</tr>
<tr>
<td>CHARSET()</td>
<td>Return the character set of the argument</td>
</tr>
<tr>
<td>COALESCE()</td>
<td>Return the first non-NULL argument</td>
</tr>
<tr>
<td>COERCIBILITY()</td>
<td>Return the collation coercibility value of the string argument</td>
</tr>
<tr>
<td>COLLATION()</td>
<td>Return the collation of the string argument</td>
</tr>
<tr>
<td>COMPRESS()</td>
<td>Return result as a binary string</td>
</tr>
<tr>
<td>CONCAT()</td>
<td>Return concatenated string</td>
</tr>
<tr>
<td>CONCAT_WS()</td>
<td>Return concatenate with separator</td>
</tr>
<tr>
<td>CONNECTION_ID()</td>
<td>Return the connection ID (thread ID) for the connection</td>
</tr>
<tr>
<td>Contains()</td>
<td>Whether MBR of one geometry contains MBR of another</td>
</tr>
<tr>
<td>CONV()</td>
<td>Convert numbers between different number bases</td>
</tr>
<tr>
<td>CONVERT()</td>
<td>Cast a value as a certain type</td>
</tr>
<tr>
<td>CONVERT_TZ()</td>
<td>Convert from one time zone to another</td>
</tr>
<tr>
<td>COS()</td>
<td>Return the cosine</td>
</tr>
<tr>
<td>COT()</td>
<td>Return the cotangent</td>
</tr>
<tr>
<td>COUNT()</td>
<td>Return a count of the number of rows returned</td>
</tr>
<tr>
<td>COUNT(DISTINCT)</td>
<td>Return the count of a number of different values</td>
</tr>
<tr>
<td>CRC32()</td>
<td>Compute a cyclic redundancy check value</td>
</tr>
<tr>
<td>Crosses()</td>
<td>Whether one geometry crosses another</td>
</tr>
<tr>
<td>CURDATE()</td>
<td>Return the current date</td>
</tr>
<tr>
<td>CURRENT_DATE(), CURRENT_DATE</td>
<td>Synonyms for CURDATE()</td>
</tr>
<tr>
<td>CURRENT_TIME(), CURRENT_TIME</td>
<td>Synonyms for CURTIME()</td>
</tr>
<tr>
<td>CURRENT_TIMESTAMP(), CURRENT_TIMESTAMP</td>
<td>Synonyms for NOW()</td>
</tr>
<tr>
<td>CURRENT_USER(), CURRENT_USER</td>
<td>The authenticated user name and host name</td>
</tr>
<tr>
<td>CURTIME()</td>
<td>Return the current time</td>
</tr>
<tr>
<td>DATABASE()</td>
<td>Return the default (current) database name</td>
</tr>
<tr>
<td>DATE()</td>
<td>Extract the date part of a date or datetime expression</td>
</tr>
<tr>
<td>DATE_ADD()</td>
<td>Add time values (intervals) to a date value</td>
</tr>
<tr>
<td>DATE_FORMAT()</td>
<td>Format date as specified</td>
</tr>
<tr>
<td>DATE_SUB()</td>
<td>Subtract a time value (interval) from a date</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DATEDIFF()</td>
<td>Subtract two dates</td>
</tr>
<tr>
<td>DAY()</td>
<td>Synonym for DAYOFMONTH()</td>
</tr>
<tr>
<td>DAYNAME()</td>
<td>Return the name of the weekday</td>
</tr>
<tr>
<td>DAYOFMONTH()</td>
<td>Return the day of the month (0-31)</td>
</tr>
<tr>
<td>DAYOFWEEK()</td>
<td>Return the weekday index of the argument</td>
</tr>
<tr>
<td>DAYOFYEAR()</td>
<td>Return the day of the year (1-366)</td>
</tr>
<tr>
<td>DECODE()</td>
<td>Decode a string encrypted using ENCODE()</td>
</tr>
<tr>
<td>DEFAULT()</td>
<td>Return the default value for a table column</td>
</tr>
<tr>
<td>DEGREES()</td>
<td>Convert radians to degrees</td>
</tr>
<tr>
<td>DES_DECRYPT()</td>
<td>Decrypt a string</td>
</tr>
<tr>
<td>DES_ENCRYPT()</td>
<td>Encrypt a string</td>
</tr>
<tr>
<td>Dimension()</td>
<td>Dimension of geometry</td>
</tr>
<tr>
<td>Disjoint()</td>
<td>Whether MBRs of two geometries are disjoint</td>
</tr>
<tr>
<td>DIV</td>
<td>Integer division</td>
</tr>
<tr>
<td>ELT()</td>
<td>Return string at index number</td>
</tr>
<tr>
<td>ENCODE()</td>
<td>Encode a string</td>
</tr>
<tr>
<td>ENCRYPT()</td>
<td>Encrypt a string</td>
</tr>
<tr>
<td>EndPoint()</td>
<td>End Point of LineString</td>
</tr>
<tr>
<td>Envelope()</td>
<td>Return MBR of geometry</td>
</tr>
<tr>
<td>Equals()</td>
<td>Whether MBRs of two geometries are equal</td>
</tr>
<tr>
<td>EXP()</td>
<td>Raise to the power of</td>
</tr>
<tr>
<td>EXPORT_SET()</td>
<td>Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string</td>
</tr>
<tr>
<td>ExteriorRing()</td>
<td>Return exterior ring of Polygon</td>
</tr>
<tr>
<td>EXTRACT()</td>
<td>Extract part of a date</td>
</tr>
<tr>
<td>ExtractValue()</td>
<td>Extract a value from an XML string using XPath notation</td>
</tr>
<tr>
<td>FIELD()</td>
<td>Index (position) of first argument in subsequent arguments</td>
</tr>
<tr>
<td>FIND_IN_SET()</td>
<td>Index (position) of first argument within second argument</td>
</tr>
<tr>
<td>FLOOR()</td>
<td>Return the largest integer value not greater than the argument</td>
</tr>
<tr>
<td>FORMAT()</td>
<td>Return a number formatted to specified number of decimal places</td>
</tr>
<tr>
<td>FOUND_ROWS()</td>
<td>For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause</td>
</tr>
<tr>
<td>FROM_DAYS()</td>
<td>Convert a day number to a date</td>
</tr>
<tr>
<td>FROM_UNIXTIME()</td>
<td>Format Unix timestamp as a date</td>
</tr>
<tr>
<td>GeomCollFromText(),</td>
<td>Return geometry collection from WKT</td>
</tr>
<tr>
<td>GeometryCollectionFromText()</td>
<td></td>
</tr>
<tr>
<td>GeomCollFromWKB(),</td>
<td>Return geometry collection from WKB</td>
</tr>
<tr>
<td>GeometryCollectionFromWKB()</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>GeometryCollection()</td>
<td>Construct geometry collection from geometries</td>
</tr>
<tr>
<td>GeometryN()</td>
<td>Return N-th geometry from geometry collection</td>
</tr>
<tr>
<td>GeometryType()</td>
<td>Return name of geometry type</td>
</tr>
<tr>
<td>GeomFromText(), GeometryFromText()</td>
<td>Return geometry from WKT</td>
</tr>
<tr>
<td>GeomFromWKB(), GeometryFromWKB()</td>
<td>Return geometry from WKB</td>
</tr>
<tr>
<td>GET_FORMAT()</td>
<td>Return a date format string</td>
</tr>
<tr>
<td>GET_LOCK()</td>
<td>Get a named lock</td>
</tr>
<tr>
<td>GLength()</td>
<td>Return length of LineString</td>
</tr>
<tr>
<td>GREATEST()</td>
<td>Return the largest argument</td>
</tr>
<tr>
<td>GROUP_CONCAT()</td>
<td>Return a concatenated string</td>
</tr>
<tr>
<td>HEX()</td>
<td>Hexadecimal representation of decimal or string value</td>
</tr>
<tr>
<td>HOUR()</td>
<td>Extract the hour</td>
</tr>
<tr>
<td>IF()</td>
<td>If/else construct</td>
</tr>
<tr>
<td>IFNULL()</td>
<td>Null if/else construct</td>
</tr>
<tr>
<td>IN()</td>
<td>Whether a value is within a set of values</td>
</tr>
<tr>
<td>INET_ATON()</td>
<td>Return the numeric value of an IP address</td>
</tr>
<tr>
<td>INET_NTOA()</td>
<td>Return the IP address from a numeric value</td>
</tr>
<tr>
<td>INSERT()</td>
<td>Insert substring at specified position up to specified number of characters</td>
</tr>
<tr>
<td>INSTR()</td>
<td>Return the index of the first occurrence of substring</td>
</tr>
<tr>
<td>InteriorRingN()</td>
<td>Return N-th interior ring of Polygon</td>
</tr>
<tr>
<td>Intersects()</td>
<td>Whether MBRs of two geometries intersect</td>
</tr>
<tr>
<td>INTERVAL()</td>
<td>Return the index of the argument that is less than the first argument</td>
</tr>
<tr>
<td>IS</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS_FREE_LOCK()</td>
<td>Whether the named lock is free</td>
</tr>
<tr>
<td>IS NOT</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS NOT NULL</td>
<td>NOT NULL value test</td>
</tr>
<tr>
<td>IS NULL</td>
<td>NULL value test</td>
</tr>
<tr>
<td>IS_USED_LOCK()</td>
<td>Whether the named lock is in use; return connection identifier if true</td>
</tr>
<tr>
<td>IsClosed()</td>
<td>Whether a geometry is closed and simple</td>
</tr>
<tr>
<td>IsEmpty()</td>
<td>Placeholder function</td>
</tr>
<tr>
<td>ISNULL()</td>
<td>Test whether the argument is NULL</td>
</tr>
<tr>
<td>IsSimple()</td>
<td>Whether a geometry is simple</td>
</tr>
<tr>
<td>LAST_DAY</td>
<td>Return the last day of the month for the argument</td>
</tr>
<tr>
<td>LAST_INSERT_ID()</td>
<td>Value of the AUTOINCREMENT column for the last INSERT</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LCASE()</td>
<td>Synonym for LOWER()</td>
</tr>
<tr>
<td>LEAST()</td>
<td>Return the smallest argument</td>
</tr>
<tr>
<td>LEFT()</td>
<td>Return the leftmost number of characters as specified</td>
</tr>
<tr>
<td>LENGTH()</td>
<td>Return the length of a string in bytes</td>
</tr>
<tr>
<td>LIKE</td>
<td>Simple pattern matching</td>
</tr>
<tr>
<td>LineFromText()</td>
<td>Construct LineString from WKT</td>
</tr>
<tr>
<td>LineStringFromText()</td>
<td>Construct LineString from WKT</td>
</tr>
<tr>
<td>LineFromWKB()</td>
<td>Construct LineString from WKB</td>
</tr>
<tr>
<td>LineStringFromWKB()</td>
<td>Construct LineString from WKB</td>
</tr>
<tr>
<td>LineString()</td>
<td>Construct LineString from Point values</td>
</tr>
<tr>
<td>LN()</td>
<td>Return the natural logarithm of the argument</td>
</tr>
<tr>
<td>LOAD_FILE()</td>
<td>Load the named file</td>
</tr>
<tr>
<td>LOCALTIME()</td>
<td>Synonym for NOW()</td>
</tr>
<tr>
<td>LOCALTIMESTAMP()</td>
<td>Synonym for NOW()</td>
</tr>
<tr>
<td>LOCATE()</td>
<td>Return the position of the first occurrence of substring</td>
</tr>
<tr>
<td>LOG()</td>
<td>Return the natural logarithm of the first argument</td>
</tr>
<tr>
<td>LOG10()</td>
<td>Return the base-10 logarithm of the argument</td>
</tr>
<tr>
<td>LOG2()</td>
<td>Return the base-2 logarithm of the argument</td>
</tr>
<tr>
<td>LOWER()</td>
<td>Return the argument in lowercase</td>
</tr>
<tr>
<td>LPAD()</td>
<td>Return the string argument, left-padded with the specified string</td>
</tr>
<tr>
<td>LTRIM()</td>
<td>Remove leading spaces</td>
</tr>
<tr>
<td>MAKE_SET()</td>
<td>Return a set of comma-separated strings that have the corresponding bit in bits set</td>
</tr>
<tr>
<td>MAKEDATE()</td>
<td>Create a date from the year and day of year</td>
</tr>
<tr>
<td>MAKETIME()</td>
<td>Create time from hour, minute, second</td>
</tr>
<tr>
<td>MASTER_POS_WAIT()</td>
<td>Block until the slave has read and applied all updates up to the specified position</td>
</tr>
<tr>
<td>MATCH</td>
<td>Perform full-text search</td>
</tr>
<tr>
<td>MAX()</td>
<td>Return the maximum value</td>
</tr>
<tr>
<td>MBRContains()</td>
<td>Whether MBR of one geometry contains MBR of another</td>
</tr>
<tr>
<td>MBRDisjoint()</td>
<td>Whether MBRs of two geometries are disjoint</td>
</tr>
<tr>
<td>MBREqual()</td>
<td>Whether MBRs of two geometries are equal</td>
</tr>
<tr>
<td>MBRIntersects()</td>
<td>Whether MBRs of two geometries intersect</td>
</tr>
<tr>
<td>MBROverlaps()</td>
<td>Whether MBRs of two geometries overlap</td>
</tr>
<tr>
<td>MBRTouches()</td>
<td>Whether MBRs of two geometries touch</td>
</tr>
<tr>
<td>MBRWithin()</td>
<td>Whether MBR of one geometry is within MBR of another</td>
</tr>
<tr>
<td>MD5()</td>
<td>Calculate MD5 checksum</td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>MICROSECOND()</td>
<td>Return the microseconds from argument</td>
</tr>
<tr>
<td>MID()</td>
<td>Return a substring starting from the specified position</td>
</tr>
<tr>
<td>MIN()</td>
<td>Return the minimum value</td>
</tr>
<tr>
<td>MINUTE()</td>
<td>Return the minute from the argument</td>
</tr>
<tr>
<td>MLineFromText(),</td>
<td>Construct MultiLineString from WKT</td>
</tr>
<tr>
<td>MultiLineStringFromText()</td>
<td></td>
</tr>
<tr>
<td>MLineFromWKB(),</td>
<td>Construct MultiLineString from WKB</td>
</tr>
<tr>
<td>MultiLineStringFromWKB()</td>
<td></td>
</tr>
<tr>
<td>MOD()</td>
<td>Return the remainder</td>
</tr>
<tr>
<td>MONTH()</td>
<td>Return the month from the date passed</td>
</tr>
<tr>
<td>MONTNAME()</td>
<td>Return the name of the month</td>
</tr>
<tr>
<td>MPointFromText(),</td>
<td>Construct MultiPoint from WKT</td>
</tr>
<tr>
<td>MultiPointFromText()</td>
<td></td>
</tr>
<tr>
<td>MPointFromWKB(),</td>
<td>Construct MultiPoint from WKB</td>
</tr>
<tr>
<td>MultiPointFromWKB()</td>
<td></td>
</tr>
<tr>
<td>MPolyFromText(),</td>
<td>Construct MultiPolygon from WKT</td>
</tr>
<tr>
<td>MultiPolygonFromText()</td>
<td></td>
</tr>
<tr>
<td>MPolyFromWKB(),</td>
<td>Construct MultiPolygon from WKB</td>
</tr>
<tr>
<td>MultiPolygonFromWKB()</td>
<td></td>
</tr>
<tr>
<td>MultiLineString()</td>
<td>Contruct MultiLineString from LineString values</td>
</tr>
<tr>
<td>MultiPoint()</td>
<td>Construct MultiPoint from Point values</td>
</tr>
<tr>
<td>MultiPolygon()</td>
<td>Construct MultiPolygon from Polygon values</td>
</tr>
<tr>
<td>NAME_CONST()</td>
<td>Cause the column to have the given name</td>
</tr>
<tr>
<td>NOT, !</td>
<td>Negates value</td>
</tr>
<tr>
<td>NOT BETWEEN ... AND ...</td>
<td>Whether a value is not within a range of values</td>
</tr>
<tr>
<td>NOT IN()</td>
<td>Whether a value is not within a set of values</td>
</tr>
<tr>
<td>NOT LIKE</td>
<td>Negation of simple pattern matching</td>
</tr>
<tr>
<td>NOT REGEXP</td>
<td>Negation of REGEXP</td>
</tr>
<tr>
<td>NOW()</td>
<td>Return the current date and time</td>
</tr>
<tr>
<td>NULLIF()</td>
<td>Return NULL if expr1 = expr2</td>
</tr>
<tr>
<td>NumGeometries()</td>
<td>Return number of geometries in geometry collection</td>
</tr>
<tr>
<td>NumInteriorRings()</td>
<td>Return number of interior rings in Polygon</td>
</tr>
<tr>
<td>NumPoints()</td>
<td>Return number of points in LineString</td>
</tr>
<tr>
<td>OCT()</td>
<td>Return a string containing octal representation of a number</td>
</tr>
<tr>
<td>OCTET_LENGTH()</td>
<td>Synonym for LENGTH()</td>
</tr>
<tr>
<td>OLD_PASSWORD()</td>
<td>Return the value of the pre-4.1 implementation of PASSWORD</td>
</tr>
<tr>
<td>OR,</td>
<td></td>
</tr>
<tr>
<td>ORD()</td>
<td>Return character code for leftmost character of the argument</td>
</tr>
<tr>
<td>Overlaps()</td>
<td>Whether MBRs of two geometries overlap</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>PASSWORD()</td>
<td>Calculate and return a password string</td>
</tr>
<tr>
<td>PERIOD_ADD()</td>
<td>Add a period to a year-month</td>
</tr>
<tr>
<td>PERIOD_DIFF()</td>
<td>Return the number of months between periods</td>
</tr>
<tr>
<td>PI()</td>
<td>Return the value of pi</td>
</tr>
<tr>
<td>Point()</td>
<td>Construct Point from coordinates</td>
</tr>
<tr>
<td>PointFromText()</td>
<td>Construct Point from WKT</td>
</tr>
<tr>
<td>PointFromWKB()</td>
<td>Construct Point from WKB</td>
</tr>
<tr>
<td>PointN()</td>
<td>Return N-th point from LineString</td>
</tr>
<tr>
<td>PolyFromText(), PolyFromWKT()</td>
<td>Construct Polygon from WKT</td>
</tr>
<tr>
<td>PolyFromWKB(), PolygonFromWKB()</td>
<td>Construct Polygon from WKB</td>
</tr>
<tr>
<td>Polygon()</td>
<td>Construct Polygon from LineString arguments</td>
</tr>
<tr>
<td>POSITION()</td>
<td>Synonym for LOCATE()</td>
</tr>
<tr>
<td>POW()</td>
<td>Return the argument raised to the specified power</td>
</tr>
<tr>
<td>POWER()</td>
<td>Return the argument raised to the specified power</td>
</tr>
<tr>
<td>PROCEDURE ANALYSE()</td>
<td>Analyze the results of a query</td>
</tr>
<tr>
<td>QUARTER()</td>
<td>Return the quarter from a date argument</td>
</tr>
<tr>
<td>QUOTE()</td>
<td>Escape the argument for use in an SQL statement</td>
</tr>
<tr>
<td>RADIANS()</td>
<td>Return argument converted to radians</td>
</tr>
<tr>
<td>RAND()</td>
<td>Return a random floating-point value</td>
</tr>
<tr>
<td>REGEXP</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>RELEASE_LOCK()</td>
<td>Release the named lock</td>
</tr>
<tr>
<td>REPEAT()</td>
<td>Repeat a string the specified number of times</td>
</tr>
<tr>
<td>REPLACE()</td>
<td>Replace occurrences of a specified string</td>
</tr>
<tr>
<td>REVERSE()</td>
<td>Reverse the characters in a string</td>
</tr>
<tr>
<td>RIGHT()</td>
<td>Return the specified rightmost number of characters</td>
</tr>
<tr>
<td>RLIKE</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>ROUND()</td>
<td>Round the argument</td>
</tr>
<tr>
<td>ROW_COUNT()</td>
<td>The number of rows updated</td>
</tr>
<tr>
<td>RPAD()</td>
<td>Append string the specified number of times</td>
</tr>
<tr>
<td>RTRIM()</td>
<td>Remove trailing spaces</td>
</tr>
<tr>
<td>SCHEMA()</td>
<td>Synonym for DATABASE()</td>
</tr>
<tr>
<td>SEC_TO_TIME()</td>
<td>Converts seconds to 'hh:mm:ss' format</td>
</tr>
<tr>
<td>SECOND()</td>
<td>Return the second (0-59)</td>
</tr>
<tr>
<td>SESSION_USER()</td>
<td>Synonym for USER()</td>
</tr>
<tr>
<td>SHA1(), SHA2()</td>
<td>Calculate an SHA-1 160-bit checksum</td>
</tr>
<tr>
<td>SHA2()</td>
<td>Calculate an SHA-2 checksum</td>
</tr>
<tr>
<td>SIGN()</td>
<td>Return the sign of the argument</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SIN()</td>
<td>Return the sine of the argument</td>
</tr>
<tr>
<td>SLEEP()</td>
<td>Sleep for a number of seconds</td>
</tr>
<tr>
<td>SOUNDEX()</td>
<td>Return a soundex string</td>
</tr>
<tr>
<td>SOUNDS LIKE</td>
<td>Compare sounds</td>
</tr>
<tr>
<td>SPACE()</td>
<td>Return a string of the specified number of spaces</td>
</tr>
<tr>
<td>SQRT()</td>
<td>Return the square root of the argument</td>
</tr>
<tr>
<td>SRID()</td>
<td>Return spatial reference system ID for geometry</td>
</tr>
<tr>
<td>StartPoint()</td>
<td>Start Point of LineString</td>
</tr>
<tr>
<td>STD()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV_POP()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV_SAMP()</td>
<td>Return the sample standard deviation</td>
</tr>
<tr>
<td>STR_TO_DATE()</td>
<td>Convert a string to a date</td>
</tr>
<tr>
<td>STRCMP()</td>
<td>Compare two strings</td>
</tr>
<tr>
<td>SUBDATE()</td>
<td>Synonym for DATE_SUB() when invoked with three arguments</td>
</tr>
<tr>
<td>SUBSTR()</td>
<td>Return the substring as specified</td>
</tr>
<tr>
<td>SUBSTRING()</td>
<td>Return the substring as specified</td>
</tr>
<tr>
<td>SUBSTRING_INDEX()</td>
<td>Return a substring from a string before the specified number of occurrences of the delimiter</td>
</tr>
<tr>
<td>SUBTIME()</td>
<td>Subtract times</td>
</tr>
<tr>
<td>SUM()</td>
<td>Return the sum</td>
</tr>
<tr>
<td>SYSDATE()</td>
<td>Return the time at which the function executes</td>
</tr>
<tr>
<td>SYSTEM_USER()</td>
<td>Synonym for USER()</td>
</tr>
<tr>
<td>TAN()</td>
<td>Return the tangent of the argument</td>
</tr>
<tr>
<td>TIME()</td>
<td>Extract the time portion of the expression passed</td>
</tr>
<tr>
<td>TIME_FORMAT()</td>
<td>Format as time</td>
</tr>
<tr>
<td>TIME_TO_SEC()</td>
<td>Return the argument converted to seconds</td>
</tr>
<tr>
<td>TIMEDIFF()</td>
<td>Subtract time</td>
</tr>
<tr>
<td>TIMESTAMP()</td>
<td>With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments</td>
</tr>
<tr>
<td>TIMESTAMPADD()</td>
<td>Add an interval to a datetime expression</td>
</tr>
<tr>
<td>TIMESTAMPDIFF()</td>
<td>Subtract an interval from a datetime expression</td>
</tr>
<tr>
<td>TO_DAYS()</td>
<td>Return the date argument converted to days</td>
</tr>
<tr>
<td>TO_SECONDS()</td>
<td>Return the date or datetime argument converted to seconds since Year 0</td>
</tr>
<tr>
<td>Touches()</td>
<td>Whether one geometry touches another</td>
</tr>
<tr>
<td>TRIM()</td>
<td>Remove leading and trailing spaces</td>
</tr>
<tr>
<td>TRUNCATE()</td>
<td>Truncate to specified number of decimal places</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>UCASE()</td>
<td>Synonym for UPPER()</td>
</tr>
<tr>
<td>UNCOMPRESS()</td>
<td>Uncompress a string compressed</td>
</tr>
<tr>
<td>UNCOMPRESSED_LENGTH()</td>
<td>Return the length of a string before compression</td>
</tr>
<tr>
<td>UNHEX()</td>
<td>Return a string containing hex representation of a number</td>
</tr>
<tr>
<td>UNIX_TIMESTAMP()</td>
<td>Return a Unix timestamp</td>
</tr>
<tr>
<td>UpdateXML()</td>
<td>Return replaced XML fragment</td>
</tr>
<tr>
<td>UPPER()</td>
<td>Convert to uppercase</td>
</tr>
<tr>
<td>USER()</td>
<td>The user name and host name provided by the client</td>
</tr>
<tr>
<td>UTC_DATE()</td>
<td>Return the current UTC date</td>
</tr>
<tr>
<td>UTC_TIME()</td>
<td>Return the current UTC time</td>
</tr>
<tr>
<td>UTC_TIMESTAMP()</td>
<td>Return the current UTC date and time</td>
</tr>
<tr>
<td>UUID()</td>
<td>Return a Universal Unique Identifier (UUID)</td>
</tr>
<tr>
<td>UUID_SHORT()</td>
<td>Return an integer-valued universal identifier</td>
</tr>
<tr>
<td>VALUES()</td>
<td>Define the values to be used during an INSERT</td>
</tr>
<tr>
<td>VAR_POP()</td>
<td>Return the population standard variance</td>
</tr>
<tr>
<td>VAR_SAMP()</td>
<td>Return the sample variance</td>
</tr>
<tr>
<td>VARIANCE()</td>
<td>Return the population standard variance</td>
</tr>
<tr>
<td>VERSION()</td>
<td>Return a string that indicates the MySQL server version</td>
</tr>
<tr>
<td>WEEK()</td>
<td>Return the week number</td>
</tr>
<tr>
<td>WEEKDAY()</td>
<td>Return the weekday index</td>
</tr>
<tr>
<td>WEEKOFYEAR()</td>
<td>Return the calendar week of the date (1-53)</td>
</tr>
<tr>
<td>Within()</td>
<td>Whether MBR of one geometry is within MBR of another</td>
</tr>
<tr>
<td>X()</td>
<td>Return X coordinate of Point</td>
</tr>
<tr>
<td>XOR</td>
<td>Logical XOR</td>
</tr>
<tr>
<td>Y()</td>
<td>Return Y coordinate of Point</td>
</tr>
<tr>
<td>YEAR()</td>
<td>Return the year</td>
</tr>
<tr>
<td>YEARWEEK()</td>
<td>Return the year and week</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>~</td>
<td>Bitwise inversion</td>
</tr>
</tbody>
</table>

### 12.2 Type Conversion in Expression Evaluation

When an operator is used with operands of different types, type conversion occurs to make the operands compatible. Some conversions occur implicitly. For example, MySQL automatically converts strings to numbers as necessary, and vice versa.

```sql
mysql> SELECT 1+'1';
-> 2
mysql> SELECT CONCAT(2, ' test');
-> '2 test'
```

It is also possible to convert a number to a string explicitly using the `CAST()` function. Conversion occurs implicitly with the `CONCAT()` function because it expects string arguments.
Type Conversion in Expression Evaluation

The following rules describe how conversion occurs for comparison operations:

- If one or both arguments are NULL, the result of the comparison is NULL, except for the NULL-safe <= comparison operator. For NULL <= NULL, the result is true. No conversion is needed.

- If both arguments in a comparison operation are strings, they are compared as strings.

- If both arguments are integers, they are compared as integers.

- Hexadecimal values are treated as binary strings if not compared to a number.

- If one of the arguments is a TIMESTAMP or DATETIME column and the other argument is a constant, the constant is converted to a timestamp before the comparison is performed. This is done to be more ODBC-friendly. This is not done for the arguments to IN(). To be safe, always use complete datetime, date, or time strings when doing comparisons. For example, to achieve best results when using BETWEEN with date or time values, use CAST() to explicitly convert the values to the desired data type.

- If one of the arguments is a decimal value, comparison depends on the other argument. The arguments are compared as decimal values if the other argument is a decimal or integer value, or as floating-point values if the other argument is a floating-point value.

- In all other cases, the arguments are compared as floating-point (real) numbers. For example, a comparison of string and numeric operands takes place as a comparison of floating-point numbers.

For information about conversion of values from one temporal type to another, see Section 11.2.8, “Conversion Between Date and Time Types”.

The following examples illustrate conversion of strings to numbers for comparison operations:

```sql
mysql> SELECT '18015376320243458' = 18015376320243458;
       -1226
```

For comparisons of a string column with a number, MySQL cannot use an index on the column to look up the value quickly. If str_col is an indexed string column, the index cannot be used when performing the lookup in the following statement:

```sql
SELECT * FROM tbl_name WHERE str_col=1;
```

The reason for this is that there are many different strings that may convert to the value 1, such as '1', '1', or '1a'.

Comparisons that use floating-point numbers (or values that are converted to floating-point numbers) are approximate because such numbers are inexact. This might lead to results that appear inconsistent:

```sql
mysql> SELECT '18015376320243458' = 18015376320243458;
       -1226
```
Type Conversion in Expression Evaluation

Such results can occur because the values are converted to floating-point numbers, which have only 53 bits of precision and are subject to rounding:

```
mysql> SELECT '18015376320243459' = 18015376320243459;
-> 0
```

Furthermore, the conversion from string to floating-point and from integer to floating-point do not necessarily occur the same way. The integer may be converted to floating-point by the CPU, whereas the string is converted digit by digit in an operation that involves floating-point multiplications.

The results shown will vary on different systems, and can be affected by factors such as computer architecture or the compiler version or optimization level. One way to avoid such problems is to use `CAST()` so that a value is not converted implicitly to a float-point number:

```
mysql> SELECT CAST('18015376320243459' AS UNSIGNED) = 18015376320243459;
-> 1
```

For more information about floating-point comparisons, see Section B.4.4.8, “Problems with Floating-Point Values”.

The server includes `dtoa`, a conversion library that provides the basis for improved conversion between string or `DECIMAL` values and approximate-value (`FLOAT`/`DOUBLE`) numbers:

- Consistent conversion results across platforms, which eliminates, for example, Unix versus Windows conversion differences.
- Accurate representation of values in cases where results previously did not provide sufficient precision, such as for values close to IEEE limits.
- Conversion of numbers to string format with the best possible precision. The precision of `dtoa` is always the same or better than that of the standard C library functions.

Because the conversions produced by this library differ in some cases from non-`dtoa` results, the potential exists for incompatibilities in applications that rely on previous results. For example, applications that depend on a specific exact result from previous conversions might need adjustment to accommodate additional precision.

The `dtoa` library provides conversions with the following properties. `\(D\)` represents a value with a `DECIMAL` or string representation, and `\(F\)` represents a floating-point number in native binary (IEEE) format.

- `\(F \rightarrow D\)` conversion is done with the best possible precision, returning `\(D\)` as the shortest string that yields `\(F\)` when read back in and rounded to the nearest value in native binary format as specified by IEEE.
- `\(D \rightarrow F\)` conversion is done such that `\(F\)` is the nearest native binary number to the input decimal string `\(D\)`.

These properties imply that `\(F \rightarrow D \rightarrow F\)` conversions are lossless unless `\(F\)` is `-inf`, `+inf`, or `NaN`. The latter values are not supported because the SQL standard defines them as invalid values for `FLOAT` or `DOUBLE`.

For `\(D \rightarrow F \rightarrow D\)` conversions, a sufficient condition for losslessness is that `\(D\)` uses 15 or fewer digits of precision, is not a denormal value, `-inf`, `+inf`, or `NaN`. In some cases, the conversion is lossless even if `\(D\)` has more than 15 digits of precision, but this is not always the case.

Implicit conversion of a numeric or temporal value to string produces a value that has a character set and collation determined by the `character_set_connection` and `collation_connection` system variables.
variables. (These variables commonly are set with `SET NAMES`. For information about connection character sets, see Section 10.4, "Connection Character Sets and Collations".)

This means that such a conversion results in a character (nonbinary) string (a `CHAR`, `VARCHAR`, or `LONGTEXT` value), except in the case that the connection character set is set to `binary`. In that case, the conversion result is a binary string (a `BINARY`, `VARBINARY`, or `LONGBLOB` value).

For integer expressions, the preceding remarks about expression evaluation apply somewhat differently for expression assignment; for example, in a statement such as this:

```
CREATE TABLE t SELECT integer_expr;
```

In this case, the table in the column resulting from the expression has type `INT` or `BIGINT` depending on the length of the integer expression. If the maximum length of the expression does not fit in an `INT`, `BIGINT` is used instead. The length is taken from the `max_length` value of the `SELECT` result set metadata (see Section 23.7.4, “C API Data Structures”). This means that you can force a `BIGINT` rather than `INT` by use of a sufficiently long expression:

```
CREATE TABLE t SELECT 000000000000000000000;
```

### 12.3 Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&amp;</code></td>
<td>Bitwise AND</td>
</tr>
<tr>
<td><code>&gt;</code></td>
<td>Greater than operator</td>
</tr>
<tr>
<td><code>&gt;&gt;</code></td>
<td>Right shift</td>
</tr>
<tr>
<td><code>&gt;=</code></td>
<td>Greater than or equal operator</td>
</tr>
<tr>
<td><code>&lt;</code></td>
<td>Less than operator</td>
</tr>
<tr>
<td><code>&lt;&gt;</code></td>
<td>Not equal operator</td>
</tr>
<tr>
<td><code>&lt;&lt;</code></td>
<td>Left shift</td>
</tr>
<tr>
<td><code>&lt;=</code></td>
<td>Less than or equal operator</td>
</tr>
<tr>
<td><code>=&gt;</code></td>
<td>NULL-safe equal to operator</td>
</tr>
<tr>
<td><code>%</code>, <code>MOD</code></td>
<td>Modulo operator</td>
</tr>
<tr>
<td><code>*</code></td>
<td>Multiplication operator</td>
</tr>
<tr>
<td><code>+</code></td>
<td>Addition operator</td>
</tr>
<tr>
<td><code>-</code></td>
<td>Minus operator</td>
</tr>
<tr>
<td><code>-</code></td>
<td>Change the sign of the argument</td>
</tr>
<tr>
<td><code>/</code></td>
<td>Division operator</td>
</tr>
<tr>
<td><code>:=</code></td>
<td>Assign a value</td>
</tr>
<tr>
<td><code>=</code></td>
<td>Assign a value (as part of a <code>SET</code> statement, or as part of the <code>SET</code> clause in an <code>UPDATE</code> statement)</td>
</tr>
<tr>
<td><code>=</code></td>
<td>Equal operator</td>
</tr>
<tr>
<td><code>^</code></td>
<td>Bitwise XOR</td>
</tr>
<tr>
<td><code>AND</code>, <code>&amp;&amp;</code></td>
<td>Logical AND</td>
</tr>
<tr>
<td><code>BETWEEN ... AND ...</code></td>
<td>Whether a value is within a range of values</td>
</tr>
<tr>
<td><code>BINARY</code></td>
<td>Cast a string to a binary string</td>
</tr>
</tbody>
</table>
## Operator Precedence

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASE</td>
<td>Case operator</td>
</tr>
<tr>
<td>DIV</td>
<td>Integer division</td>
</tr>
<tr>
<td>IN()</td>
<td>Whether a value is within a set of values</td>
</tr>
<tr>
<td>IS</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS NOT</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS NOT NULL</td>
<td>NOT NULL value test</td>
</tr>
<tr>
<td>IS NULL</td>
<td>NULL value test</td>
</tr>
<tr>
<td>LIKE</td>
<td>Simple pattern matching</td>
</tr>
<tr>
<td>NOT, !</td>
<td>Negates value</td>
</tr>
<tr>
<td>NOT BETWEEN ... AND ...</td>
<td>Whether a value is not within a range of values</td>
</tr>
<tr>
<td>NOT IN()</td>
<td>Whether a value is not within a set of values</td>
</tr>
<tr>
<td>NOT LIKE</td>
<td>Negation of simple pattern matching</td>
</tr>
<tr>
<td>NOT REGEXP</td>
<td>Negation of REGEXP</td>
</tr>
<tr>
<td>OR,</td>
<td></td>
</tr>
<tr>
<td>REGEXP</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>RLIKE</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>SOUNDS LIKE</td>
<td>Compare sounds</td>
</tr>
<tr>
<td>XOR</td>
<td>Logical XOR</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>~</td>
<td>Bitwise inversion</td>
</tr>
</tbody>
</table>

### 12.3.1 Operator Precedence

Operator precedences are shown in the following list, from highest precedence to the lowest. Operators that are shown together on a line have the same precedence.

```
INTERVAL
BINARY, COLLATE
!, ~ (unary minus), ~ (unary bit inversion)
^, *, /, DIV, %, MOD
-, +
<, <=, >, >=

| (comparison), <=>, >-, >, <=, <, <<, >>, !=, IS, LIKE, REGEXP, IN BETWEEN, CASE, WHEN, THEN, ELSE
NOT
AND, &&
XOR
OR, ||
= (assignment), :=
```

The precedence of `=` depends on whether it is used as a comparison operator (`) or as an assignment operator (```). When used as a comparison operator, it has the same precedence as `<=>, >=, >, <=, <, <<, >>, !=, IS, LIKE, REGEXP, IN BETWEEN, CASE, WHEN, THEN, ELSE
NOT
AND, &&
XOR
OR, ||
= (assignment), :=

When used as an assignment operator, it has the same precedence as `:=`. Section 13.7.4.1, "SET Syntax for Variable Assignment", and Section 9.4, "User-Defined Variables", explain how MySQL determines which interpretation of `=` should apply.
Comparison Functions and Operators

For operators that occur at the same precedence level within an expression, evaluation proceeds left to right, with the exception that assignments evaluate right to left.

The precedence and meaning of some operators depends on the SQL mode:

- By default, || is a logical OR operator. With PIPES_AS_CONCAT enabled, || is string concatenation, with a precedence between ^ and the unary operators.
- By default, ! has a higher precedence than NOT. With HIGH_NOT_PRECEDENCE enabled, ! and NOT have the same precedence.

See Section 5.1.10, “Server SQL Modes”.

The precedence of operators determines the order of evaluation of terms in an expression. To override this order and group terms explicitly, use parentheses. For example:

```sql
mysql> SELECT 1+2*3;
-> 7
mysql> SELECT (1+2)*3;
-> 9
```

12.3.2 Comparison Functions and Operators

Table 12.3 Comparison Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;</td>
<td>Greater than operator</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater than or equal operator</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than operator</td>
</tr>
<tr>
<td>&lt;&gt;, !=</td>
<td>Not equal operator</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal operator</td>
</tr>
<tr>
<td>&lt;=&gt;</td>
<td>NULL-safe equal to operator</td>
</tr>
<tr>
<td>=</td>
<td>Equal operator</td>
</tr>
<tr>
<td>BETWEEN ... AND ...</td>
<td>Whether a value is within a range of values</td>
</tr>
<tr>
<td>COALESCE()</td>
<td>Return the first non-NULL argument</td>
</tr>
<tr>
<td>GREATEST()</td>
<td>Return the largest argument</td>
</tr>
<tr>
<td>IN()</td>
<td>Whether a value is within a set of values</td>
</tr>
<tr>
<td>INTERVAL()</td>
<td>Return the index of the argument that is less than the first argument</td>
</tr>
<tr>
<td>IS</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS NOT</td>
<td>Test a value against a boolean</td>
</tr>
<tr>
<td>IS NOT NULL</td>
<td>NOT NULL value test</td>
</tr>
<tr>
<td>IS NULL</td>
<td>NULL value test</td>
</tr>
<tr>
<td>ISNULL()</td>
<td>Test whether the argument is NULL</td>
</tr>
<tr>
<td>LEAST()</td>
<td>Return the smallest argument</td>
</tr>
<tr>
<td>LIKE</td>
<td>Simple pattern matching</td>
</tr>
<tr>
<td>NOT BETWEEN ... AND ...</td>
<td>Whether a value is not within a range of values</td>
</tr>
<tr>
<td>NOT IN()</td>
<td>Whether a value is not within a set of values</td>
</tr>
</tbody>
</table>
Comparison Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT LIKE</td>
<td>Negation of simple pattern matching</td>
</tr>
<tr>
<td>STRCMP()</td>
<td>Compare two strings</td>
</tr>
</tbody>
</table>

Comparison operations result in a value of 1 (TRUE), 0 (FALSE), or NULL. These operations work for both numbers and strings. Strings are automatically converted to numbers and numbers to strings as necessary.

The following relational comparison operators can be used to compare not only scalar operands, but row operands:

\[- \quad > \quad < \quad >= \quad <= \quad <> \quad !=\]

The descriptions for those operators later in this section detail how they work with row operands. For additional examples of row comparisons in the context of row subqueries, see Section 13.2.10.5, "Row Subqueries".

Some of the functions in this section return values other than 1 (TRUE), 0 (FALSE), or NULL. LEAST() and GREATEST() are examples of such functions; Section 12.2, "Type Conversion in Expression Evaluation", describes the rules for comparison operations performed by these and similar functions for determining their return values.

To convert a value to a specific type for comparison purposes, you can use the CAST() function. String values can be converted to a different character set using CONVERT(). See Section 12.10, "Cast Functions and Operators".

By default, string comparisons are not case-sensitive and use the current character set. The default is latin1 (cp1252 West European), which also works well for English.

- =

Equal:

```
mysql> SELECT 1 = 0;
-> 0
mysql> SELECT '0' = 0;
-> 1
mysql> SELECT '0.0' = 0;
-> 1
mysql> SELECT '0.01' = 0;
-> 0
mysql> SELECT '.01' = 0.01;
-> 1
```

For row comparisons, \((a, \ b) = (x, \ y)\) is equivalent to:

\[(a = x) \text{ AND } (b = y)\]

- <=>

NULL-safe equal. This operator performs an equality comparison like the = operator, but returns 1 rather than NULL if both operands are NULL, and 0 rather than NULL if one operand is NULL.

The <=> operator is equivalent to the standard SQL IS NOT DISTINCT FROM operator.

```
mysql> SELECT 1 <=> 1, NULL <=> NULL, 1 <=> NULL;
-> 1, 1, 0
mysql> SELECT 1 = 1, NULL = NULL, 1 = NULL;
-> 1, NULL, NULL
```
Comparison Functions and Operators

For row comparisons, \((a, b) \iff (x, y)\) is equivalent to:

\[(a \iff x) \land (b \iff y)\]

- \(<>, !=\)

Not equal:

mysql> SELECT '.01' <> '0.01';
   -> 1
mysql> SELECT .01 <> '0.01';
   -> 0
mysql> SELECT 'zapp' <> 'zappp';
   -> 1

For row comparisons, \((a, b) <> (x, y)\) and \((a, b) != (x, y)\) are equivalent to:

\[(a <> x) \lor (b <> y)\]

- \(\leq\)

Less than or equal:

mysql> SELECT 0.1 <= 2;
   -> 1

For row comparisons, \((a, b) \leq (x, y)\) is equivalent to:

\[(a < x) \lor ((a = x) \land (b \leq y))\]

- \(<\)

Less than:

mysql> SELECT 2 < 2;
   -> 0

For row comparisons, \((a, b) < (x, y)\) is equivalent to:

\[(a < x) \lor ((a = x) \land (b < y))\]

- \(\geq\)

Greater than or equal:

mysql> SELECT 2 >= 2;
   -> 1

For row comparisons, \((a, b) \geq (x, y)\) is equivalent to:

\[(a > x) \lor ((a = x) \land (b \geq y))\]

- \(>\)

Greater than:

mysql> SELECT 2 > 2;
   -> 0

For row comparisons, \((a, b) > (x, y)\) is equivalent to:

\[(a > x) \lor ((a = x) \land (b > y))\]
Comparison Functions and Operators

- **expr BETWEEN min AND max**

  If `expr` is greater than or equal to `min` and `expr` is less than or equal to `max`, `BETWEEN` returns 1, otherwise it returns 0. This is equivalent to the expression `(min <= expr AND expr <= max)` if all the arguments are of the same type. Otherwise type conversion takes place according to the rules described in Section 12.2, “Type Conversion in Expression Evaluation”, but applied to all the three arguments.

```
mysql> SELECT 2 BETWEEN 1 AND 3, 2 BETWEEN 3 AND 1;
-> 1, 0
mysql> SELECT 1 BETWEEN 2 AND 3;
-> 0
mysql> SELECT 'b' BETWEEN 'a' AND 'c';
-> 1
mysql> SELECT 2 BETWEEN 2 AND '3';
-> 1
mysql> SELECT 2 BETWEEN 2 AND 'x-3';
-> 0
```

For best results when using `BETWEEN` with date or time values, use `CAST()` to explicitly convert the values to the desired data type. Examples: If you compare a `DATETIME` to two `DATE` values, convert the `DATE` values to `DATETIME` values. If you use a string constant such as `'2001-1-1'` in a comparison to a `DATE`, cast the string to a `DATE`.

- **expr NOT BETWEEN min AND max**

  This is the same as `NOT (expr BETWEEN min AND max)`.

- **COALESCE(value, ...)**

  Returns the first non-NULL value in the list, or `NULL` if there are no non-NULL values.

  The return type of `COALESCE()` is the aggregated type of the argument types.

```
mysql> SELECT COALESCE(NULL,1);
-> 1
mysql> SELECT COALESCE(NULL,NULL,NULL);
-> NULL
```

- **GREATEST(value1, value2, ...)**

  With two or more arguments, returns the largest (maximum-valued) argument. The arguments are compared using the same rules as for `LEAST()`.

```
mysql> SELECT GREATEST(2,0);
-> 2
mysql> SELECT GREATEST(34.0,3.0,5.0,767.0);
-> 767.0
mysql> SELECT GREATEST('B','A','C');
-> 'C'
```

`GREATEST()` returns `NULL` if any argument is `NULL`.

- **expr IN (value, ...)**

  Returns 1 (true) if `expr` is equal to any of the values in the `IN()` list, else returns 0 (false).

  Type conversion takes place according to the rules described in Section 12.2, “Type Conversion in Expression Evaluation”, applied to all the arguments. If no type conversion is needed for the values in the `IN()` list, they are all constants of the same type, and `expr` can be compared to each of them as a value of the same type (possibly after type conversion), an optimization takes place. The values the list
Comparison Functions and Operators

are sorted and the search for \textit{expr} is done using a binary search, which makes the \textbf{IN()} operation very quick.

```sql
mysql> SELECT 2 IN (0,3,5,7);
-> 0
mysql> SELECT 'wefwf' IN ('wee','wefwf','weg');
-> 1
```

\textbf{IN()} can be used to compare row constructors:

```sql
mysql> SELECT (3,4) IN ((1,2), (3,4));
-> 1
mysql> SELECT (3,4) IN ((1,2), (3,5));
-> 0
```

You should never mix quoted and unquoted values in an \textbf{IN()} list because the comparison rules for quoted values (such as strings) and unquoted values (such as numbers) differ. Mixing types may therefore lead to inconsistent results. For example, do not write an \textbf{IN()} expression like this:

```sql
SELECT val1 FROM tbl1 WHERE val1 IN (1,2,'a');
```

Instead, write it like this:

```sql
SELECT val1 FROM tbl1 WHERE val1 IN ('1','2','a');
```

Implicit type conversion may produce nonintuitive results:

```sql
mysql> SELECT 'a' IN (0), 0 IN ('b');
-> 1, 1
```

In both cases, the comparison values are converted to floating-point values, yielding 0.0 in each case, and a comparison result of 1 (true).

The number of values in the \textbf{IN()} list is only limited by the \texttt{max_allowed_packet} value.

To comply with the SQL standard, \textbf{IN()} returns \texttt{NULL} not only if the expression on the left hand side is \texttt{NULL}, but also if no match is found in the list and one of the expressions in the list is \texttt{NULL}.

\textbf{IN()} syntax can also be used to write certain types of subqueries. See Section 13.2.10.3, “Subqueries with ANY, IN, or SOME”.

- \textbf{expr NOT IN} (\textit{value},...)
  
  This is the same as \textbf{NOT (expr IN} (\textit{value},...))

- \textbf{INTERVAL}(\textit{N,N1,N2,N3,...})

  Returns 0 if \textit{N} < \textit{N1}, 1 if \textit{N} < \textit{N2} and so on or -1 if \textit{N} is \texttt{NULL}. All arguments are treated as integers. It is required that \textit{N1} < \textit{N2} < \textit{N3} < \ldots < \textit{Nn} for this function to work correctly. This is because a binary search is used (very fast).

```sql
mysql> SELECT INTERVAL(23, 1, 15, 17, 30, 44, 200);
-> 3
mysql> SELECT INTERVAL(10, 1, 100, 1000);
-> 2
mysql> SELECT INTERVAL(22, 23, 30, 44, 200);
-> 0
```

- \textbf{IS boolean_value}

  Tests a value against a boolean value, where \textit{boolean_value} can be \texttt{TRUE}, \texttt{FALSE}, or \texttt{UNKNOWN}.  

1234
Comparison Functions and Operators

mysql> SELECT 1 IS TRUE, 0 IS FALSE, NULL IS UNKNOWN;
-> 1, 1, 1

• **IS NOT boolean_value**

Tests a value against a boolean value, where `boolean_value` can be `TRUE`, `FALSE`, or `UNKNOWN`.

mysql> SELECT 1 IS NOT UNKNOWN, 0 IS NOT UNKNOWN, NULL IS NOT UNKNOWN;
-> 1, 1, 0

• **IS NULL**

Tests whether a value is `NULL`.

mysql> SELECT 1 IS NULL, 0 IS NULL, NULL IS NULL;
-> 0, 0, 1

To work well with ODBC programs, MySQL supports the following extra features when using `IS NULL`:

• If `sql_auto_is_null` variable is set to 1, then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.15, “Information Functions”. If no `AUTO_INCREMENT` value was successfully inserted, the `SELECT` statement returns no row.

The behavior of retrieving an `AUTO_INCREMENT` value by using an `IS NULL` comparison can be disabled by setting `sql_auto_is_null = 0`. See Section 5.1.7, “Server System Variables”.

The default value of `sql_auto_is_null` is 0.

• For `DATE` and `DATETIME` columns that are declared as `NOT NULL`, you can find the special date `'0000-00-00'` by using a statement like this:

```
SELECT * FROM tbl_name WHERE date_column IS NULL
```

This is needed to get some ODBC applications to work because ODBC does not support a `'0000-00-00'` date value.

See Obtaining Auto-Increment Values, and the description for the `FLAG_AUTO_IS_NULL` option at Connector/ODBC Connection Parameters.

• **IS NOT NULL**

Tests whether a value is not `NULL`.

mysql> SELECT 1 IS NOT NULL, 0 IS NOT NULL, NULL IS NOT NULL;
-> 1, 1, 0

• **ISNULL(expr)**

If `expr` is `NULL`, `ISNULL()` returns 1, otherwise it returns 0.

mysql> SELECT ISNULL(1+1);
-> 0

mysql> SELECT ISNULL(1/0);
ISNULL() can be used instead of = to test whether a value is NULL. (Comparing a value to NULL using = always yields NULL.)

The ISNULL() function shares some special behaviors with the IS NULL comparison operator. See the description of IS NULL.

- LEAST(value1, value2,...)

With two or more arguments, returns the smallest (minimum-valued) argument. The arguments are compared using the following rules:

- If any argument is NULL, the result is NULL. No comparison is needed.
- If all arguments are integer-valued, they are compared as integers.
- If at least one argument is double precision, they are compared as double-precision values. Otherwise, if at least one argument is a DECIMAL value, they are compared as DECIMAL values.
- If the arguments comprise a mix of numbers and strings, they are compared as numbers.
- If any argument is a nonbinary (character) string, the arguments are compared as nonbinary strings.
- In all other cases, the arguments are compared as binary strings.

The return type of LEAST() is the aggregated type of the comparison argument types.

```
mysql> SELECT LEAST(2,0);
-> 0
mysql> SELECT LEAST(34.0,3.0,5.0,767.0);
-> 3.0
mysql> SELECT LEAST('B','A','C');
-> 'A'
```

12.3.3 Logical Operators

### Table 12.4 Logical Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND, &amp; &amp;</td>
<td>Logical AND</td>
</tr>
<tr>
<td>NOT, !</td>
<td>Negates value</td>
</tr>
<tr>
<td>OR,</td>
<td></td>
</tr>
<tr>
<td>XOR</td>
<td>Logical XOR</td>
</tr>
</tbody>
</table>

In SQL, all logical operators evaluate to TRUE, FALSE, or NULL (UNKNOWN). In MySQL, these are implemented as 1 (TRUE), 0 (FALSE), and NULL. Most of this is common to different SQL database servers, although some servers may return any nonzero value for TRUE.

MySQL evaluates any nonzero, non-NULL value to TRUE. For example, the following statements all assess to TRUE:

```
mysql> SELECT 10 IS TRUE;
-> 1
mysql> SELECT -10 IS TRUE;
-> 1
mysql> SELECT 'string' IS NOT NULL;
-> 1
```
Logical Operators

• **NOT, !**

Logical NOT. Evaluates to 1 if the operand is 0, to 0 if the operand is nonzero, and NOT NULL returns NULL.

```sql
mysql> SELECT NOT 10;
-> 0
mysql> SELECT NOT 0;
-> 1
mysql> SELECT NOT NULL;
-> NULL
mysql> SELECT ! (1+1);
-> 0
mysql> SELECT ! 1+1;
-> 1
```

The last example produces 1 because the expression evaluates the same way as (!1)+1.

• **AND, & &**

Logical AND. Evaluates to 1 if all operands are nonzero and not NULL, to 0 if one or more operands are 0, otherwise NULL is returned.

```sql
mysql> SELECT 1 AND 1;
-> 1
mysql> SELECT 1 AND 0;
-> 0
mysql> SELECT 1 AND NULL;
-> NULL
mysql> SELECT 0 AND NULL;
-> 0
mysql> SELECT NULL AND 0;
-> 0
```

• **OR, ||**

Logical OR. When both operands are non-NULL, the result is 1 if any operand is nonzero, and 0 otherwise. With a NULL operand, the result is 1 if the other operand is nonzero, and NULL otherwise. If both operands are NULL, the result is NULL.

```sql
mysql> SELECT 1 OR 1;
-> 1
mysql> SELECT 1 OR 0;
-> 1
mysql> SELECT 0 OR 0;
-> 0
mysql> SELECT 0 OR NULL;
-> NULL
mysql> SELECT 1 OR NULL;
-> 1
```

**Note**

If the PIPES_AS_CONCAT SQL mode is enabled, || signifies the SQL-standard string concatenation operator (like CONCAT()).

• **XOR**

Logical XOR. Returns NULL if either operand is NULL. For non-NULL operands, evaluates to 1 if an odd number of operands is nonzero, otherwise 0 is returned.

```sql
mysql> SELECT 1 XOR 1;
-> 0
```
Assignment Operators

a XOR b is mathematically equal to \((a \text{ AND } \lnot b) \text{ OR } ((\lnot a) \text{ and } b)\).

12.3.4 Assignment Operators

Table 12.5 Assignment Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:=</td>
<td>Assign a value</td>
</tr>
<tr>
<td>=</td>
<td>Assign a value (as part of a SET statement, or as part of the SET clause in an UPDATE statement)</td>
</tr>
</tbody>
</table>

- :=

Assignment operator. Causes the user variable on the left hand side of the operator to take on the value to its right. The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same SET statement. You can perform multiple assignments in the same statement.

Unlike =, the := operator is never interpreted as a comparison operator. This means you can use := in any valid SQL statement (not just in SET statements) to assign a value to a variable.

```sql
mysql> SELECT @var1, @var2;
-> NULL, NULL
mysql> SELECT @var1 := 1, @var2;
-> 1, NULL
mysql> SELECT @var1, @var2;
-> 1, NULL
mysql> SELECT @var1, @var2 := @var1;
-> 1, 1
mysql> SELECT @var1, @var2;
-> 1, 1
mysql> SELECT @var1:=COUNT(*) FROM t1;
-> 4
mysql> SELECT @var1;
-> 4
```

You can make value assignments using := in other statements besides SELECT, such as UPDATE, as shown here:

```sql
mysql> SELECT @var1;
-> 4
mysql> SELECT * FROM t1;
-> 1, 3, 5, 7
mysql> UPDATE t1 SET c1 = 2 WHERE c1 = @var1:= 1;
Query OK, 1 row affected (0.00 sec)
Rows matched: 1  Changed: 1  Warnings: 0
mysql> SELECT @var1;
-> 1
mysql> SELECT * FROM t1;
-> 2, 3, 5, 7
```
While it is also possible both to set and to read the value of the same variable in a single SQL statement using the := operator, this is not recommended. Section 9.4, “User-Defined Variables”, explains why you should avoid doing this.

- =

This operator is used to perform value assignments in two cases, described in the next two paragraphs.

Within a SET statement, = is treated as an assignment operator that causes the user variable on the left hand side of the operator to take on the value to its right. (In other words, when used in a SET statement, = is treated identically to :=.) The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same SET statement.

In the SET clause of an UPDATE statement, = also acts as an assignment operator; in this case, however, it causes the column named on the left hand side of the operator to assume the value given to the right, provided any WHERE conditions that are part of the UPDATE are met. You can make multiple assignments in the same SET clause of an UPDATE statement.

In any other context, = is treated as a comparison operator.

mysql> SELECT @var1, @var2;
-> NULL, NULL
mysql> SELECT @var1 := 1, @var2;
-> 1, NULL
mysql> SELECT @var1, @var2;
-> 1, NULL
mysql> SELECT @var1, @var2 := @var1;
-> 1, 1
mysql> SELECT @var1, @var2;
-> 1, 1

For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”, Section 13.2.11, “UPDATE Statement”, and Section 13.2.10, “Subqueries”.

### 12.4 Control Flow Functions

#### Table 12.6 Flow Control Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASE</td>
<td>Case operator</td>
</tr>
<tr>
<td>IF()</td>
<td>If/else construct</td>
</tr>
<tr>
<td>IFNULL()</td>
<td>Null if/else construct</td>
</tr>
<tr>
<td>NULLIF()</td>
<td>Return NULL if expr1 = expr2</td>
</tr>
</tbody>
</table>

- **CASE value WHEN [compare_value] THEN result [WHEN [compare_value] THEN result ...] [ELSE result] END**

CASE WHEN [condition] THEN result [WHEN [condition] THEN result ...] [ELSE result] END

The first CASE syntax returns the result for the first value=compare_value comparison that is true. The second syntax returns the result for the first condition that is true. If no comparison or condition is true, the result after ELSE is returned, or NULL if there is no ELSE part.
Control Flow Functions

Note
The syntax of the `CASE expr` described here differs slightly from that of the SQL `CASE statement` described in Section 13.6.5.1, "CASE Statement", for use inside stored programs. The `CASE` statement cannot have an `ELSE NULL` clause, and it is terminated with `END CASE` instead of `END`.

The return type of a `CASE` expression result is the aggregated type of all result values.

```sql
mysql> SELECT CASE WHEN 1 THEN 'one'
          -> WHEN 2 THEN 'two' ELSE 'more' END;
          -> 'one'
mysql> SELECT CASE WHEN 1>0 THEN 'true'
          -> ELSE 'false' END;
          -> 'true'
mysql> SELECT CASE WHEN BINARY 'B'
          -> WHEN 'a' THEN 1 WHEN 'b' THEN 2 END;
          -> NULL
```

- **IF(expr1, expr2, expr3)**

  If `expr1` is TRUE (`expr1 <> 0` and `expr1 <> NULL`), `IF()` returns `expr2`. Otherwise, it returns `expr3`.

  Note
  There is also an `IF statement`, which differs from the `IF() function` described here. See Section 13.6.5.2, "IF Statement".

  If only one of `expr2` or `expr3` is explicitly NULL, the result type of the `IF()` function is the type of the non-NULL expression.

  The default return type of `IF()` (which may matter when it is stored into a temporary table) is calculated as follows:

  - If `expr2` or `expr3` produce a string, the result is a string.
    - If `expr2` and `expr3` are both strings, the result is case-sensitive if either string is case-sensitive.
  - If `expr2` or `expr3` produce a floating-point value, the result is a floating-point value.
  - If `expr2` or `expr3` produce an integer, the result is an integer.

```sql
mysql> SELECT IF(1>2,2,3);
          -> 3
mysql> SELECT IF(1<2,'yes','no');
          -> 'yes'
mysql> SELECT IF(STRCMP('test', 'test1'), 'no', 'yes');
          -> 'no'
```

- **IFNULL(expr1, expr2)**

  If `expr1` is not NULL, `IFNULL()` returns `expr1`; otherwise it returns `expr2`.

```sql
mysql> SELECT IFNULL(1,0);
          -> 1
mysql> SELECT IFNULL(NULL,10);
          -> 10
mysql> SELECT IFNULL(1/0,10);
          -> 10
mysql> SELECT IFNULL(1/0,'yes');
```
The default return type of `IFNULL(expr1, expr2)` is the more "general" of the two expressions, in the order `STRING`, `REAL`, or `INTEGER`. Consider the case of a table based on expressions or where MySQL must internally store a value returned by `IFNULL()` in a temporary table:

```sql
mysql> CREATE TABLE tmp SELECT IFNULL(1,'test') AS test;
mysql> DESCRIBE tmp;
```

```
+-------+--------------+------+-----+---------+-------+
| Field | Type         | Null | Key | Default | Extra |
+-------+--------------+------+-----+---------+-------+
| test  | varbinary(4) | NO   |     |         |       |
+-------+--------------+------+-----+---------+-------+
```

In this example, the type of the `test` column is `VARBINARY(4)` (a string type).

• `NULLIF(expr1, expr2)`

Returns `NULL` if `expr1 = expr2` is true, otherwise returns `expr1`. This is the same as `CASE WHEN expr1 = expr2 THEN NULL ELSE expr1 END`.

The return value has the same type as the first argument.

```sql
mysql> SELECT NULLIF(1,1);
-> NULL
mysql> SELECT NULLIF(1,2);
-> 1
```

Note
MySQL evaluates `expr1` twice if the arguments are not equal.

### 12.5 Numeric Functions and Operators

#### Table 12.7 Numeric Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>%</code>, <code>MOD</code></td>
<td>Modulo operator</td>
</tr>
<tr>
<td><code>*</code></td>
<td>Multiplication operator</td>
</tr>
<tr>
<td><code>+</code></td>
<td>Addition operator</td>
</tr>
<tr>
<td><code>-</code></td>
<td>Minus operator</td>
</tr>
<tr>
<td><code>−</code></td>
<td>Change the sign of the argument</td>
</tr>
<tr>
<td><code>/</code></td>
<td>Division operator</td>
</tr>
<tr>
<td><code>ABS()</code></td>
<td>Return the absolute value</td>
</tr>
<tr>
<td><code>ACOS()</code></td>
<td>Return the arc cosine</td>
</tr>
<tr>
<td><code>ASIN()</code></td>
<td>Return the arc sine</td>
</tr>
<tr>
<td><code>ATAN()</code></td>
<td>Return the arc tangent</td>
</tr>
<tr>
<td><code>ATAN2()</code>, <code>ATAN()</code></td>
<td>Return the arc tangent of the two arguments</td>
</tr>
<tr>
<td><code>CEIL()</code></td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td><code>CEILING()</code></td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td><code>CONV()</code></td>
<td>Convert numbers between different number bases</td>
</tr>
</tbody>
</table>
### Arithmetic Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COS()</td>
<td>Return the cosine</td>
</tr>
<tr>
<td>COT()</td>
<td>Return the cotangent</td>
</tr>
<tr>
<td>CRC32()</td>
<td>Compute a cyclic redundancy check value</td>
</tr>
<tr>
<td>DEGREES()</td>
<td>Convert radians to degrees</td>
</tr>
<tr>
<td>DIV</td>
<td>Integer division</td>
</tr>
<tr>
<td>EXP()</td>
<td>Raise to the power of</td>
</tr>
<tr>
<td>FLOOR()</td>
<td>Return the largest integer value not greater than the argument</td>
</tr>
<tr>
<td>LN()</td>
<td>Return the natural logarithm of the argument</td>
</tr>
<tr>
<td>LOG()</td>
<td>Return the natural logarithm of the first argument</td>
</tr>
<tr>
<td>LOG10()</td>
<td>Return the base-10 logarithm of the argument</td>
</tr>
<tr>
<td>LOG2()</td>
<td>Return the base-2 logarithm of the argument</td>
</tr>
<tr>
<td>MOD()</td>
<td>Return the remainder</td>
</tr>
<tr>
<td>PI()</td>
<td>Return the value of pi</td>
</tr>
<tr>
<td>POW()</td>
<td>Return the argument raised to the specified power</td>
</tr>
<tr>
<td>POWER()</td>
<td>Return the argument raised to the specified power</td>
</tr>
<tr>
<td>RADIANS()</td>
<td>Return argument converted to radians</td>
</tr>
<tr>
<td>RAND()</td>
<td>Return a random floating-point value</td>
</tr>
<tr>
<td>ROUND()</td>
<td>Round the argument</td>
</tr>
<tr>
<td>SIGN()</td>
<td>Return the sign of the argument</td>
</tr>
<tr>
<td>SIN()</td>
<td>Return the sine of the argument</td>
</tr>
<tr>
<td>SQRT()</td>
<td>Return the square root of the argument</td>
</tr>
<tr>
<td>TAN()</td>
<td>Return the tangent of the argument</td>
</tr>
<tr>
<td>TRUNCATE()</td>
<td>Truncate to specified number of decimal places</td>
</tr>
</tbody>
</table>

12.5.1 Arithmetic Operators

Table 12.8 Arithmetic Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%, MOD</td>
<td>Modulo operator</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication operator</td>
</tr>
<tr>
<td>+</td>
<td>Addition operator</td>
</tr>
<tr>
<td>-</td>
<td>Minus operator</td>
</tr>
<tr>
<td></td>
<td>Change the sign of the argument</td>
</tr>
<tr>
<td>/</td>
<td>Division operator</td>
</tr>
<tr>
<td>DIV</td>
<td>Integer division</td>
</tr>
</tbody>
</table>

The usual arithmetic operators are available. The result is determined according to the following rules:

- In the case of -, +, and *, the result is calculated with **BIGINT** (64-bit) precision if both operands are integers.
Arithmetic Operators

• If both operands are integers and any of them are unsigned, the result is an unsigned integer. For subtraction, if the **NO_UNSIGNED_SUBTRACTION** SQL mode is enabled, the result is signed even if any operand is unsigned.

• If any of the operands of a `+`, `−`, `/`, `*`, `%` is a real or string value, the precision of the result is the precision of the operand with the maximum precision.

• In division performed with `/`, the scale of the result when using two exact-value operands is the scale of the first operand plus the value of the `div_precision_increment` system variable (which is 4 by default). For example, the result of the expression `5.05 / 0.014` has a scale of six decimal places (360.714286).

These rules are applied for each operation, such that nested calculations imply the precision of each component. Hence, `(14620 / 9432456) / (24250 / 9432456)`, resolves first to `(0.0014) / (0.0026)`, with the final result having 8 decimal places (0.60288653).

Because of these rules and the way they are applied, care should be taken to ensure that components and subcomponents of a calculation use the appropriate level of precision. See Section 12.10, "Cast Functions and Operators".

For information about handling of overflow in numeric expression evaluation, see Section 11.1.7, "Out-of-Range and Overflow Handling".

Arithmetic operators apply to numbers. For other types of values, alternative operations may be available. For example, to add date values, use `DATE_ADD()`; see Section 12.6, "Date and Time Functions".

• **+**

  Addition:

  ```
  mysql> SELECT 3+5;
  -> 8
  ```

• **−**

  Subtraction:

  ```
  mysql> SELECT 3-5;
  -> -2
  ```

• **−**

  Unary minus. This operator changes the sign of the operand.

  ```
  mysql> SELECT - 2;
  -> -2
  ```

  **Note**

  If this operator is used with a `BIGINT`, the return value is also a `BIGINT`. This means that you should avoid using `−` on integers that may have the value of $-2^{63}$.

• **×**

  Multiplication:

  ```
  mysql> SELECT 3*5;
  -> 15
  mysql> SELECT 18014398509481984*18014398509481984.0;
  -> 324518553658426726783156020576256.0
  ```
The last expression produces an error because the result of the integer multiplication exceeds the 64-bit range of `BIGINT` calculations. (See Section 11.1, “Numeric Data Types”.)

- `/`

Division:

```mysql
mysql> SELECT 3/5;
-> 0.60
```

Division by zero produces a `NULL` result:

```mysql
mysql> SELECT 102/(1-1);
-> NULL
```

A division is calculated with `BIGINT` arithmetic only if performed in a context where its result is converted to an integer.

- `DIV`

Integer division. Discards from the division result any fractional part to the right of the decimal point.

If either operand has a noninteger type, the operands are converted to `DECIMAL` and divided using `DECIMAL` arithmetic before converting the result to `BIGINT`. If the result exceeds `BIGINT` range, an error occurs.

```mysql
mysql> SELECT 5 DIV 2, -5 DIV 2, 5 DIV -2, -5 DIV -2;
-> 2, -2, -2, 2
```

- `N % M, N MOD M`

Modulo operation. Returns the remainder of `N` divided by `M`. For more information, see the description for the `MOD()` function in Section 12.5.2, “Mathematical Functions”.

### 12.5.2 Mathematical Functions

#### Table 12.9 Mathematical Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS()</td>
<td>Return the absolute value</td>
</tr>
<tr>
<td>ACOS()</td>
<td>Return the arc cosine</td>
</tr>
<tr>
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<td>Return the arc sine</td>
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<tr>
<td>ATAN()</td>
<td>Return the arc tangent</td>
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<tr>
<td>ATAN2(), ATAN()</td>
<td>Return the arc tangent of the two arguments</td>
</tr>
<tr>
<td>CEIL()</td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td>CEILING()</td>
<td>Return the smallest integer value not less than the argument</td>
</tr>
<tr>
<td>CONV()</td>
<td>Convert numbers between different number bases</td>
</tr>
<tr>
<td>COS()</td>
<td>Return the cosine</td>
</tr>
<tr>
<td>COT()</td>
<td>Return the cotangent</td>
</tr>
<tr>
<td>CRC32()</td>
<td>Compute a cyclic redundancy check value</td>
</tr>
<tr>
<td>DEGREES()</td>
<td>Convert radians to degrees</td>
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</table>
Mathematical Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP()</td>
<td>Raise to the power of</td>
</tr>
<tr>
<td>FLOOR()</td>
<td>Return the largest integer value not greater than the argument</td>
</tr>
<tr>
<td>LN()</td>
<td>Return the natural logarithm of the argument</td>
</tr>
<tr>
<td>LOG()</td>
<td>Return the natural logarithm of the first argument</td>
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<tr>
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<td>Return the tangent of the argument</td>
</tr>
<tr>
<td>TRUNCATE()</td>
<td>Truncate to specified number of decimal places</td>
</tr>
</tbody>
</table>

All mathematical functions return **NULL** in the event of an error.

- **ABS(X)**

  Returns the absolute value of **X**.

  ```sql
  mysql> SELECT ABS(2);
  -> 2
  mysql> SELECT ABS(-32);
  -> 32
  ```

  This function is safe to use with **BIGINT** values.

- **ACOS(X)**

  Returns the arc cosine of **X**, that is, the value whose cosine is **X**. Returns **NULL** if **X** is not in the range **−1** to **1**.

  ```sql
  mysql> SELECT ACOS(1);
  -> 0
  mysql> SELECT ACOS(1.0001);
  -> NULL
  mysql> SELECT ACOS(0);
  -> 1.5707963267949
  ```

- **ASIN(X)**

  Returns the arc sine of **X**, that is, the value whose sine is **X**. Returns **NULL** if **X** is not in the range **−1** to **1**.

  ```sql
  mysql> SELECT ASIN(0.2);
  -> 0.20135792079033
  mysql> SELECT ASIN('foo');
  ```
### Mathematical Functions

- **ASIN('foo')**

<table>
<thead>
<tr>
<th>ASIN('foo')</th>
<th>0</th>
</tr>
</thead>
</table>

1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------+
| Level   | Code | Message                                 |
|---------+------|-----------------------------------------|
| Warning | 1292 | Truncated incorrect DOUBLE value: 'foo' |

• **ATAN(X)**

Returns the arc tangent of \( X \), that is, the value whose tangent is \( X \).

mysql> SELECT ATAN(2);
-> 1.1071487177941
mysql> SELECT ATAN(-2);
-> -1.1071487177941

• **ATAN(Y, X), ATAN2(Y, X)**

Returns the arc tangent of the two variables \( X \) and \( Y \). It is similar to calculating the arc tangent of \( \frac{Y}{X} \), except that the signs of both arguments are used to determine the quadrant of the result.

mysql> SELECT ATAN(-2,2);
-> -0.78539816339745
mysql> SELECT ATAN2(PI(),0);
-> 1.5707963267949

• **CEIL(X)**

**CEIL()** is a synonym for **CEILING()**.

• **CEILING(X)**

Returns the smallest integer value not less than \( X \).

mysql> SELECT CEILING(1.23);
-> 2
mysql> SELECT CEILING(-1.23);
-> -1

For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.

• **CONV(N, from_base, to_base)**

Converts numbers between different number bases. Returns a string representation of the number \( N \), converted from base **from_base** to base **to_base**. Returns **NULL** if any argument is **NULL**. The argument \( N \) is interpreted as an integer, but may be specified as an integer or a string. The minimum base is 2 and the maximum base is 36. If **from_base** is a negative number, \( N \) is regarded as a signed number. Otherwise, \( N \) is treated as unsigned. **CONV()** works with 64-bit precision.

mysql> SELECT CONV('a',16,2);
-> '1010'
mysql> SELECT CONV('6E',18,8);
-> '172'
mysql> SELECT CONV(-17,10,-18);
**Mathematical Functions**

- **COS**(X)
  Returns the cosine of X, where X is given in radians.

  
  ```
  mysql> SELECT COS(PI());
  -> -1
  ```

- **COT**(X)
  Returns the cotangent of X.

  ```
  mysql> SELECT COT(12);
  -> -1.5726734063977
  mysql> SELECT COT(0);
  -> out-of-range error
  ```

- **CRC32**(expr)
  Computes a cyclic redundancy check value and returns a 32-bit unsigned value. The result is NULL if the argument is NULL. The argument is expected to be a string and (if possible) is treated as one if it is not.

  ```
  mysql> SELECT CRC32('MySQL');
  -> 3259397556
  mysql> SELECT CRC32('mysql');
  -> 2501908538
  ```

- **DEGREES**(X)
  Returns the argument X, converted from radians to degrees.

  ```
  mysql> SELECT DEGREES(PI());
  -> 180
  mysql> SELECT DEGREES(PI() / 2);
  -> 90
  ```

- **EXP**(X)
  Returns the value of e (the base of natural logarithms) raised to the power of X. The inverse of this function is **LOG** (using a single argument only) or **LN**.

  ```
  mysql> SELECT EXP(2);
  -> 7.3890560989307
  mysql> SELECT EXP(-2);
  -> 0.13533528323661
  mysql> SELECT EXP(0);
  -> 1
  ```

- **FLOOR**(X)
  Returns the largest integer value not greater than X.

  ```
  mysql> SELECT FLOOR(1.23), FLOOR(-1.23);
  -> 1, -2
  ```

For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.
• **FORMAT (**$X, D$$)**

  Formats the number $X$ to a format like '###,###,###.###', rounded to $D$ decimal places, and returns the result as a string. For details, see Section 12.7, “String Functions and Operators”.

• **HEX (**$N_or_S$$)**

  This function can be used to obtain a hexadecimal representation of a decimal number or a string; the manner in which it does so varies according to the argument’s type. See this function’s description in Section 12.7, “String Functions and Operators”, for details.

• **LN (**$X$$)**

  Returns the natural logarithm of $X$; that is, the base-$e$ logarithm of $X$. If $X$ is less than or equal to 0, then **NULL** is returned.

  ```
  mysql> SELECT LN(2);
  -> 0.69314718055995
  mysql> SELECT LN(-2);
  -> NULL
  ```

  This function is synonymous with LOG (**$X$$**). The inverse of this function is the **EXP** () function.

• **LOG (**$X$$**), LOG (**$B, X$$**)**

  If called with one parameter, this function returns the natural logarithm of $X$. If $X$ is less than or equal to 0, then **NULL** is returned.

  The inverse of this function (when called with a single argument) is the **EXP** () function.

  ```
  mysql> SELECT LOG(2);
  -> 0.69314718055995
  mysql> SELECT LOG(-2);
  -> NULL
  ```

  If called with two parameters, this function returns the logarithm of $X$ to the base $B$. If $X$ is less than or equal to 0, or if $B$ is less than or equal to 1, then **NULL** is returned.

  ```
  mysql> SELECT LOG(2,65536);
  -> 16
  mysql> SELECT LOG(10,100);
  -> 2
  mysql> SELECT LOG(1,100);
  -> NULL
  ```

  **LOG (**$B, X$$**) is equivalent to **LOG (**$X$$**) / LOG (**$B$$**).**

• **LOG2 (**$X$$**)**

  Returns the base-2 logarithm of $X$.

  ```
  mysql> SELECT LOG2(65536);
  -> 16
  mysql> SELECT LOG2(-100);
  -> NULL
  ```

  **LOG2 ()** is useful for finding out how many bits a number requires for storage. This function is equivalent to the expression **LOG (**$X$$**) / LOG (**$2$$**).**
• **LOG10**(X)

Returns the base-10 logarithm of X.

mysql> SELECT LOG10(2);
-> 0.30102999566398
mysql> SELECT LOG10(100);
-> 2
mysql> SELECT LOG10(-100);
-> NULL

**LOG10**(X) is equivalent to **LOG**(10, X).

• **MOD**(N, M), N % M, N MOD M

Modulo operation. Returns the remainder of N divided by M.

mysql> SELECT MOD(234, 10);
-> 4
mysql> SELECT 253 % 7;
-> 1
mysql> SELECT MOD(29, 9);
-> 2
mysql> SELECT 29 MOD 9;
-> 2

This function is safe to use with BIGINT values.

**MOD**(N, 0) returns NULL.

• **PI()**

Returns the value of π (pi). The default number of decimal places displayed is seven, but MySQL uses the full double-precision value internally.

mysql> SELECT PI();
-> 3.141593
mysql> SELECT PI()+0.000000000000000000;
-> 3.141592653589793116

• **POW**(X, Y)

Returns the value of X raised to the power of Y.

mysql> SELECT POW(2, 2);
-> 4
mysql> SELECT POW(2, -2);
-> 0.25

• **POWER**(X, Y)

This is a synonym for **POW**( ).

• **RADIANS**(X)

Returns the argument X, converted from degrees to radians. (Note that π radians equals 180 degrees.)

mysql> SELECT RADIANS(90);
• **RAND ([N])**

Returns a random floating-point value \( v \) in the range \( 0 \leq v < 1.0 \). To obtain a random integer \( R \) in the range \( i \leq R < j \), use the expression \( \text{FLOOR}(i + \text{RAND()} \times (j - i)) \). For example, to obtain a random integer in the range the range \( 7 \leq R < 12 \), use the following statement:

```
SELECT FLOOR(7 + (RAND() * 5));
```

If an integer argument \( N \) is specified, it is used as the seed value:

- With a constant initializer argument, the seed is initialized once when the statement is prepared, prior to execution.
- With a nonconstant initializer argument (such as a column name), the seed is initialized with the value for each invocation of \( \text{RAND()} \).

One implication of this behavior is that for equal argument values, \( \text{RAND}(N) \) returns the same value each time, and thus produces a repeatable sequence of column values. In the following example, the sequence of values produced by \( \text{RAND}(3) \) is the same both places it occurs.
Mathematical Functions

RAND() in a WHERE clause is evaluated for every row (when selecting from one table) or combination of rows (when selecting from a multiple-table join). Thus, for optimizer purposes, RAND() is not a constant value and cannot be used for index optimizations. For more information, see Section 8.2.1.14, “Function Call Optimization”.

Use of a column with RAND() values in an ORDER BY or GROUP BY clause may yield unexpected results because for either clause a RAND() expression can be evaluated multiple times for the same row, each time returning a different result. If the goal is to retrieve rows in random order, you can use a statement like this:

```sql
SELECT * FROM tbl_name ORDER BY RAND();
```

To select a random sample from a set of rows, combine ORDER BY RAND() with LIMIT:

```sql
SELECT * FROM table1, table2 WHERE a=b AND c<d ORDER BY RAND() LIMIT 1000;
```

RAND() is not meant to be a perfect random generator. It is a fast way to generate random numbers on demand that is portable between platforms for the same MySQL version.

This function is unsafe for statement-based replication. A warning is logged if you use this function when binlog_format is set to STATEMENT.

- ROUND(X), ROUND(X, D)

Rounds the argument X to D decimal places. The rounding algorithm depends on the data type of X. D defaults to 0 if not specified. D can be negative to cause D digits left of the decimal point of the value X to become zero.

```sql
mysql> SELECT ROUND(-1.23);  
-> -1
mysql> SELECT ROUND(-1.58);  
-> -2
mysql> SELECT ROUND(1.58);   
-> 2
mysql> SELECT ROUND(1.298, 1);  
-> 1.3
mysql> SELECT ROUND(1.298, 0);  
-> 1
mysql> SELECT ROUND(23.298, -1);  
-> 20
```

The return value has the same type as the first argument (assuming that it is integer, double, or decimal). This means that for an integer argument, the result is an integer (no decimal places):

```sql
mysql> SELECT ROUND(150.000,2), ROUND(150,2);  
+------------------+--------------+  
| ROUND(150.000,2) | ROUND(150,2) |  
+------------------+--------------+  
| 150.00           | 150          |  
+------------------+--------------+  
```

ROUND() uses the following rules depending on the type of the first argument:

- For exact-value numbers, ROUND() uses the “round half away from zero” or “round toward nearest” rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down
to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative.

- For approximate-value numbers, the result depends on the C library. On many systems, this means that `ROUND()` uses the “round to nearest even” rule: A value with a fractional part exactly half way between two integers is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

<table>
<thead>
<tr>
<th>mysql&gt; SELECT ROUND(2.5), ROUND(25E-1);</th>
</tr>
</thead>
<tbody>
<tr>
<td>+----------+------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>+----------+------------------</td>
</tr>
</tbody>
</table>

For more information, see Section 12.19, “Precision Math”.

- `SIGN(X)`

Returns the sign of the argument as -1, 0, or 1, depending on whether X is negative, zero, or positive.

<table>
<thead>
<tr>
<th>mysql&gt; SELECT SIGN(-32);</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; -1</td>
</tr>
<tr>
<td>mysql&gt; SELECT SIGN(0);</td>
</tr>
<tr>
<td>-&gt; 0</td>
</tr>
<tr>
<td>mysql&gt; SELECT SIGN(234);</td>
</tr>
<tr>
<td>-&gt; 1</td>
</tr>
</tbody>
</table>

- `SIN(X)`

Returns the sine of X, where X is given in radians.

<table>
<thead>
<tr>
<th>mysql&gt; SELECT SIN(PI());</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; 1.2246063538224e-16</td>
</tr>
<tr>
<td>mysql&gt; SELECT ROUND(SIN(PI()));</td>
</tr>
<tr>
<td>-&gt; 0</td>
</tr>
</tbody>
</table>

- `SQRT(X)`

Returns the square root of a nonnegative number X.

<table>
<thead>
<tr>
<th>mysql&gt; SELECT SQRT(4);</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; 2</td>
</tr>
<tr>
<td>mysql&gt; SELECT SQRT(20);</td>
</tr>
<tr>
<td>-&gt; 4.4721359549996</td>
</tr>
<tr>
<td>mysql&gt; SELECT SQRT(-16);</td>
</tr>
<tr>
<td>-&gt; NULL</td>
</tr>
</tbody>
</table>

- `TAN(X)`

Returns the tangent of X, where X is given in radians.

<table>
<thead>
<tr>
<th>mysql&gt; SELECT TAN(PI());</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; -1.2246063538224e-16</td>
</tr>
<tr>
<td>mysql&gt; SELECT TAN(PI()+1);</td>
</tr>
<tr>
<td>-&gt; 1.557407246549</td>
</tr>
</tbody>
</table>

- `TRUNCATE(X, D)`

Returns the number X, truncated to D decimal places. If D is 0, the result has no decimal point or fractional part. D can be negative to cause D digits left of the decimal point of the value X to become zero.
All numbers are rounded toward zero.

## 12.6 Date and Time Functions

This section describes the functions that can be used to manipulate temporal values. See Section 11.2, “Date and Time Data Types”, for a description of the range of values each date and time type has and the valid formats in which values may be specified.

### Table 12.10 Date and Time Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDDATE()</td>
<td>Add time values (intervals) to a date value</td>
</tr>
<tr>
<td>ADDTIME()</td>
<td>Add time</td>
</tr>
<tr>
<td>CONVERT_TZ()</td>
<td>Convert from one time zone to another</td>
</tr>
<tr>
<td>CURDATE()</td>
<td>Return the current date</td>
</tr>
<tr>
<td>CURRENT_DATE(), CURRENT_DATE</td>
<td>Synonyms for CURDATE()</td>
</tr>
<tr>
<td>CURRENT_TIME(), CURRENT_TIME</td>
<td>Synonyms for CURTIME()</td>
</tr>
<tr>
<td>CURRENT_TIMESTAMP(), CURRENT_TIMESTAMP</td>
<td>Synonyms for NOW()</td>
</tr>
<tr>
<td>CURTIME()</td>
<td>Return the current time</td>
</tr>
<tr>
<td>DATE()</td>
<td>Extract the date part of a date or datetime expression</td>
</tr>
<tr>
<td>DATE_ADD()</td>
<td>Add time values (intervals) to a date value</td>
</tr>
<tr>
<td>DATE_FORMAT()</td>
<td>Format date as specified</td>
</tr>
<tr>
<td>DATE_SUB()</td>
<td>Subtract a time value (interval) from a date</td>
</tr>
<tr>
<td>DATEDIFF()</td>
<td>Subtract two dates</td>
</tr>
<tr>
<td>DAY()</td>
<td>Synonym for DAYOFMONTH()</td>
</tr>
<tr>
<td>DAYNAME()</td>
<td>Return the name of the weekday</td>
</tr>
<tr>
<td>DAYOFMONTH()</td>
<td>Return the day of the month (0-31)</td>
</tr>
<tr>
<td>DAYOFWEEK()</td>
<td>Return the weekday index of the argument</td>
</tr>
<tr>
<td>DAYOFYEAR()</td>
<td>Return the day of the year (1-366)</td>
</tr>
<tr>
<td>EXTRACT()</td>
<td>Extract part of a date</td>
</tr>
<tr>
<td>FROM_DAYS()</td>
<td>Convert a day number to a date</td>
</tr>
<tr>
<td>FROM_UNIXTIME()</td>
<td>Format Unix timestamp as a date</td>
</tr>
<tr>
<td>GET_FORMAT()</td>
<td>Return a date format string</td>
</tr>
<tr>
<td>HOUR()</td>
<td>Extract the hour</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LAST_DAY</td>
<td>Return the last day of the month for the argument</td>
</tr>
<tr>
<td>LOCALTIME(), LOCALTIME</td>
<td>Synonym for NOW()</td>
</tr>
<tr>
<td>LOCALTIMESTAMP, LOCALTIMESTAMP</td>
<td>Synonym for NOW()</td>
</tr>
<tr>
<td>MAKEDATE()</td>
<td>Create a date from the year and day of year</td>
</tr>
<tr>
<td>MAKETIME()</td>
<td>Create time from hour, minute, second</td>
</tr>
<tr>
<td>MICROSECOND()</td>
<td>Return the microseconds from argument</td>
</tr>
<tr>
<td>MINUTE()</td>
<td>Return the minute from the argument</td>
</tr>
<tr>
<td>MONTH()</td>
<td>Return the month from the date passed</td>
</tr>
<tr>
<td>MONTHNAME()</td>
<td>Return the name of the month</td>
</tr>
<tr>
<td>NOW()</td>
<td>Return the current date and time</td>
</tr>
<tr>
<td>PERIOD_ADD()</td>
<td>Add a period to a year-month</td>
</tr>
<tr>
<td>PERIOD_DIFF()</td>
<td>Return the number of months between periods</td>
</tr>
<tr>
<td>QUARTER()</td>
<td>Return the quarter from a date argument</td>
</tr>
<tr>
<td>SEC_TO_TIME()</td>
<td>Converts seconds to 'hh:mm:ss' format</td>
</tr>
<tr>
<td>SECOND()</td>
<td>Return the second (0-59)</td>
</tr>
<tr>
<td>STR_TO_DATE()</td>
<td>Convert a string to a date</td>
</tr>
<tr>
<td>SUBDATE()</td>
<td>Synonym for DATE_SUB() when invoked with three arguments</td>
</tr>
<tr>
<td>SUBTIME()</td>
<td>Subtract times</td>
</tr>
<tr>
<td>SYSDATE()</td>
<td>Return the time at which the function executes</td>
</tr>
<tr>
<td>TIME()</td>
<td>Extract the time portion of the expression passed</td>
</tr>
<tr>
<td>TIME_FORMAT()</td>
<td>Format as time</td>
</tr>
<tr>
<td>TIME_TO_SEC()</td>
<td>Return the argument converted to seconds</td>
</tr>
<tr>
<td>TIMEDIFF()</td>
<td>Subtract time</td>
</tr>
<tr>
<td>TIMESTAMP()</td>
<td>With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments</td>
</tr>
<tr>
<td>TIMESTAMPADD()</td>
<td>Add an interval to a datetime expression</td>
</tr>
<tr>
<td>TIMESTAMPDIFF()</td>
<td>Subtract an interval from a datetime expression</td>
</tr>
<tr>
<td>TO_DAYS()</td>
<td>Return the date argument converted to days</td>
</tr>
<tr>
<td>TO_SECONDS()</td>
<td>Return the date or datetime argument converted to seconds since Year 0</td>
</tr>
<tr>
<td>UNIX_TIMESTAMP()</td>
<td>Return a Unix timestamp</td>
</tr>
<tr>
<td>UTC_DATE()</td>
<td>Return the current UTC date</td>
</tr>
<tr>
<td>UTC_TIME()</td>
<td>Return the current UTC time</td>
</tr>
<tr>
<td>UTC_TIMESTAMP()</td>
<td>Return the current UTC date and time</td>
</tr>
<tr>
<td>WEEK()</td>
<td>Return the week number</td>
</tr>
<tr>
<td>WEEKDAY()</td>
<td>Return the weekday index</td>
</tr>
<tr>
<td>WEEKOFYEAR()</td>
<td>Return the calendar week of the date (1-53)</td>
</tr>
</tbody>
</table>
Date and Time Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR()</td>
<td>Return the year</td>
</tr>
<tr>
<td>YEARWEEK()</td>
<td>Return the year and week</td>
</tr>
</tbody>
</table>

Here is an example that uses date functions. The following query selects all rows with a `date_col` value from within the last 30 days:

```sql
mysql> SELECT something FROM tbl_name
    -> WHERE DATE_SUB(CURDATE(), INTERVAL 30 DAY) <= date_col;
```

The query also selects rows with dates that lie in the future.

Functions that expect date values usually accept datetime values and ignore the time part. Functions that expect time values usually accept datetime values and ignore the date part.

Functions that return the current date or time each are evaluated only once per query at the start of query execution. This means that multiple references to a function such as `NOW()` within a single query always produce the same result. (For our purposes, a single query also includes a call to a stored program (stored routine, trigger, or event) and all subprograms called by that program.) This principle also applies to `CURDATE()`, `CURTIME()`, `UTC_DATE()`, `UTC_TIME()`, `UTC_TIMESTAMP()`, and to any of their synonyms.

The `CURRENT_TIMESTAMP()`, `CURRENT_TIME()`, `CURRENT_DATE()`, and `FROM_UNIXTIME()` functions return values in the current session time zone, which is available as the session value of the `time_zone` system variable. In addition, `UNIX_TIMESTAMP()` assumes that its argument is a datetime value in the session time zone. See Section 5.1.12, “MySQL Server Time Zone Support”.

Some date functions can be used with “zero” dates or incomplete dates such as '2001-11-00', whereas others cannot. Functions that extract parts of dates typically work with incomplete dates and thus can return 0 when you might otherwise expect a nonzero value. For example:

```sql
mysql> SELECT DAYOFMONTH('2001-11-00'), MONTH('2005-00-00');
    -> 0, 0
```

Other functions expect complete dates and return `NULL` for incomplete dates. These include functions that perform date arithmetic or that map parts of dates to names. For example:

```sql
mysql> SELECT DATE_ADD('2006-05-00', INTERVAL 1 DAY);
    -> NULL
mysql> SELECT DAYNAME('2006-05-00');
    -> NULL
```

**Note**

From MySQL 5.5.16 to 5.5.20, a change in handling of a date-related assertion caused several functions to become more strict when passed a `DATE()` function value as their argument and reject incomplete dates with a day part of zero. These functions are affected: `CONVERT_TZ()`, `DATE_ADD()`, `DATE_SUB()`, `DAYOFYEAR()`, `LAST_DAY()`, `TIMESTAMPDIFF()`, `TO_DAYS()`, `TO_SECONDS()`, `WEEK()`, `WEEKDAY()`, `WEEKOFYEAR()`, `YEARWEEK()`. Because this changes date-handling behavior in General Availability-status series MySQL 5.5, the change was reverted in 5.5.21.

- `ADDDATE(date, INTERVAL expr unit)`, `ADDDATE(expr, days)`

When invoked with the `INTERVAL` form of the second argument, `ADDDATE()` is a synonym for `DATE_ADD()`. The related function `SUBDATE()` is a synonym for `DATE_SUB()`. For information on the `INTERVAL unit` argument, see Temporal Intervals.
When invoked with the *days* form of the second argument, MySQL treats it as an integer number of days to be added to *expr*.

- **ADDTIME**(expr1, expr2)**

  ADDTIME() adds expr2 to expr1 and returns the result. expr1 is a time or datetime expression, and expr2 is a time expression.

- **CONVERT_TZ**(dt, from_tz, to_tz)**

  CONVERT_TZ() converts a datetime value dt from the time zone given by from_tz to the time zone given by to_tz and returns the resulting value. Time zones are specified as described in Section 5.1.12, "MySQL Server Time Zone Support". This function returns NULL if the arguments are invalid.

  If the value falls out of the supported range of the TIMESTAMP type when converted from from_tz to UTC, no conversion occurs. The TIMESTAMP range is described in Section 11.2.1, "Date and Time Data Type Syntax".

- **CURDATE()**

  Returns the current date as a value in 'YYYY-MM-DD' or YYYYMMDD format, depending on whether the function is used in string or numeric context.

- **CURRENT_DATE**, **CURRENT_DATE()**

  CURRENT_DATE and CURRENT_DATE() are synonyms for CURDATE().

- **CURRENT_TIME**, **CURRENT_TIME()**

  CURRENT_TIME and CURRENT_TIME() are synonyms for CURTIME().
• **CURRENT_TIMESTAMP, CURRENT_TIMESTAMP()**

`CURRENT_TIMESTAMP` and `CURRENT_TIMESTAMP()` are synonyms for `NOW()`.

• **CURTIME()**

Returns the current time as a value in 'hh:mm:ss' or hhmmss format, depending on whether the function is used in string or numeric context. The value is expressed in the session time zone.

```
mysql> SELECT CURTIME();
-> '23:50:26'
```

```
mysql> SELECT CURTIME() + 0;
-> 235026.000000
```

• **DATE(expr)**

Extracts the date part of the date or datetime expression `expr`.

```
mysql> SELECT DATE('2003-12-31 01:02:03');
-> '2003-12-31'
```

• **DATEDIFF(expr1, expr2)**

`DATEDIFF()` returns `expr1 - expr2` expressed as a value in days from one date to the other. `expr1` and `expr2` are date or date-and-time expressions. Only the date parts of the values are used in the calculation.

```
mysql> SELECT DATEDIFF('2007-12-31 23:59:59','2007-12-30');
-> 1
```

```
mysql> SELECT DATEDIFF('2010-11-30 23:59:59','2010-12-31');
-> -31
```

• **DATE_ADD(date, INTERVAL expr unit), DATE_SUB(date, INTERVAL expr unit)**

These functions perform date arithmetic. The `date` argument specifies the starting date or datetime value. `expr` is an expression specifying the interval value to be added or subtracted from the starting date. `expr` is evaluated as a string; it may start with a - for negative intervals. `unit` is a keyword indicating the units in which the expression should be interpreted.

For more information about temporal interval syntax, including a full list of `unit` specifiers, the expected form of the `expr` argument for each `unit` value, and rules for operand interpretation in temporal arithmetic, see Temporal Intervals.

The return value depends on the arguments:

• **DATE** if the `date` argument is a `DATE` value and your calculations involve only `YEAR`, `MONTH`, and `DAY` parts (that is, no time parts).

• **DATETIME** if the first argument is a `DATETIME` (or `TIMESTAMP`) value, or if the first argument is a `DATE` and the `unit` value uses `HOURS`, `MINUTES`, or `SECONDS`.

• String otherwise.

To ensure that the result is `DATETIME`, you can use `CAST()` to convert the first argument to `DATETIME`.

```
mysql> SELECT DATE_ADD('2018-05-01',INTERVAL 1 DAY);
-> '2018-05-02'
```

```
mysql> SELECT DATE_SUB('2018-05-01',INTERVAL 1 YEAR);
-> '2017-05-01'
```

```
mysql> SELECT DATE_ADD('2020-12-31 23:59:59', INTERVAL 1 SECOND);
```
Date and Time Functions

mysql> SELECT DATE_ADD('2018-12-31 23:59:59',
                   INTERVAL 1 DAY);
-> '2019-01-01 23:59:59'

mysql> SELECT DATE_ADD('2100-12-31 23:59:59',
                   INTERVAL '1:1' MINUTE_SECOND);
-> '2101-01-01 00:01:00'

mysql> SELECT DATE_SUB('2025-01-01 00:00:00',
                   INTERVAL '1 1:1:1' DAY_SECOND);
-> '2024-12-30 22:58:59'

mysql> SELECT DATE_ADD('1900-01-01 00:00:00',
                   INTERVAL '-1 10' DAY_HOUR);
-> '1899-12-30 14:00:00'

mysql> SELECT DATE_SUB('1998-01-02', INTERVAL 31 DAY);
-> '1997-12-02'

mysql> SELECT DATE_ADD('1992-12-31 23:59:59.000002',
                   INTERVAL '1.999999' SECOND_MICROSECOND);
-> '1993-01-01 00:00:01.000001'

- **DATE_FORMAT**(date, format)

Formats the *date* value according to the *format* string.

The specifiers shown in the following table may be used in the *format* string. The % character is required before format specifier characters. The specifiers apply to other functions as well: `STR_TO_DATE()`, `TIME_FORMAT()`, `UNIX_TIMESTAMP()`.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%a</td>
<td>Abbreviated weekday name (Sun..Sat)</td>
</tr>
<tr>
<td>%b</td>
<td>Abbreviated month name (Jan..Dec)</td>
</tr>
<tr>
<td>%c</td>
<td>Month, numeric (0..12)</td>
</tr>
<tr>
<td>%D</td>
<td>Day of the month with English suffix (0th, 1st, 2nd, 3rd, ...)</td>
</tr>
<tr>
<td>%d</td>
<td>Day of the month, numeric (00..31)</td>
</tr>
<tr>
<td>%e</td>
<td>Day of the month, numeric (0..31)</td>
</tr>
<tr>
<td>%f</td>
<td>Microseconds (000000..999999)</td>
</tr>
<tr>
<td>%H</td>
<td>Hour (00..23)</td>
</tr>
<tr>
<td>%h</td>
<td>Hour (01..12)</td>
</tr>
<tr>
<td>%I</td>
<td>Hour (01..12)</td>
</tr>
<tr>
<td>%i</td>
<td>Minutes, numeric (00..59)</td>
</tr>
<tr>
<td>%j</td>
<td>Day of year (001..366)</td>
</tr>
<tr>
<td>%k</td>
<td>Hour (0..23)</td>
</tr>
<tr>
<td>%l</td>
<td>Hour (1..12)</td>
</tr>
<tr>
<td>%M</td>
<td>Month name (January..December)</td>
</tr>
<tr>
<td>%m</td>
<td>Month, numeric (00..12)</td>
</tr>
<tr>
<td>%p</td>
<td>AM OR PM</td>
</tr>
<tr>
<td>%r</td>
<td>Time, 12-hour (hh:mm:ss followed by AM or PM)</td>
</tr>
<tr>
<td>%S</td>
<td>Seconds (00..59)</td>
</tr>
<tr>
<td>%s</td>
<td>Seconds (00..59)</td>
</tr>
<tr>
<td>%T</td>
<td>Time, 24-hour (hh:mm:ss)</td>
</tr>
</tbody>
</table>
**Specifier** | **Description**  
---|---  
%% | A literal % character  
%x | x, for any "x" not listed above  
%U | Week (00..53), where Sunday is the first day of the week; `WEEK()` mode 0  
%u | Week (00..53), where Monday is the first day of the week; `WEEK()` mode 1  
%V | Week (01..53), where Sunday is the first day of the week; `WEEK()` mode 2; used with %X  
%v | Week (01..53), where Monday is the first day of the week; `WEEK()` mode 3; used with %x  
%W | Weekday name (Sunday..Saturday)  
%w | Day of the week (0=Sunday..6=Saturday)  
%X | Year for the week where Sunday is the first day of the week, numeric, four digits; used with %V  
%x | Year for the week, where Monday is the first day of the week, numeric, four digits; used with %v  
%Y | Year, numeric, four digits  
%y | Year, numeric (two digits)  
%% | A literal % character  
%X | Year for the week where Sunday is the first day of the week, numeric, four digits; used with %V  
%x | Year for the week, where Monday is the first day of the week, numeric, four digits; used with %v  
%Y | Year, numeric, four digits  
%y | Year, numeric (two digits)  
%% | A literal % character  
%x | x, for any "x" not listed above

Ranges for the month and day specifiers begin with zero due to the fact that MySQL permits the storing of incomplete dates such as '2014-00-00'.

The language used for day and month names and abbreviations is controlled by the value of the `lc_time_names` system variable (Section 10.16, "MySQL Server Locale Support").

For the %U, %u, %V, and %v specifiers, see the description of the `WEEK()` function for information about the mode values. The mode affects how week numbering occurs.

`DATE_FORMAT()` returns a string with a character set and collation given by `character_set_connection` and `collation_connection` so that it can return month and weekday names containing non-ASCII characters.

```sql
mysql> SELECT DATE_FORMAT('2009-10-04 22:23:00', '%W %M %Y');
-> 'Sunday October 2009'
mysql> SELECT DATE_FORMAT('2007-10-04 22:23:00', '%H:%i:%s');
-> '22:23:00'
mysql> SELECT DATE_FORMAT('1900-10-04 22:23:00', '-\d %a %d %m %b %j');
-> '4th 00 Thu 04 10 Oct 2777'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00', '-\%h %I %r %T %S %w');
-> '22 22 10 10:23:00 PM 22:23:00 00 6'
mysql> SELECT DATE_FORMAT('1999-01-01', '%X %V');
-> '1998 52'
mysql> SELECT DATE_FORMAT('2006-06-00', '%d');
-> '00'
```

- `DATE_SUB(date,INTERVAL expr unit)`

  See the description for `DATE_ADD()`. 

1259
Date and Time Functions

- **DAY(date)**
  
  `DAY()` is a synonym for `DAYOFMONTH()`.

- **DAYNAME(date)**

  Returns the name of the weekday for `date`. The language used for the name is controlled by the value of the `lc_time_names` system variable (Section 10.16, “MySQL Server Locale Support”).

```sql
mysql> SELECT DAYNAME('2007-02-03');
-> 'Saturday'
```

- **DAYOFMONTH(date)**

  Returns the day of the month for `date`, in the range 1 to 31, or 0 for dates such as '0000-00-00' or '2008-00-00' that have a zero day part.

```sql
mysql> SELECT DAYOFMONTH('2007-02-03');
-> 3
```

- **DAYOFWEEK(date)**

  Returns the weekday index for `date` (1 = Sunday, 2 = Monday, ..., 7 = Saturday). These index values correspond to the ODBC standard.

```sql
mysql> SELECT DAYOFWEEK('2007-02-03');
-> 7
```

- **DAYOFYEAR(date)**

  Returns the day of the year for `date`, in the range 1 to 366.

```sql
mysql> SELECT DAYOFYEAR('2007-02-03');
-> 34
```

- **EXTRACT(unit FROM date)**

  The `EXTRACT()` function uses the same kinds of `unit` specifiers as `DATE_ADD()` or `DATE_SUB()`, but extracts parts from the date rather than performing date arithmetic. For information on the `unit` argument, see Temporal Intervals.

```sql
mysql> SELECT EXTRACT(YEAR FROM '2019-07-02');
-> 2019
mysql> SELECT EXTRACT(YEAR_MONTH FROM '2019-07-02 01:02:03');
-> 201907
mysql> SELECT EXTRACT(DAY_MINUTE FROM '2019-07-02 01:02:03');
-> 20102
mysql> SELECT EXTRACT(MICROSECOND FROM '2003-01-02 10:30:00.000123');
-> 123
```

- **FROM_DAYS(N)**

  Given a day number `N`, returns a DATE value.

```sql
mysql> SELECT FROM_DAYS(730669);
-> '2000-07-03'
```

Use `FROM_DAYS()` with caution on old dates. It is not intended for use with values that precede the advent of the Gregorian calendar (1582). See Section 12.8, “What Calendar Is Used By MySQL?”.

- **FROM_UNIXTIME(unix_timestamp[, format])**
Returns a representation of the `unix_timestamp` argument as a value in 'YYYY-MM-DD hh:mm:ss' or 'YYYYMMDDhhmmss' format, depending on whether the function is used in string or numeric context. `unix_timestamp` is an internal timestamp value representing seconds since '1970-01-01 00:00:00' UTC, such as produced by the `UNIX_TIMESTAMP()` function.

The return value is expressed in the session time zone. (Clients can set the session time zone as described in Section 5.1.12, “MySQL Server Time Zone Support”.) The `format` string, if given, is used to format the result the same way as described in the entry for the `DATE_FORMAT()` function.

```sql
mysql> SELECT FROM_UNIXTIME(1447430881);
--> '2015-11-13 10:08:01'
mysql> SELECT FROM_UNIXTIME(1447430881) + 0;
--> 20151113100801
mysql> SELECT FROM_UNIXTIME(1447430881, 'Y %D %M %h:%i:%s %x');
--> '2015 13th November 10:08:01 2015'
```

**Note**

If you use `UNIX_TIMESTAMP()` and `FROM_UNIXTIME()` to convert between values in a non-UTC time zone and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For details, see the description of the `UNIX_TIMESTAMP()` function.

- **GET_FORMAT({DATE|TIME|DATETIME}, {'EUR'|'USA'|'JIS'|'ISO'|'INTERNAL'})**

Returns a format string. This function is useful in combination with the `DATE_FORMAT()` and the `STR_TO_DATE()` functions.

The possible values for the first and second arguments result in several possible format strings (for the specifiers used, see the table in the `DATE_FORMAT()` function description). ISO format refers to ISO 9075, not ISO 8601.

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET_FORMAT(DATE, 'USA')</td>
<td>'%m.%d.%Y'</td>
</tr>
<tr>
<td>GET_FORMAT(DATE, 'JIS')</td>
<td>'%Y-%m-%d'</td>
</tr>
<tr>
<td>GET_FORMAT(DATE, 'ISO')</td>
<td>'%Y-%m-%d'</td>
</tr>
<tr>
<td>GET_FORMAT(DATE, 'EUR')</td>
<td>'%d.%m.%Y'</td>
</tr>
<tr>
<td>GET_FORMAT(DATE, 'INTERNAL')</td>
<td>'%Y%m%d'</td>
</tr>
<tr>
<td>GET_FORMAT(DATETIME, 'USA')</td>
<td>'%Y-%m-%d %H.%i.%s'</td>
</tr>
<tr>
<td>GET_FORMAT(DATETIME, 'JIS')</td>
<td>'%Y-%m-%d %H:%i:%s'</td>
</tr>
<tr>
<td>GET_FORMAT(DATETIME, 'ISO')</td>
<td>'%Y-%m-%d %H:%i:%s'</td>
</tr>
<tr>
<td>GET_FORMAT(DATETIME, 'EUR')</td>
<td>'%Y-%m-%d %H.%i.%s'</td>
</tr>
<tr>
<td>GET_FORMAT(DATETIME, 'INTERNAL')</td>
<td>'%Y%m%d%H%i%s'</td>
</tr>
<tr>
<td>GET_FORMAT(TIME, 'USA')</td>
<td>'%h:%i:%s %p'</td>
</tr>
<tr>
<td>GET_FORMAT(TIME, 'JIS')</td>
<td>'%H:%i:%s'</td>
</tr>
<tr>
<td>GET_FORMAT(TIME, 'ISO')</td>
<td>'%H:%i:%s'</td>
</tr>
<tr>
<td>GET_FORMAT(TIME, 'EUR')</td>
<td>'%H.%i.%s'</td>
</tr>
</tbody>
</table>
### Date and Time Functions

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>GET_FORMAT(TIME, 'INTERNAL')</code></td>
<td>'%H%i%s'</td>
</tr>
</tbody>
</table>

`TIMESTAMP` can also be used as the first argument to `GET_FORMAT()`, in which case the function returns the same values as for `DATETIME`.

```
mysql> SELECT DATE_FORMAT('2003-10-03', GET_FORMAT(DATE, 'EUR'));
-> '03.10.2003'
```

```
mysql> SELECT STR_TO_DATE('10.31.2003', GET_FORMAT(DATE, 'USA'));
-> '2003-10-31'
```

- **HOUR(time)**

  Returns the hour for `time`. The range of the return value is 0 to 23 for time-of-day values. However, the range of `TIME` values actually is much larger, so `HOUR` can return values greater than 23.

```
mysql> SELECT HOUR('10:05:03');
-> 10
```

```
mysql> SELECT HOUR('272:59:59');
-> 272
```

- **LAST_DAY(date)**

  Takes a date or datetime value and returns the corresponding value for the last day of the month. Returns `NULL` if the argument is invalid.

```
mysql> SELECT LAST_DAY('2003-02-05');
-> '2003-02-28'
```

```
mysql> SELECT LAST_DAY('2004-02-05');
-> '2004-02-29'
```

```
mysql> SELECT LAST_DAY('2004-01-01 01:01:01');
-> '2004-01-31'
```

```
mysql> SELECT LAST_DAY('2003-03-32');
-> NULL
```

- **LOCALTIME, LOCALTIME()**

  `LOCALTIME` and `LOCALTIME()` are synonyms for `NOW()`.

- **LOCALTIMESTAMP, LOCALTIMESTAMP()**

  `LOCALTIMESTAMP` and `LOCALTIMESTAMP()` are synonyms for `NOW()`.

- **MAKEDATE(year, dayofyear)**

  Returns a date, given year and day-of-year values. `dayofyear` must be greater than 0 or the result is `NULL`.

```
mysql> SELECT MAKEDATE(2011,31), MAKEDATE(2011,32);
-> '2011-01-31', '2011-02-01'
```

```
mysql> SELECT MAKEDATE(2011,365), MAKEDATE(2014,365);
-> '2011-12-31', '2014-12-31'
```

```
mysql> SELECT MAKEDATE(2011,0);
-> NULL
```

- **MAKETIME(hour, minute, second)**

  Returns a time value calculated from the `hour, minute, and second` arguments.

```
mysql> SELECT MAKETIME(12, 15, 30);
-> '12:15:30'
```
Date and Time Functions

- **MICROSECOND(expr)**
  
  Returns the microseconds from the time or datetime expression `expr` as a number in the range from 0 to 999999.

  ```
  mysql> SELECT MICROSECOND('12:00:00.123456');
  -> 123456
  ```

  ```
  mysql> SELECT MICROSECOND('2019-12-31 23:59:59.000010');
  -> 10
  ```

- **MINUTE(time)**
  
  Returns the minute for `time`, in the range 0 to 59.

  ```
  mysql> SELECT MINUTE('2008-02-03 10:05:03');
  -> 5
  ```

- **MONTH(date)**
  
  Returns the month for `date`, in the range 1 to 12 for January to December, or 0 for dates such as '0000-00-00' or '2008-00-00' that have a zero month part.

  ```
  mysql> SELECT MONTH('2008-02-03');
  -> 2
  ```

- **MONTHNAME(date)**
  
  Returns the full name of the month for `date`. The language used for the name is controlled by the value of the `lc_time_names` system variable (Section 10.16, "MySQL Server Locale Support").

  ```
  mysql> SELECT MONTHNAME('2008-02-03');
  -> 'February'
  ```

- **NOW()**
  
  Returns the current date and time as a value in 'YYYY-MM-DD hh:mm:ss' or 'YYYYMMDDhhmmss' format, depending on whether the function is used in string or numeric context. The value is expressed in the session time zone.

  ```
  mysql> SELECT NOW();
  -> '2007-12-15 23:50:26'
  ```

  ```
  mysql> SELECT NOW() + 0;
  -> 20071215235026.000000
  ```

  **NOW()** returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, **NOW()** returns the time at which the function or triggering statement began to execute.) This differs from the behavior for **SYSDATE()**, which returns the exact time at which it executes.

  ```
  mysql> SELECT NOW(), SLEEP(2), NOW();
  +---------------------+----------+---------------------+
  | NOW()              | SLEEP(2) | NOW()              |
  +---------------------+----------+---------------------+
  +---------------------+----------+---------------------+
  mysql> SELECT SYSDATE(), SLEEP(2), SYSDATE();
  +---------------------+----------+---------------------+
  | SYSDATE()           | SLEEP(2) | SYSDATE()           |
  +---------------------+----------+---------------------+
  ```
In addition, the SET_TIMESTAMP statement affects the value returned by NOW() but not by SYSDATE(). This means that timestamp settings in the binary log have no effect on invocations of SYSDATE(). Setting the timestamp to a nonzero value causes each subsequent invocation of NOW() to return that value. Setting the timestamp to zero cancels this effect so that NOW() once again returns the current date and time.

See the description for SYSDATE() for additional information about the differences between the two functions.

1. **PERIOD_ADD(\(P, N\))**

   Adds \(N\) months to period \(P\) (in the format YYYYMM or YYYYMM). Returns a value in the format YYYYMM. Note that the period argument \(P\) is not a date value.

   ```
   mysql> SELECT PERIOD_ADD(200801,2);
   -> 200803
   ```

2. **PERIOD_DIFF(\(P1, P2\))**

   Returns the number of months between periods \(P1\) and \(P2\). \(P1\) and \(P2\) should be in the format YYMM or YYYYMM. Note that the period arguments \(P1\) and \(P2\) are not date values.

   ```
   mysql> SELECT PERIOD_DIFF(200802,200703);
   -> 11
   ```

3. **QUARTER(date)**

   Returns the quarter of the year for date, in the range 1 to 4.

   ```
   mysql> SELECT QUARTER('2008-04-01');
   -> 2
   ```

4. **SECOND(time)**

   Returns the second for time, in the range 0 to 59.

   ```
   mysql> SELECT SECOND('10:05:03');
   -> 3
   ```

5. **SEC_TO_TIME(seconds)**

   Returns the seconds argument, converted to hours, minutes, and seconds, as a TIME value. The range of the result is constrained to that of the TIME data type. A warning occurs if the argument corresponds to a value outside that range.

   ```
   mysql> SELECT SEC_TO_TIME(2378);
   -> '00:39:38'
   ```

   ```
   mysql> SELECT SEC_TO_TIME(2378) + 0;
   -> 3938
   ```

6. **STR_TO_DATE(str, format)**

   This is the inverse of the DATE_FORMAT() function. It takes a string \(str\) and a format string \(format\). STR_TO_DATE() returns a DATETIME value if the format string contains both date and time parts, or
Date and Time Functions

a DATE or TIME value if the string contains only date or time parts. If the date, time, or datetime value extracted from str is illegal, STR_TO_DATE() returns NULL and produces a warning.

The server scans str attempting to match format to it. The format string can contain literal characters and format specifiers beginning with %. Literal characters in format must match literally in str. Format specifiers in format must match a date or time part in str. For the specifiers that can be used in format, see the DATE_FORMAT() function description.

mysql> SELECT STR_TO_DATE('01,5,2013','%d,%m,%Y');
-> '2013-05-01'

mysql> SELECT STR_TO_DATE('May 1, 2013','%M %d,%Y');
-> '2013-05-01'

Scanning starts at the beginning of str and fails if format is found not to match. Extra characters at the end of str are ignored.

mysql> SELECT STR_TO_DATE('a09:30:17','a%h:%i:%s');
-> '09:30:17'

mysql> SELECT STR_TO_DATE('a09:30:17','%h:%i:%s');
-> NULL

mysql> SELECT STR_TO_DATE('09:30:17a','%h:%i:%s');
-> '09:30:17'

Unspecified date or time parts have a value of 0, so incompletely specified values in str produce a result with some or all parts set to 0:

mysql> SELECT STR_TO_DATE('abc','abc');
-> '0000-00-00'

mysql> SELECT STR_TO_DATE('9','%m');
-> '0000-09-00'

mysql> SELECT STR_TO_DATE('9','%s');
-> '00:00:09'

Range checking on the parts of date values is as described in Section 11.2.2, "The DATE, DATETIME, and TIMESTAMP Types". This means, for example, that “zero” dates or dates with part values of 0 are permitted unless the SQL mode is set to disallow such values.

mysql> SELECT STR_TO_DATE('00/00/0000', '%m/%d/%Y');
-> '0000-00-00'

mysql> SELECT STR_TO_DATE('04/31/2004', '%m/%d/%Y');
-> '2004-04-31'

If the NO_ZERO_DATE or NO_ZERO_IN_DATE SQL mode is enabled, zero dates or part of dates are disallowed. In that case, STR_TO_DATE() returns NULL and generates a warning:

```sql
mysql> SET sql_mode = '';
mysql> SELECT STR_TO_DATE('15:35:00', '%H:%i:%s');
+-------------------------------------+
| STR_TO_DATE('15:35:00', '%H:%i:%s') |
+-------------------------------------+
| 15:35:00                            |
+-------------------------------------+

mysql> SET sql_mode = 'NO_ZERO_IN_DATE';

mysql> SELECT STR_TO_DATE('15:35:00', '%h:%i:%s');
+-------------------------------------+
| STR_TO_DATE('15:35:00', '%h:%i:%s') |
+-------------------------------------+
| 15:35:00                            |
+-------------------------------------+

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
Level: Warning
Code: 1411
```
Date and Time Functions

Message: Incorrect datetime value: '15:35:00' for function str_to_date

Note
You cannot use format "\%X\%V" to convert a year-week string to a date because the combination of a year and week does not uniquely identify a year and month if the week crosses a month boundary. To convert a year-week to a date, you should also specify the weekday:

```sql
mysql> SELECT STR_TO_DATE('200442 Monday', '%X%V %W');
-> '2004-10-18'
```

- **SUBDATE(date, INTERVAL expr unit), SUBDATE(expr, days)**

When invoked with the `INTERVAL` form of the second argument, `SUBDATE()` is a synonym for `DATE_SUB()`. For information on the `INTERVAL unit` argument, see the discussion for `DATE_ADD()`.

```sql
mysql> SELECT DATE_SUB('2008-01-02', INTERVAL 31 DAY);
-> '2007-12-02'
mysql> SELECT SUBDATE('2008-01-02', INTERVAL 31 DAY);
-> '2007-12-02'
```

The second form enables the use of an integer value for `days`. In such cases, it is interpreted as the number of days to be subtracted from the date or datetime expression `expr`.

```sql
mysql> SELECT SUBDATE('2008-01-02 12:00:00', 31);
-> '2007-12-02 12:00:00'
```

- **SUBTIME(expr1, expr2)**

`SUBTIME()` returns `expr1 - expr2` expressed as a value in the same format as `expr1`. `expr1` is a time or datetime expression, and `expr2` is a time expression.

```sql
mysql> SELECT SUBTIME('2007-12-31 23:59:59.999999','1 1:1:1.000002');
-> '2007-12-30 22:58:58.999997'
mysql> SELECT SUBTIME('01:00:00.999999', '02:00:00.999998');
-> '-00:59:59.999999'
```

- **SYSDATE()**

Returns the current date and time as a value in 'YYYY-MM-DD hh:mm:ss' or 'YYYYMMDDhhmms' format, depending on whether the function is used in string or numeric context.

`SYSDATE()` returns the time at which it executes. This differs from the behavior for `NOW()`, which returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, `NOW()` returns the time at which the function or triggering statement began to execute.)

```sql
mysql> SELECT NOW(), SLEEP (2), NOW();
+---------------------+----------+---------------------+
<table>
<thead>
<tr>
<th>NOW()</th>
<th>SLEEP (2)</th>
<th>NOW()</th>
</tr>
</thead>
</table>
+---------------------+----------+---------------------+
mysql> SELECT SYSDATE(), SLEEP (2), SYSDATE();
+---------------------+----------+---------------------+
<table>
<thead>
<tr>
<th>SYSDATE()</th>
<th>SLEEP (2)</th>
<th>SYSDATE()</th>
</tr>
</thead>
</table>
+---------------------+----------+---------------------+
In addition, the `SET_TIMESTAMP` statement affects the value returned by `NOW()` but not by `SYSDATE()`. This means that timestamp settings in the binary log have no effect on invocations of `SYSDATE()`.

Because `SYSDATE()` can return different values even within the same statement, and is not affected by `SET_TIMESTAMP`, it is nondeterministic and therefore unsafe for replication if statement-based binary logging is used. If that is a problem, you can use row-based logging.

Alternatively, you can use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This works if the option is used on both the master and the slave.

The nondeterministic nature of `SYSDATE()` also means that indexes cannot be used for evaluating expressions that refer to it.

• `TIME(expr)`

Extracts the time part of the time or datetime expression `expr` and returns it as a string.

This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

```
mysql> SELECT TIME('2003-12-31 01:02:03');
-> '01:02:03'
mysql> SELECT TIME('2003-12-31 01:02:03.000123');
-> '01:02:03.000123'
```

• `TIMEDIFF(expr1, expr2)`

`TIMEDIFF()` returns `expr1 - expr2` expressed as a time value. `expr1` and `expr2` are time or date-and-time expressions, but both must be of the same type.

The result returned by `TIMEDIFF()` is limited to the range allowed for `TIME` values. Alternatively, you can use either of the functions `TIMESTAMPDIFF()` and `UNIX_TIMESTAMP()`, both of which return integers.

```
mysql> SELECT TIMEDIFF('2000:01:01 00:00:00',
-> '2000:01:01 00:00:00.000001');
-> '-00:00:00.000001'
mysql> SELECT TIMEDIFF('2008-12-31 23:59:59.000001',
-> '2008-12-30 01:01:01.000002');
-> '46:58:57.999999'
```

• `TIMESTAMP(expr), TIMESTAMP(expr1, expr2)`

With a single argument, this function returns the date or datetime expression `expr` as a datetime value. With two arguments, it adds the time expression `expr2` to the date or datetime expression `expr1` and returns the result as a datetime value.

```
mysql> SELECT TIMESTAMP('2003-12-31');
-> '2003-12-31 00:00:00'
mysql> SELECT TIMESTAMP('2003-12-31 12:00:00', '12:00:00');
-> '2004-01-01 00:00:00'
```
• **TIMESTAMPADD**(unit, interval, datetime_expr)

Adds the integer expression *interval* to the date or datetime expression *datetime_expr*. The unit for *interval* is given by the *unit* argument, which should be one of the following values: MICROSECOND (microseconds), SECOND, MINUTE, HOUR, DAY, WEEK, MONTH, QUARTER, or YEAR.

The *unit* value may be specified using one of keywords as shown, or with a prefix of SQL_TSI_. For example, DAY and SQL_TSI_DAY both are legal.

```sql
mysql> SELECT TIMESTAMPADD(MINUTE,1,'2003-01-02');
-> '2003-01-02 00:01:00'
mysql> SELECT TIMESTAMPADD(WEEK,1,'2003-01-02');
-> '2003-01-09'
```

• **TIMESTAMPDIFF**(unit, datetime_expr1, datetime_expr2)

Returns *datetime_expr2* − *datetime_expr1*, where *datetime_expr1* and *datetime_expr2* are date or datetime expressions. One expression may be a date and the other a datetime; a date value is treated as a datetime having the time part '00:00:00' where necessary. The unit for the result (an integer) is given by the *unit* argument. The legal values for *unit* are the same as those listed in the description of the **TIMESTAMPADD()** function.

```sql
mysql> SELECT TIMESTAMPDIFF(MONTH,'2003-02-01','2003-05-01');
-> 3
mysql> SELECT TIMESTAMPDIFF(YEAR,'2002-05-01','2001-01-01');
-> -1
mysql> SELECT TIMESTAMPDIFF(MINUTE,'2003-02-01','2003-05-01 12:05:55');
-> 128885
```

**Note**

The order of the date or datetime arguments for this function is the opposite of that used with the **TIMESTAMP()** function when invoked with 2 arguments.

• **TIME_FORMAT**(time, format)

This is used like the **DATE_FORMAT()** function, but the *format* string may contain format specifiers only for hours, minutes, seconds, and microseconds. Other specifiers produce a NULL value or 0.

If the *time* value contains an hour part that is greater than 23, the %H and %k hour format specifiers produce a value larger than the usual range of 0..23. The other hour format specifiers produce the hour value modulo 12.

```sql
mysql> SELECT TIME_FORMAT('100:00:00', '%H %k %h %I %l');
-> '100 100 04 04 4'
```

• **TIME_TO_SEC**(time)

Returns the *time* argument, converted to seconds.

```sql
mysql> SELECT TIME_TO_SEC('22:23:00');
-> 80580
mysql> SELECT TIME_TO_SEC('00:39:38');
-> 2378
```

• **TO_DAYS**(date)

Given a date *date*, returns a day number (the number of days since year 0).

```sql
mysql> SELECT TO_DAYS(950501);
-> 728779
```
TO_DAYS() is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable. See Section 12.8, “What Calendar Is Used By MySQL?”, for details.

Remember that MySQL converts two-digit year values in dates to four-digit form using the rules in Section 11.2, “Date and Time Data Types”. For example, '2008–10–07' and '08–10–07' are seen as identical dates:

```
mysql> SELECT TO_DAYS('2008-10-07'), TO_DAYS('08-10-07');
-> 733687, 733687
```

In MySQL, the zero date is defined as '0000-00-00', even though this date is itself considered invalid. This means that, for '0000–00–00' and '0000–01–01', TO_DAYS() returns the values shown here:

```
mysql> SELECT TO_DAYS('0000-00-00');
+-----------------------+
| to_days('0000-00-00') |
+-----------------------+
|                     NULL |
+-----------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------+
| Level   | Code | Message                                |
+---------+------+----------------------------------------+
| Warning | 1292 | Incorrect datetime value: '0000-00-00' |
+---------+------+----------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT TO_DAYS('0000-01-01');
+-----------------------+
| to_days('0000-01-01') |
+-----------------------+
|                     1 |
+-----------------------+
1 row in set (0.00 sec)
```

This is true whether or not the ALLOW_INVALID_DATES SQL server mode is enabled.

- **TO_SECONDS(expr)**

  Given a date or datetime `expr`, returns the number of seconds since the year 0. If `expr` is not a valid date or datetime value, returns NULL.

```
mysql> SELECT TO_SECONDS(950501);  
-> 6296505600
mysql> SELECT TO_SECONDS('2009-11-29');  
-> 63426672000
mysql> SELECT TO_SECONDS('2009-11-29 13:43:32');  
-> 63426721412
mysql> SELECT TO_SECONDS(NOW());  
-> 63426721458
```

Like TO_DAYS(), TO_SECONDS() is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the
Date and Time Functions

calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable. See Section 12.8, “What Calendar Is Used By MySQL?” for details.

Like `TO_DAYS()`, `TO_SECONDS()`, converts two-digit year values in dates to four-digit form using the rules in Section 11.2, “Date and Time Data Types”.

In MySQL, the zero date is defined as `"0000-00-00"`, even though this date is itself considered invalid. This means that, for `"0000-00-00"` and `"0000-01-01"`, `TO_SECONDS()` returns the values shown here:

```
mysql> SELECT TO_SECONDS('0000-00-00');
+--------------------------+
| TO_SECONDS('0000-00-00') |
+--------------------------+
|                     NULL |
+--------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------+
| Level   | Code | Message                                |
|---------+------|----------------------------------------|
| Warning | 1292 | Incorrect datetime value: '0000-00-00' |
+---------+------|----------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT TO_SECONDS('0000-01-01');
+--------------------------+
| TO_SECONDS('0000-01-01') |
+--------------------------+
|                    86400 |
+--------------------------+
1 row in set (0.00 sec)
```

This is true whether or not the ALLOW_INVALID_DATES SQL server mode is enabled.

- `UNIX_TIMESTAMP([date])`

  If `UNIX_TIMESTAMP()` is called with no `date` argument, it returns a Unix timestamp representing seconds since `"1970-01-01 00:00:00"` UTC.

  If `UNIX_TIMESTAMP()` is called with a `date` argument, it returns the value of the argument as seconds since `"1970-01-01 00:00:00"` UTC. The server interprets `date` as a value in the session time zone and converts it to an internal Unix timestamp value in UTC. (Clients can set the session time zone as described in Section 5.1.12, “MySQL Server Time Zone Support”.) The `date` argument may be a `DATE`, `DATETIME`, or `TIMESTAMP` string, or a number in `YYYYMMDD`, `YYYYMMDDhhmmss`, `YYYYMMDD`, or `YYYYMMDDhhmmss` format.

  The return value is an unsigned integer.

  When the `date` argument is a `TIMESTAMP` column, `UNIX_TIMESTAMP()` returns the internal timestamp value directly, with no implicit “string-to-Unix-timestamp” conversion.

  The valid range of argument values is the same as for the `TIMESTAMP` data type: `"1970-01-01 00:00:01.000000"` UTC to `"2038-01-19 03:14:07.999999"` UTC. If you pass an out-of-range date to `UNIX_TIMESTAMP()`, it returns 0.

```
mysql> SELECT UNIX_TIMESTAMP();
  -> 1447316666

mysql> SELECT UNIX_TIMESTAMP('2015-11-13 10:20:19');
```
If you use `UNIX_TIMESTAMP()` and `FROM_UNIXTIME()` to convert between values in a non-UTC time zone and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For example, due to conventions for local time zone changes such as Daylight Saving Time (DST), it is possible for `UNIX_TIMESTAMP()` to map two values that are distinct in a non-UTC time zone to the same Unix timestamp value. `FROM_UNIXTIME()` will map that value back to only one of the original values. Here is an example, using values that are distinct in the MET time zone:

```sql
mysql> SET time_zone = 'MET';
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 03:00:00');
+---------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 03:00:00') |
+---------------------------------------+
|                            1111885200 |
+---------------------------------------+
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 02:00:00');
+---------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 02:00:00') |
+---------------------------------------+
|                            1111885200 |
+---------------------------------------+
mysql> SELECT FROM_UNIXTIME(1111885200);
+---------------------------+
| FROM_UNIXTIME(1111885200) |
+---------------------------+
| 2005-03-27 03:00:00       |
+---------------------------+
```

Note

To use named time zones such as 'MET' or 'Europe/Amsterdam', the time zone tables must be properly set up. For instructions, see Section 5.1.12, "MySQL Server Time Zone Support".

If you want to subtract `UNIX_TIMESTAMP()` columns, you might want to cast them to signed integers. See Section 12.10, "Cast Functions and Operators".

- **UTC_DATE, UTC_DATE()**

  Returns the current UTC date as a value in 'YYYY-MM-DD' or 'YYYYMMDD' format, depending on whether the function is used in string or numeric context.

  ```sql
  mysql> SELECT UTC_DATE(), UTC_DATE() + 0;
  -> '2003-08-14', 20030814
  ```

- **UTC_TIME, UTC_TIME()**

  Returns the current UTC time as a value in 'hh:mm:ss' or 'hhmmss' format, depending on whether the function is used in string or numeric context.

  ```sql
  mysql> SELECT UTC_TIME(), UTC_TIME() + 0;
  -> '18:07:53', 180753.000000
  ```

- **UTC_TIMESTAMP, UTC_TIMESTAMP()**

  Returns the current UTC date and time as a value in 'YYYY-MM-DD hh:mm:ss' or 'YYYYMMDDhhmmss' format, depending on whether the function is used in string or numeric context.

  ```sql
  mysql> SELECT UTC_TIMESTAMP(), UTC_TIMESTAMP() + 0;
  -> '2003-08-14 18:08:04', 20030814180804.000000
  ```
• `WEEK(date[, mode])`

This function returns the week number for `date`. The two-argument form of `WEEK()` enables you to specify whether the week starts on Sunday or Monday and whether the return value should be in the range from 0 to 53 or from 1 to 53. If the `mode` argument is omitted, the value of the `default_week_format` system variable is used. See Section 5.1.7, "Server System Variables".

The following table describes how the `mode` argument works.

<table>
<thead>
<tr>
<th>Mode</th>
<th>First day of week</th>
<th>Range</th>
<th>Week 1 is the first week ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sunday</td>
<td>0-53</td>
<td>with a Sunday in this year</td>
</tr>
<tr>
<td>1</td>
<td>Monday</td>
<td>0-53</td>
<td>with 4 or more days this year</td>
</tr>
<tr>
<td>2</td>
<td>Sunday</td>
<td>1-53</td>
<td>with a Sunday in this year</td>
</tr>
<tr>
<td>3</td>
<td>Monday</td>
<td>1-53</td>
<td>with 4 or more days this year</td>
</tr>
<tr>
<td>4</td>
<td>Sunday</td>
<td>0-53</td>
<td>with 4 or more days this year</td>
</tr>
<tr>
<td>5</td>
<td>Monday</td>
<td>0-53</td>
<td>with a Monday in this year</td>
</tr>
<tr>
<td>6</td>
<td>Sunday</td>
<td>1-53</td>
<td>with 4 or more days this year</td>
</tr>
<tr>
<td>7</td>
<td>Monday</td>
<td>1-53</td>
<td>with a Monday in this year</td>
</tr>
</tbody>
</table>

For `mode` values with a meaning of “with 4 or more days this year,” weeks are numbered according to ISO 8601:1988:

• If the week containing January 1 has 4 or more days in the new year, it is week 1.

• Otherwise, it is the last week of the previous year, and the next week is week 1.

```
mysql> SELECT WEEK('2008-02-20');
-> 7
mysql> SELECT WEEK('2008-02-20',0);
-> 7
mysql> SELECT WEEK('2008-02-20',1);
-> 8
mysql> SELECT WEEK('2008-12-31',1);
-> 53
```

If a date falls in the last week of the previous year, MySQL returns 0 if you do not use 2, 3, 6, or 7 as the optional `mode` argument:

```
mysql> SELECT YEAR('2000-01-01'), WEEK('2000-01-01',0);
-> 2000, 0
```

One might argue that `WEEK()` should return 52 because the given date actually occurs in the 52nd week of 1999. `WEEK()` returns 0 instead so that the return value is “the week number in the given year.” This makes use of the `WEEK()` function reliable when combined with other functions that extract a date part from a date.

If you prefer a result evaluated with respect to the year that contains the first day of the week for the given date, use 0, 2, 5, or 7 as the optional `mode` argument.

```
mysql> SELECT WEEK('2000-01-01',2);
-> 52
```

Alternatively, use the `YEARWEEK()` function:

```
mysql> SELECT YEARWEEK('2000-01-01');
```

1272
• **WEEKDAY**(date)
  
  Returns the weekday index for date (0 = Monday, 1 = Tuesday, ... 6 = Sunday).

  ```
  mysql> SELECT WEEKDAY('2008-02-03 22:23:00');
  -> 6
  mysql> SELECT WEEKDAY('2007-11-06');
  -> 1
  ```

• **WEEKOFYEAR**(date)
  
  Returns the calendar week of the date as a number in the range from 1 to 53. WEEKOFYEAR() is a compatibility function that is equivalent to WEEK(date,3).

  ```
  mysql> SELECT WEEKOFYEAR('2008-02-20');
  -> 8
  ```

• **YEAR**(date)
  
  Returns the year for date, in the range 1000 to 9999, or 0 for the “zero” date.

  ```
  mysql> SELECT YEAR('1987-01-01');
  -> 1987
  ```

• **YEARWEEK**(date), **YEARWEEK**(date, mode)
  
  Returns year and week for a date. The year in the result may be different from the year in the date argument for the first and the last week of the year.

  The mode argument works exactly like the mode argument to WEEK(). For the single-argument syntax, a mode value of 0 is used. Unlike WEEK(), the value of default_week_format does not influence YEARWEEK().

  ```
  mysql> SELECT YEARWEEK('1987-01-01');
  -> 198704
  ```

  The week number is different from what the WEEK() function would return (0) for optional arguments 0 or 1, as WEEK() then returns the week in the context of the given year.

### 12.7 String Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII()</td>
<td>Return numeric value of left-most character</td>
</tr>
<tr>
<td>BIN()</td>
<td>Return a string containing binary representation of a number</td>
</tr>
<tr>
<td>BIT_LENGTH()</td>
<td>Return length of argument in bits</td>
</tr>
<tr>
<td>CHAR()</td>
<td>Return the character for each integer passed</td>
</tr>
<tr>
<td>CHAR_LENGTH()</td>
<td>Return number of characters in argument</td>
</tr>
<tr>
<td>CHARACTER_LENGTH()</td>
<td>Synonym for CHAR_LENGTH()</td>
</tr>
<tr>
<td>CONCAT()</td>
<td>Return concatenated string</td>
</tr>
<tr>
<td>CONCAT_WS()</td>
<td>Return concatenate with separator</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ELT()</td>
<td>Return string at index number</td>
</tr>
<tr>
<td>EXPORT_SET()</td>
<td>Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string</td>
</tr>
<tr>
<td>FIELD()</td>
<td>Index (position) of first argument in subsequent arguments</td>
</tr>
<tr>
<td>FIND_IN_SET()</td>
<td>Index (position) of first argument within second argument</td>
</tr>
<tr>
<td>FORMAT()</td>
<td>Return a number formatted to specified number of decimal places</td>
</tr>
<tr>
<td>HEX()</td>
<td>Hexadecimal representation of decimal or string value</td>
</tr>
<tr>
<td>INSERT()</td>
<td>Insert substring at specified position up to specified number of characters</td>
</tr>
<tr>
<td>INSTR()</td>
<td>Return the index of the first occurrence of substring</td>
</tr>
<tr>
<td>LCASE()</td>
<td>Synonym for LOWER()</td>
</tr>
<tr>
<td>LEFT()</td>
<td>Return the leftmost number of characters as specified</td>
</tr>
<tr>
<td>LENGTH()</td>
<td>Return the length of a string in bytes</td>
</tr>
<tr>
<td>LIKE</td>
<td>Simple pattern matching</td>
</tr>
<tr>
<td>LOAD_FILE()</td>
<td>Load the named file</td>
</tr>
<tr>
<td>LOCATE()</td>
<td>Return the position of the first occurrence of substring</td>
</tr>
<tr>
<td>LOWER()</td>
<td>Return the argument in lowercase</td>
</tr>
<tr>
<td>LPAD()</td>
<td>Return the string argument, left-padded with the specified string</td>
</tr>
<tr>
<td>LTRIM()</td>
<td>Remove leading spaces</td>
</tr>
<tr>
<td>MAKE_SET()</td>
<td>Return a set of comma-separated strings that have the corresponding bit in bits set</td>
</tr>
<tr>
<td>MATCH</td>
<td>Perform full-text search</td>
</tr>
<tr>
<td>MID()</td>
<td>Return a substring starting from the specified position</td>
</tr>
<tr>
<td>NOT LIKE</td>
<td>Negation of simple pattern matching</td>
</tr>
<tr>
<td>NOT REGEXP</td>
<td>Negation of REGEXP</td>
</tr>
<tr>
<td>OCT()</td>
<td>Return a string containing octal representation of a number</td>
</tr>
<tr>
<td>OCTET_LENGTH()</td>
<td>Synonym for LENGTH()</td>
</tr>
<tr>
<td>ORD()</td>
<td>Return character code for leftmost character of the argument</td>
</tr>
<tr>
<td>POSITION()</td>
<td>Synonym for LOCATE()</td>
</tr>
<tr>
<td>QUOTE()</td>
<td>Escape the argument for use in an SQL statement</td>
</tr>
<tr>
<td>REGEXP</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>REPEAT()</td>
<td>Repeat a string the specified number of times</td>
</tr>
<tr>
<td>REPLACE()</td>
<td>Replace occurrences of a specified string</td>
</tr>
<tr>
<td>REVERSE()</td>
<td>Reverse the characters in a string</td>
</tr>
<tr>
<td>RIGHT()</td>
<td>Return the specified rightmost number of characters</td>
</tr>
<tr>
<td>RLIKE</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>RPAD()</td>
<td>Append string the specified number of times</td>
</tr>
</tbody>
</table>
### String Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>RTRIM()</code></td>
<td>Remove trailing spaces</td>
</tr>
<tr>
<td><code>SOUNDEX()</code></td>
<td>Return a soundex string</td>
</tr>
<tr>
<td><code>SOUNDS LIKE</code></td>
<td>Compare sounds</td>
</tr>
<tr>
<td><code>SPACE()</code></td>
<td>Return a string of the specified number of spaces</td>
</tr>
<tr>
<td><code>STRCMP()</code></td>
<td>Compare two strings</td>
</tr>
<tr>
<td><code>SUBSTR()</code></td>
<td>Return the substring as specified</td>
</tr>
<tr>
<td><code>SUBSTRING()</code></td>
<td>Return the substring as specified</td>
</tr>
<tr>
<td><code>SUBSTRING_INDEX()</code></td>
<td>Return a substring from a string before the specified number of occurrences of the delimiter</td>
</tr>
<tr>
<td><code>TRIM()</code></td>
<td>Remove leading and trailing spaces</td>
</tr>
<tr>
<td><code>UCASE()</code></td>
<td>Synonym for UPPER()</td>
</tr>
<tr>
<td><code>UNHEX()</code></td>
<td>Return a string containing hex representation of a number</td>
</tr>
<tr>
<td><code>UPPER()</code></td>
<td>Convert to uppercase</td>
</tr>
</tbody>
</table>

String-valued functions return `NULL` if the length of the result would be greater than the value of the `max_allowed_packet` system variable. See Section 5.1.1, “Configuring the Server”.

For functions that operate on string positions, the first position is numbered 1.

For functions that take length arguments, noninteger arguments are rounded to the nearest integer.

- **ASCII(str)**
  - Returns the numeric value of the leftmost character of the string `str`. Returns 0 if `str` is the empty string. Returns `NULL` if `str` is `NULL`. `ASCII()` works for 8-bit characters.

  ```sql
  mysql> SELECT ASCII('2');
  -> 50
  mysql> SELECT ASCII(2);
  -> 50
  mysql> SELECT ASCII('dx');
  -> 100
  ```

  See also the `ORD()` function.

- **BIN(N)**
  - Returns a string representation of the binary value of `N`, where `N` is a longlong (BIGINT) number. This is equivalent to `CONV(N,10,2)`. Returns `NULL` if `N` is `NULL`.

  ```sql
  mysql> SELECT BIN(12);
  -> '1100'
  ```

- **BIT_LENGTH(str)**
  - Returns the length of the string `str` in bits.

  ```sql
  mysql> SELECT BIT_LENGTH('text');
  -> 32
  ```

- **CHAR(N,... [USING charset_name])**
**STRING FUNCTIONS AND OPERATORS**

**CHAR()** interprets each argument as an integer and returns a string consisting of the characters given by the code values of those integers. **NULL** values are skipped.

```sql
mysql> SELECT CHAR(77,121,83,81,'76');
-> 'MySQL'
mysql> SELECT CHAR(77,77.3,'77.3');
-> 'MMM'
```

**CHAR()** arguments larger than 255 are converted into multiple result bytes. For example, **CHAR(256)** is equivalent to **CHAR(1,0)**, and **CHAR(256*256)** is equivalent to **CHAR(1,0,0)**:

```sql
mysql> SELECT HEX(CHAR(1,0)), HEX(CHAR(256));
+----------------+----------------+
| HEX(CHAR(1,0)) | HEX(CHAR(256)) |
+----------------+----------------+
| 0100           | 0100           |
+----------------+----------------+
mysql> SELECT HEX(CHAR(1,0,0)), HEX(CHAR(256*256));
+------------------+--------------------+
| HEX(CHAR(1,0,0)) | HEX(CHAR(256*256)) |
+------------------+--------------------+
| 010000           | 010000             |
+------------------+--------------------+
```

By default, **CHAR()** returns a binary string. To produce a string in a given character set, use the optional **USING** clause:

```sql
mysql> SELECT CHARSET(CHAR(X'65')), CHARSET(CHAR(X'65' USING utf8));
+----------------------+---------------------------------+
| CHARSET(CHAR(X'65')) | CHARSET(CHAR(X'65' USING utf8)) |
+----------------------+---------------------------------+
| binary               | utf8                            |
+----------------------+---------------------------------+
```

If **USING** is given and the result string is illegal for the given character set, a warning is issued. Also, if strict SQL mode is enabled, the result from **CHAR()** becomes NULL.

- **CHAR_LENGTH(str)**

  Returns the length of the string `str`, measured in characters. A multibyte character counts as a single character. This means that for a string containing five 2-byte characters, **LENGTH()** returns 10, whereas **CHAR_LENGTH()** returns 5.

- **CHARACTER_LENGTH(str)**

  **CHARACTER_LENGTH()** is a synonym for **CHAR_LENGTH()**.

- **CONCAT(str1, str2, ...)**

  Returns the string that results from concatenating the arguments. May have one or more arguments. If all arguments are nonbinary strings, the result is a nonbinary string. If the arguments include any binary strings, the result is a binary string. A numeric argument is converted to its equivalent nonbinary string form.

  **CONCAT()** returns **NULL** if any argument is **NULL**.

```sql
mysql> SELECT CONCAT('My', 'S', 'QL');
-> 'MySQL'
mysql> SELECT CONCAT('My', NULL, 'QL');
-> NULL
mysql> SELECT CONCAT(14.3);
1276
```
For quoted strings, concatenation can be performed by placing the strings next to each other:

```sql
mysql> SELECT 'My' 'S' 'QL';
-> 'MySQL'
```

- **CONCAT_WS(separator,str1,str2,...)**

`CONCAT_WS()` stands for Concatenate With Separator and is a special form of `CONCAT()`. The first argument is the separator for the rest of the arguments. The separator is added between the strings to be concatenated. The separator can be a string, as can the rest of the arguments. If the separator is `NULL`, the result is `NULL`.

```sql
mysql> SELECT CONCAT_WS(' ','First name','Second name','Last Name');
-> 'First name,Second name,Last Name'
mysql> SELECT CONCAT_WS(' ','First name',NULL,'Last Name');
-> 'First name,Last Name'
```

`CONCAT_WS()` does not skip empty strings. However, it does skip any `NULL` values after the separator argument.

- **ELT(N,str1,str2,str3,...)**

`ELT()` returns the `N`th element of the list of strings: `str1` if `N = 1`, `str2` if `N = 2`, and so on. Returns `NULL` if `N` is less than `1` or greater than the number of arguments. `ELT()` is the complement of `FIELD()`.

```sql
mysql> SELECT ELT(1, 'Aa', 'Bb', 'Cc', 'Dd');
-> 'Aa'
mysql> SELECT ELT(4, 'Aa', 'Bb', 'Cc', 'Dd');
-> 'Dd'
```

- **EXPORT_SET(bits,on,off[,separator[,number_of_bits]])**

Returns a string such that for every bit set in the value `bits`, you get an `on` string and for every bit not set in the value, you get an `off` string. Bits in `bits` are examined from right to left (from low-order to high-order bits). Strings are added to the result from left to right, separated by the `separator` string (the default being the comma character, ,). The number of bits examined is given by `number_of_bits`, which has a default of `64` if not specified. `number_of_bits` is silently clipped to `64` if larger than `64`. It is treated as an unsigned integer, so a value of `-1` is effectively the same as `64`.

```sql
mysql> SELECT EXPORT_SET(5,'Y','N',',',4);
-> 'Y,N,Y,N'
mysql> SELECT EXPORT_SET(6,'1','0',',',10);
-> '0,1,1,0,0,0,0,0,0,0'
```

- **FIELD(str,str1,str2,str3,...)**

Returns the index (position) of `str` in the `str1,str2,str3,...` list. Returns `0` if `str` is not found.

If all arguments to `FIELD()` are strings, all arguments are compared as strings. If all arguments are numbers, they are compared as numbers. Otherwise, the arguments are compared as double.

If `str` is `NULL`, the return value is `0` because `NULL` fails equality comparison with any value. `FIELD()` is the complement of `ELT()`.

```sql
mysql> SELECT FIELD('Bb', 'Aa', 'Bb', 'Cc', 'Dd', 'FF');
-> 2
mysql> SELECT FIELD('Gg', 'Aa', 'Bb', 'Cc', 'Dd', 'FF');
-> 0
```
• **FIND_IN_SET**(str, strlist)

Returns a value in the range of 1 to \( N \) if the string \( \text{str} \) is in the string list \( \text{strlist} \) consisting of \( N \) substrings. A string list is a string composed of substrings separated by \( , \) characters. If the first argument is a constant string and the second is a column of type SET, the FIND_IN_SET() function is optimized to use bit arithmetic. Returns 0 if \( \text{str} \) is not in \( \text{strlist} \) or if \( \text{strlist} \) is the empty string. Returns NULL if either argument is NULL. This function does not work properly if the first argument contains a comma (\( , \)) character.

```sql
mysql> SELECT FIND_IN_SET('b','a,b,c,d');
-> 2
```

• **FORMAT**(X, D[, locale])

Formats the number \( X \) to a format like '\#,###,###.##', rounded to \( D \) decimal places, and returns the result as a string. If \( D \) is 0, the result has no decimal point or fractional part.

The optional third parameter enables a locale to be specified to be used for the result number’s decimal point, thousands separator, and grouping between separators. Permissible locale values are the same as the legal values for the lc_time_names system variable (see Section 10.16, "MySQL Server Locale Support"). If no locale is specified, the default is 'en_US'.

```sql
mysql> SELECT FORMAT(12332.123456, 4);
-> '12,332.1235'

mysql> SELECT FORMAT(12332.1,4);
-> '12,332.0000'

mysql> SELECT FORMAT(12332.2,0);
-> '12,332'

mysql> SELECT FORMAT(12332.2,2,'de_DE');
-> '12.332,20'
```

• **HEX**(str), HEX(N)

For a string argument \( \text{str} \), HEX() returns a hexadecimal string representation of \( \text{str} \) where each byte of each character in \( \text{str} \) is converted to two hexadecimal digits. (Multibyte characters therefore become more than two digits.) The inverse of this operation is performed by the UNHEX() function.

For a numeric argument \( N \), HEX() returns a hexadecimal string representation of the value of \( N \) treated as a longlong (BIGINT) number. This is equivalent to \( \text{CONV}(N,10,16) \). The inverse of this operation is performed by \( \text{CONV}(	ext{HEX}(N),16,10) \).

```sql
mysql> SELECT X'616263', HEX('abc'), UNHEX(HEX('abc'));
-> 'abc', 616263, 'abc'

mysql> SELECT HEX(255), CONV(HEX(255),16,10);
-> 'FF', 255
```

• **INSERT**(str, pos, len, newstr)

Returns the string \( \text{str} \), with the substring beginning at position \( \text{pos} \) and \( \text{len} \) characters long replaced by the string \( \text{newstr} \). Returns the original string if \( \text{pos} \) is not within the length of the string. Replaces the rest of the string from position \( \text{pos} \) if \( \text{len} \) is not within the length of the rest of the string. Returns NULL if any argument is NULL.

```sql
mysql> SELECT INSERT('Quadratic', 3, 4, 'What');
-> 'QuWhattic'

mysql> SELECT INSERT('Quadratic', -1, 4, 'What');
-> 'Quadratic'

mysql> SELECT INSERT('Quadratic', 3, 100, 'What');
-> 1278
```
This function is multibyte safe.

- **INSTR(str, substr)**

  Returns the position of the first occurrence of substring `substr` in string `str`. This is the same as the two-argument form of `LOCATE()`, except that the order of the arguments is reversed.

  ```
  mysql> SELECT INSTR('foobarbar', 'bar');
  -> 4
  mysql> SELECT INSTR('xbar', 'foobar');
  -> 0
  ```

  This function is multibyte safe, and is case-sensitive only if at least one argument is a binary string.

- **LCASE(str)**

  `LCASE()` is a synonym for `LOWER()`.

- **LEFT(str, len)**

  Returns the leftmost `len` characters from the string `str`, or `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT LEFT('foobarbar', 5);
  -> 'fooba'
  ```

  This function is multibyte safe.

- **LENGTH(str)**

  Returns the length of the string `str`, measured in bytes. A multibyte character counts as multiple bytes. This means that for a string containing five 2-byte characters, `LENGTH()` returns 10, whereas `CHAR_LENGTH()` returns 5.

  ```
  mysql> SELECT LENGTH('text');
  -> 4
  ```

  **Note**

  The `Length()` OpenGIS spatial function is named `GLength()` in MySQL.

- **LOAD_FILE(file_name)**

  Reads the file and returns the file contents as a string. To use this function, the file must be located on the server host, you must specify the full path name to the file, and you must have the `FILE` privilege. The file must be readable by all and its size less than `max_allowed_packet` bytes. If the `secure_file_priv` system variable is set to a nonempty directory name, the file to be loaded must be located in that directory.

  If the file does not exist or cannot be read because one of the preceding conditions is not satisfied, the function returns `NULL`.

  The `character_set_filesystem` system variable controls interpretation of file names that are given as literal strings.

  ```
  mysql> UPDATE t
  SET blob_col=LOAD_FILE('/tmp/picture')
  WHERE id=1;
  ```
String Functions and Operators

- **LOCATE**(str, substr, pos)

  The first syntax returns the position of the first occurrence of substring `substr` in string `str`. The second syntax returns the position of the first occurrence of substring `substr` in string `str`, starting at position `pos`. Returns 0 if `substr` is not in `str`. Returns NULL if `substr` or `str` is NULL.

  ```
  mysql> SELECT LOCATE('bar', 'foobarbar');
  -> 4
  mysql> SELECT LOCATE('xbar', 'foobar');
  -> 0
  mysql> SELECT LOCATE('bar', 'foobarbar', 5);
  -> 7
  ```

  This function is multibyte safe, and is case-sensitive only if at least one argument is a binary string.

- **LOWER**(str)

  Returns the string `str` with all characters changed to lowercase according to the current character set mapping. The default is latin1 (cp1252 West European).

  ```
  mysql> SELECT LOWER('QUADRATICALLY');
  -> 'quadratically'
  ```

  `LOWER()` and `UPPER()` are ineffective when applied to binary strings (BINARY, VARBINARY, BLOB). To perform lettercase conversion of a binary string, first convert it to a nonbinary string using a character set appropriate for the data stored in the string:

  ```
  mysql> SET @str = BINARY 'New York';
  mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
  +-------------+-----------------------------------+
  | LOWER(@str) | LOWER(CONVERT(@str USING latin1)) |
  +-------------+-----------------------------------+
  | New York    | new york                          |
  +-------------+-----------------------------------+
  ```

  This function is multibyte safe.

- **LPAD**(str, len, padstr)

  Returns the string `str`, left-padded with the string `padstr` to a length of `len` characters. If `str` is longer than `len`, the return value is shortened to `len` characters.

  ```
  mysql> SELECT LPAD('hi', 4, '??');
  -> '??hi'
  mysql> SELECT LPAD('hi', 1, '??');
  -> 'h'
  ```

- **LTRIM**(str)

  Returns the string `str` with leading space characters removed.

  ```
  mysql> SELECT LTRIM('  barbar');
  -> 'barbar'
  ```

  This function is multibyte safe.
- **MAKE_SET(bits, str1, str2,...)**

  Returns a set value (a string containing substrings separated by , characters) consisting of the strings that have the corresponding bit in **bits** set. **str1** corresponds to bit 0, **str2** to bit 1, and so on. **NULL** values in **str1, str2, ...** are not appended to the result.

  ```sql
  mysql> SELECT MAKE_SET(1, 'a', 'b', 'c');
  -> 'a'
  mysql> SELECT MAKE_SET(1 | 4, 'hello', 'nice', 'world');
  -> 'hello,world'
  mysql> SELECT MAKE_SET(1 | 4, 'hello', 'nice', NULL, 'world');
  -> 'hello'
  mysql> SELECT MAKE_SET(0, 'a', 'b', 'c');
  -> ''
  ```

- **MID(str, pos, len)**

  **MID(str, pos, len)** is a synonym for **SUBSTRING(str, pos, len)**.

- **OCT(N)**

  Returns a string representation of the octal value of **N**, where **N** is a longlong (**BIGINT**) number. This is equivalent to **CONV(N, 10, 8)**. Returns **NULL** if **N** is **NULL**.

  ```sql
  mysql> SELECT OCT(12);
  -> '14'
  ```

- **OCTET_LENGTH(str)**

  **OCTET_LENGTH()** is a synonym for **LENGTH()**.

- **ORD(str)**

  If the leftmost character of the string **str** is a multibyte character, returns the code for that character, calculated from the numeric values of its constituent bytes using this formula:

  \[(1st\ text\ code) + (2nd\ byte\ code \times 256) + (3rd\ byte\ code \times 256^2) \ldots\]

  If the leftmost character is not a multibyte character, **ORD()** returns the same value as the **ASCII()** function.

  ```sql
  mysql> SELECT ORD('2');
  -> 50
  ```

- **POSITION(substr IN str)**

  **POSITION(substr IN str)** is a synonym for **LOCATE(substr, str)**.

- **QUOTE(str)**

  Quotes a string to produce a result that can be used as a properly escaped data value in an SQL statement. The string is returned enclosed by single quotation marks and with each instance of backslash (\), single quote (’), ASCII **NULL**, and Control+Z preceded by a backslash. If the argument is **NULL**, the return value is the word “NULL” without enclosing single quotation marks.

  ```sql
  mysql> SELECT QUOTE('Don\'t!');
  -> 'Don\'t!'
  mysql> SELECT QUOTE(NULL);
  -> NULL
  ```
String Functions and Operators

For comparison, see the quoting rules for literal strings and within the C API in Section 9.1.1, “String Literals”, and Section 23.7.6.53, “mysql_real_escape_string()”.

- **REPEAT**(str, count)

  Returns a string consisting of the string `str` repeated `count` times. If `count` is less than 1, returns an empty string. Returns **NULL** if `str` or `count` are **NULL**.

  ```sql
  mysql> SELECT REPEAT('MySQL', 3);
  -> 'MySQLMySQLMySQL'
  ```

- **REPLACE**(str, from_str, to_str)

  Returns the string `str` with all occurrences of the string `from_str` replaced by the string `to_str`. **REPLACE()** performs a case-sensitive match when searching for `from_str`.

  ```sql
  mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
  -> 'WwWwWw.mysql.com'
  ```

  This function is multibyte safe.

- **REVERSE**(str)

  Returns the string `str` with the order of the characters reversed.

  ```sql
  mysql> SELECT REVERSE('abc');
  -> 'cba'
  ```

  This function is multibyte safe.

- **RIGHT**(str, len)

  Returns the rightmost `len` characters from the string `str`, or **NULL** if any argument is **NULL**.

  ```sql
  mysql> SELECT RIGHT('foobarbar', 4);
  -> 'rbar'
  ```

  This function is multibyte safe.

- **RPAD**(str, len, padstr)

  Returns the string `str`, right-padded with the string `padstr` to a length of `len` characters. If `str` is longer than `len`, the return value is shortened to `len` characters.

  ```sql
  mysql> SELECT RPAD('hi',5,'?');
  -> 'hi???'
  mysql> SELECT RPAD('hi',1,'?');
  -> 'h'
  ```

  This function is multibyte safe.

- **RTRIM**(str)

  Returns the string `str` with trailing space characters removed.

  ```sql
  mysql> SELECT RTRIM('barbar   ');
  -> 'barbar'
  ```

  This function is multibyte safe.

- **SOUNDEX**(str)

  Returns the SOUNDEX code for `str`, which is a code that represents the pronunciation of a word. It is used for indexing and searching by phonetic similarity. This function is multibyte safe.
String Functions and Operators

Returns a soundex string from `str`. Two strings that sound almost the same should have identical soundex strings. A standard soundex string is four characters long, but the `SOUNDEX()` function returns an arbitrarily long string. You can use `SUBSTRING()` on the result to get a standard soundex string. All nonalphanumeric characters in `str` are ignored. All international alphabetic characters outside the A-Z range are treated as vowels.

**Important**

When using `SOUNDEX()`, you should be aware of the following limitations:

- This function, as currently implemented, is intended to work well with strings that are in the English language only. Strings in other languages may not produce reliable results.
- This function is not guaranteed to provide consistent results with strings that use multibyte character sets, including `utf-8`. See Bug #22638 for more information.

```
mysql> SELECT SOUNDEX('Hello');
-> 'H400'
mysql> SELECT SOUNDEX('Quadratically');
-> 'Q36324'
```

**Note**

This function implements the original Soundex algorithm, not the more popular enhanced version (also described by D. Knuth). The difference is that original version discards vowels first and duplicates second, whereas the enhanced version discards duplicates first and vowels second.

- `expr1` SOUNDS LIKE `expr2`

  This is the same as `SOUNDEX(expr1) = SOUNDEX(expr2)`.

- `SPACE(N)`

  Returns a string consisting of `N` space characters.

```
mysql> SELECT SPACE(6);
-> '      '
```

- `SUBSTR(str,pos), SUBSTR(str FROM pos), SUBSTR(str,pos,len), SUBSTR(str FROM pos FOR len)`

  `SUBSTR()` is a synonym for `SUBSTRING()`.

- `SUBSTRING(str,pos), SUBSTRING(str FROM pos), SUBSTRING(str,pos,len), SUBSTRING(str FROM pos FOR len)`

  The forms without a `len` argument return a substring from string `str` starting at position `pos`. The forms with a `len` argument return a substring `len` characters long from string `str`, starting at position `pos`. The forms that use `FROM` are standard SQL syntax. It is also possible to use a negative value for `pos`. In this case, the beginning of the substring is `pos` characters from the end of the string, rather than the
beginning. A negative value may be used for \textit{pos} in any of the forms of this function. A value of 0 for \textit{pos} returns an empty string.

For all forms of \texttt{SUBSTRING()}, the position of the first character in the string from which the substring is to be extracted is reckoned as 1.

\begin{verbatim}
mysql> SELECT SUBSTRING('Quadratically',5);
-> 'ratically'
mysql> SELECT SUBSTRING('foobabbar' FROM 4);
-> 'bbar'
mysql> SELECT SUBSTRING('Quadratically',5,6);
-> 'atica'
mysql> SELECT SUBSTRING('Sakila', -3);
-> 'ila'
mysql> SELECT SUBSTRING('Sakila', -5, 3);
-> 'aki'
mysql> SELECT SUBSTRING('Sakila' FROM -4 FOR 2);
-> 'ki'
\end{verbatim}

This function is multibyte safe.

If \textit{len} is less than 1, the result is the empty string.

\begin{verbatim}
• \texttt{SUBSTRING_INDEX(str, delim, count)}

Returns the substring from string \textit{str} before \textit{count} occurrences of the delimiter \textit{delim}. If \textit{count} is positive, everything to the left of the final delimiter (counting from the left) is returned. If \textit{count} is negative, everything to the right of the final delimiter (counting from the right) is returned. \texttt{SUBSTRING_INDEX()} performs a case-sensitive match when searching for \textit{delim}.

mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', 2);
-> 'www.mysql'
mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', -2);
-> 'mysql.com'
\end{verbatim}

This function is multibyte safe.

\begin{verbatim}
• \texttt{TRIM([{BOTH | LEADING | TRAILING} \[remstr\] FROM] str)}, \texttt{TRIM([remstr FROM] str)}

Returns the string \textit{str} with all \textit{remstr} prefixes or suffixes removed. If none of the specifiers \texttt{BOTH}, \texttt{LEADING}, or \texttt{TRAILING} is given, \texttt{BOTH} is assumed. \textit{remstr} is optional and, if not specified, spaces are removed.

mysql> SELECT TRIM('  bar   ');
-> 'bar'
mysql> SELECT TRIM(LEADING 'x' FROM 'xxxbarxxx');
-> 'barxxx'
mysql> SELECT TRIM(BOTH 'x' FROM 'xxxbarxxx');
-> 'bar'
mysql> SELECT TRIM(TRAILING 'xyz' FROM 'barxxyz');
-> 'barx'
\end{verbatim}

This function is multibyte safe.

\begin{verbatim}
• \texttt{UCASE(str)}

\texttt{UCASE()} is a synonym for \texttt{UPPER()}.  
\end{verbatim}
• **UNHEX**(*str*)

For a string argument *str*, UNHEX(*str*) interprets each pair of characters in the argument as a hexadecimal number and converts it to the byte represented by the number. The return value is a binary string.

```sql
mysql> SELECT UNHEX('4D7953514C');
-> 'MySQL'
mysql> SELECT X'4D7953514C';
-> 'MySQL'
mysql> SELECT UNHEX(HEX('string'));
-> 'string'
mysql> SELECT HEX(UNHEX('1267'));
-> '1267'
```

The characters in the argument string must be legal hexadecimal digits: '0' .. '9', 'A' .. 'F', 'a' .. 'f'. If the argument contains any nonhexadecimal digits, the result is NULL:

```sql
mysql> SELECT UNHEX('GG');
+-------------+
| UNHEX('GG') |
| NULL        |
+-------------+
```

A NULL result can occur if the argument to UNHEX() is a BINARY column, because values are padded with 0x00 bytes when stored but those bytes are not stripped on retrieval. For example, '41' is stored into a CHAR(3) column as '41 ' and retrieved as '41 ' (with the trailing pad space stripped), so UNHEX() for the column value returns 'A'. By contrast '41' is stored into a BINARY(3) column as '41\0' and retrieved as '41\0' (with the trailing pad 0x00 byte not stripped). '\0' is not a legal hexadecimal digit, so UNHEX() for the column value returns NULL.

For a numeric argument *N*, the inverse of HEX(*N*) is not performed by UNHEX(). Use CONV(HEX(*N*),16,10) instead. See the description of HEX().

• **UPPER**(*str*)

Returns the string *str* with all characters changed to uppercase according to the current character set mapping. The default is latin1 (cp1252 West European).

```sql
mysql> SELECT UPPER('Hej');
-> 'HEJ'
```

See the description of LOWER() for information that also applies to UPPER(), such as information about how to perform lettercase conversion of binary strings (BINARY, VARBINARY, BLOB) for which these functions are ineffective.

This function is multibyte safe.

### 12.7.1 String Comparison Functions and Operators

#### Table 12.12 String Comparison Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIKE</td>
<td>Simple pattern matching</td>
</tr>
<tr>
<td>NOT LIKE</td>
<td>Negation of simple pattern matching</td>
</tr>
<tr>
<td>STRCMP()</td>
<td>Compare two strings</td>
</tr>
</tbody>
</table>
If a string function is given a binary string as an argument, the resulting string is also a binary string. A number converted to a string is treated as a binary string. This affects only comparisons.

Normally, if any expression in a string comparison is case-sensitive, the comparison is performed in case-sensitive fashion.

\[ expr \texttt{LIKE} \ pat \ [\texttt{ESCAPE} '\texttt{escape_char}'] \]

Pattern matching using an SQL pattern. Returns 1 (TRUE) or 0 (FALSE). If either \( expr \) or \( pat \) is \( \texttt{NULL} \), the result is \( \texttt{NULL} \).

The pattern need not be a literal string. For example, it can be specified as a string expression or table column.

Per the SQL standard, \texttt{LIKE} performs matching on a per-character basis, thus it can produce results different from the = comparison operator:

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'ä' LIKE 'ae' COLLATE latin1_german2_ci;}
<table>
<thead>
<tr>
<th>'ä' LIKE 'ae' COLLATE latin1_german2_ci</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
\end{array}
\]

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'ä' = 'ae' COLLATE latin1_german2_ci;}
<table>
<thead>
<tr>
<th>'ä' = 'ae' COLLATE latin1_german2_ci</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>
\end{array}
\]

In particular, trailing spaces are significant, which is not true for \texttt{CHAR} or \texttt{VARCHAR} comparisons performed with the = operator:

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'a' = 'a ', 'a' LIKE 'a ' ;}
| 'a' = 'a ' | 'a' LIKE 'a ' |
|------------+---------------|
| 1          | 0             |
\end{array}
\]

1 row in set (0.00 sec)

With \texttt{LIKE} you can use the following two wildcard characters in the pattern:

- \% matches any number of characters, even zero characters.
- \_ matches exactly one character.

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'David!' LIKE 'David_';}
<table>
<thead>
<tr>
<th>'David!' LIKE 'David_'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>
\end{array}
\]

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'David!' LIKE 'David\%';}
<table>
<thead>
<tr>
<th>'David!' LIKE 'David%'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>
\end{array}
\]

To test for literal instances of a wildcard character, precede it by the escape character. If you do not specify the \texttt{ESCAPE} character, \ is assumed.

- \\% matches one \% character.
- \\_ matches one \_ character.

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'David!' LIKE 'David\%';}
<table>
<thead>
<tr>
<th>'David!' LIKE 'David%'</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
\end{array}
\]

\[
\begin{array}{c}
\text{mysql> } \texttt{SELECT 'David_' LIKE 'David\_';}
<table>
<thead>
<tr>
<th>'David_' LIKE 'David_'</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
\end{array}
\]
To specify a different escape character, use the `ESCAPE` clause:

```sql
mysql> SELECT 'David_' LIKE 'David|_' ESCAPE '|';
-> 1
```

The escape sequence should be empty or one character long. The expression must evaluate as a constant at execution time. If the `NO_BACKSLASH_ESCAPES` SQL mode is enabled, the sequence cannot be empty.

The following two statements illustrate that string comparisons are not case-sensitive unless one of the operands is case-sensitive (uses a case-sensitive collation or is a binary string):

```sql
mysql> SELECT 'abc' LIKE 'ABC';
-> 1
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_general_cs;
-> 0
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_bin;
-> 0
mysql> SELECT 'abc' LIKE BINARY 'ABC';
-> 0
```

As an extension to standard SQL, MySQL permits `LIKE` on numeric expressions.

```sql
mysql> SELECT 10 LIKE '1%';
-> 1
```

Note
---

Because MySQL uses C escape syntax in strings (for example, `\n` to represent a newline character), you must double any `\` that you use in `LIKE` strings. For example, to search for `\n`, specify it as `\\n`. To search for `\`, specify it as `\\\`; this is because the backslashes are stripped once by the parser and again when the pattern match is made, leaving a single backslash to be matched against.

Exception: At the end of the pattern string, backslash can be specified as `\\`. At the end of the string, backslash stands for itself because there is nothing following to escape. Suppose that a table contains the following values:

```sql
mysql> SELECT filename FROM t1;
```

<table>
<thead>
<tr>
<th>filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:</td>
</tr>
<tr>
<td>C:\</td>
</tr>
<tr>
<td>C:\Programs</td>
</tr>
<tr>
<td>C:\Programs\</td>
</tr>
</tbody>
</table>

To test for values that end with backslash, you can match the values using either of the following patterns:

```sql
mysql> SELECT filename, filename LIKE '%\' FROM t1;
```

<table>
<thead>
<tr>
<th>filename</th>
<th>filename LIKE '%'</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:</td>
<td>0</td>
</tr>
<tr>
<td>C:\</td>
<td>1</td>
</tr>
<tr>
<td>C:\Programs</td>
<td>0</td>
</tr>
<tr>
<td>C:\Programs\</td>
<td>1</td>
</tr>
</tbody>
</table>

```sql
```
String Comparison Functions and Operators

- `expr NOT LIKE pat [ESCAPE 'escape_char']`

  This is the same as `NOT (expr LIKE pat [ESCAPE 'escape_char'])`.

**Note**

Aggregate queries involving `NOT LIKE` comparisons with columns containing `NULL` may yield unexpected results. For example, consider the following table and data:

```sql
CREATE TABLE foo (bar VARCHAR(10));
INSERT INTO foo VALUES (NULL), (NULL);
```

The query `SELECT COUNT(*) FROM foo WHERE bar LIKE '%baz%';` returns 0. You might assume that `SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%';` would return 2. However, this is not the case: The second query returns 0. This is because `NULL NOT LIKE expr` always returns `NULL`, regardless of the value of `expr`. The same is true for aggregate queries involving `NULL` and comparisons using `NOT RLIKE` or `NOT REGEXP`. In such cases, you must test explicitly for `NOT NULL` using `OR` (and not `AND`), as shown here:

```sql
SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%' OR bar IS NULL;
```

- `STRCMP(expr1, expr2)`

  `STRCMP()` returns 0 if the strings are the same, -1 if the first argument is smaller than the second according to the current sort order, and 1 otherwise.

```sql
mysql> SELECT STRCMP('text', 'text2');
  -> -1
mysql> SELECT STRCMP('text2', 'text');
  -> 1
mysql> SELECT STRCMP('text', 'text');
  -> 0
```

`STRCMP()` performs the comparison using the collation of the arguments.

```sql
mysql> SET @s1 = _latin1 'x' COLLATE latin1_general_ci;
mysql> SET @s2 = _latin1 'X' COLLATE latin1_general_ci;
mysql> SET @s3 = _latin1 'x' COLLATE latin1_general_cs;
mysql> SET @s4 = _latin1 'X' COLLATE latin1_general_cs;
mysql> SELECT STRCMP(@s1, @s2), STRCMP(@s3, @s4);
```

```sql
+----------------+------------------+
| STRCMP(@s1, @s2) | STRCMP(@s3, @s4) |
+----------------+------------------+
|                0 |                1 |
```
If the collations are incompatible, one of the arguments must be converted to be compatible with the other. See Section 10.8.4, “Collation Coercibility in Expressions”.

```sql
mysql> SELECT STRCMP(@s1, @s3);
ERROR 1267 (HY000): Illegal mix of collations (latin1_general_ci,IMPLICIT) and (latin1_general_cs,IMPLICIT) for operation 'strcmpl'
mysql> SELECT STRCMP(@s1, @s3 COLLATE latin1_general_ci);
+--------------------------------------------+
| STRCMP(@s1, @s3 COLLATE latin1_general_ci) |
| +--------------------------------------------|
| 0 |
+--------------------------------------------+
```

### 12.7.2 Regular Expressions

#### Table 12.13 Regular Expression Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT REGEXP</td>
<td>Negation of REGEXP</td>
</tr>
<tr>
<td>REGEXP</td>
<td>Whether string matches regular expression</td>
</tr>
<tr>
<td>RLIKE</td>
<td>Whether string matches regular expression</td>
</tr>
</tbody>
</table>

A regular expression is a powerful way of specifying a pattern for a complex search. This section discusses the operators available for regular expression matching and illustrates, with examples, some of the special characters and constructs that can be used for regular expression operations. See also Section 3.3.4.7, “Pattern Matching”.

MySQL uses Henry Spencer's implementation of regular expressions, which is aimed at conformance with POSIX 1003.2. MySQL uses the extended version to support regular expression pattern-matching operations in SQL statements. This section does not contain all the details that can be found in Henry Spencer's `regex(7)` manual page. That manual page is included in MySQL source distributions, in the `regex.7` file under the `regex` directory.

- Regular Expression Operators
- Regular Expression Syntax

#### Regular Expression Operators

- `expr NOT REGEXP pat, expr NOT RLIKE pat`

  This is the same as `NOT (expr REGEXP pat)`.

- `expr REGEXP pat, expr RLIKE pat`

  Returns 1 if the string `expr` matches the regular expression specified by the pattern `pat`, 0 otherwise. If either `expr` or `pat` is NULL, the return value is NULL.

  `RLIKE` is a synonym for `REGEXP`, provided for mSQL compatibility.

  The pattern can be an extended regular expression, the syntax for which is discussed in Regular Expression Syntax. The pattern need not be a literal string. For example, it can be specified as a string expression or table column.
Note

Because MySQL uses the C escape syntax in strings (for example, \n to represent the newline character), you must double any \ that you use in your REGEXP arguments.

Regular expression operations use the character set and collation of the string expression and pattern arguments when deciding the type of a character and performing the comparison. If the arguments have different character sets or collations, coercibility rules apply as described in Section 10.8.4, “Collation Coercibility in Expressions”. If either argument is a binary string, the arguments are handled in case-sensitive fashion as binary strings.

Warning

The REGEXP and RLIKE operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

Regular Expression Syntax

A regular expression describes a set of strings. The simplest regular expression is one that has no special characters in it. For example, the regular expression hello matches hello and nothing else.

Nontrivial regular expressions use certain special constructs so that they can match more than one string. For example, the regular expression hello|world contains the | alternation operator and matches either the hello or world.

As a more complex example, the regular expression B[a-n]*s matches any of the strings Bananas, Baaaaas, Bs, and any other string starting with a B, ending with an s, and containing any number of a or n characters in between.

A regular expression for the REGEXP operator may use any of the following special characters and constructs:
Regular Expressions

- ^
  Match the beginning of a string.
  
  mysql> SELECT 'fo\no' REGEXP '^fo$'; -> 0
  mysql> SELECT 'fofo' REGEXP '^fo'; -> 1

- $
  Match the end of a string.
  
  mysql> SELECT 'fo\no' REGEXP '^fo\no$'; -> 1
  mysql> SELECT 'fo\no' REGEXP '^fo$'; -> 0

- .
  Match any character (including carriage return and newline).
  
  mysql> SELECT 'fofo' REGEXP '^f.*$'; -> 1
  mysql> SELECT 'fo\r\nfo' REGEXP '^f.*$'; -> 1

- a*
  Match any sequence of zero or more a characters.
  
  mysql> SELECT 'Ban' REGEXP '^Ba*n'; -> 1
  mysql> SELECT 'Baaan' REGEXP '^Ba*n'; -> 1
  mysql> SELECT 'Bn' REGEXP '^Ba*n'; -> 1

- a+
  Match any sequence of one or more a characters.
  
  mysql> SELECT 'Ban' REGEXP '^Ba+n'; -> 1
  mysql> SELECT 'Bn' REGEXP '^Ba+n'; -> 0

- a?
  Match either zero or one a character.
  
  mysql> SELECT 'Bn' REGEXP '^Ba?n'; -> 1
  mysql> SELECT 'Ban' REGEXP '^Ba?n'; -> 1
  mysql> SELECT 'Baan' REGEXP '^Ba?n'; -> 0

- de|abc
  Alternation; match either of the sequences de or abc.
  
  mysql> SELECT 'pi' REGEXP 'pi|apa'; -> 1
  mysql> SELECT 'axe' REGEXP 'pi|apa'; -> 0
  mysql> SELECT 'apa' REGEXP 'pi|apa'; -> 1
  mysql> SELECT 'apa' REGEXP '^(pi|apa)$'; -> 1
  mysql> SELECT 'pi' REGEXP '^(pi|apa)$'; -> 1
  mysql> SELECT 'pix' REGEXP '^(pi|apa)$'; -> 0

- (abc)*
  Match zero or more instances of the sequence abc.
  
  mysql> SELECT 'pi' REGEXP '^(pi)*$'; -> 1
  mysql> SELECT 'pip' REGEXP '^(pi)*$'; -> 0
  mysql> SELECT 'pipi' REGEXP '^(pi)*$'; -> 1
• \{1\}, \{2,3\}

Repetition; \(n\) and \(m, n\) notation provide a more general way of writing regular expressions that match many occurrences of the previous atom (or “piece”) of the pattern. \(m\) and \(n\) are integers.

• \(a^*\)

Can be written as \(a\{0,\}\).

• \(a^+\)

Can be written as \(a\{1,\}\).

• \(a?\)

Can be written as \(a\{0,1\}\).

To be more precise, \(a\{n\}\) matches exactly \(n\) instances of \(a\). \(a\{n,\}\) matches \(n\) or more instances of \(a\). \(a\{m,n\}\) matches \(m\) through \(n\) instances of \(a\), inclusive. If both \(m\) and \(n\) are given, \(m\) must be less than or equal to \(n\).

\(m\) and \(n\) must be in the range from 0 to \(\text{RE\_DUP\_MAX}\) (default 255), inclusive.

```
mysql> SELECT 'abcde' REGEXP 'a[bcd]{2}e'; -> 0
mysql> SELECT 'abcde' REGEXP 'a[bcd]{3}e'; -> 1
mysql> SELECT 'abcde' REGEXP 'a[bcd]{1,10}e'; -> 1
```

• \([a-dX],[^a-dX]\)

Matches any character that is (or is not, if \(^\) is used) either \(a\), \(b\), \(c\), \(d\) or \(X\). A – character between two other characters forms a range that matches all characters from the first character to the second. For example, \([0-9]\) matches any decimal digit. To include a literal \([\) character, it must immediately follow the opening bracket \([\). To include a literal – character, it must be written first or last. Any character that does not have a defined special meaning inside a \([\)] pair matches only itself.

```
mysql> SELECT 'abcde' REGEXP '[a-dXYZ]'; -> 1
mysql> SELECT 'abcde' REGEXP '\^[a-dXYZ]$'; -> 0
mysql> SELECT 'abcde' REGEXP '\^[^a-dXYZ]+$'; -> 0
mysql> SELECT 'gheisa' REGEXP '\^[^a-dXYZ]+$'; -> 0
```

• \([.\text{characters.}]\)

Within a bracket expression (written using \([\) and \(]\)), matches the sequence of characters of that collating element. \text{characters} is either a single character or a character name like \text{newline}. The following table lists the permissible character names.

The following table shows the permissible character names and the characters that they match. For characters given as numeric values, the values are represented in octal.

<table>
<thead>
<tr>
<th>Name</th>
<th>Character</th>
<th>Name</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUL</td>
<td>0</td>
<td>SOH</td>
<td>001</td>
</tr>
<tr>
<td>STX</td>
<td>002</td>
<td>ETX</td>
<td>003</td>
</tr>
<tr>
<td>EOT</td>
<td>004</td>
<td>ENQ</td>
<td>005</td>
</tr>
<tr>
<td>ACK</td>
<td>006</td>
<td>BEL</td>
<td>007</td>
</tr>
<tr>
<td>Name</td>
<td>Character</td>
<td>Name</td>
<td>Character</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------</td>
<td>--------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>alert</td>
<td>007</td>
<td>BS</td>
<td>010</td>
</tr>
<tr>
<td>backspace</td>
<td>'\b'</td>
<td>HT</td>
<td>011</td>
</tr>
<tr>
<td>tab</td>
<td>'\t'</td>
<td>LF</td>
<td>012</td>
</tr>
<tr>
<td>newline</td>
<td>'\n'</td>
<td>VT</td>
<td>013</td>
</tr>
<tr>
<td>vertical-tab</td>
<td>'\v'</td>
<td>FF</td>
<td>014</td>
</tr>
<tr>
<td>form-feed</td>
<td>'\f'</td>
<td>CR</td>
<td>015</td>
</tr>
<tr>
<td>carriage-return</td>
<td>'\r'</td>
<td>SO</td>
<td>016</td>
</tr>
<tr>
<td>SI</td>
<td>017</td>
<td>DLE</td>
<td>020</td>
</tr>
<tr>
<td>DC1</td>
<td>021</td>
<td>DC2</td>
<td>022</td>
</tr>
<tr>
<td>DC3</td>
<td>023</td>
<td>DC4</td>
<td>024</td>
</tr>
<tr>
<td>NAK</td>
<td>025</td>
<td>SYN</td>
<td>026</td>
</tr>
<tr>
<td>ETB</td>
<td>027</td>
<td>CAN</td>
<td>030</td>
</tr>
<tr>
<td>EM</td>
<td>031</td>
<td>SUB</td>
<td>032</td>
</tr>
<tr>
<td>ESC</td>
<td>033</td>
<td>IS4</td>
<td>034</td>
</tr>
<tr>
<td>FS</td>
<td>034</td>
<td>IS3</td>
<td>035</td>
</tr>
<tr>
<td>GS</td>
<td>035</td>
<td>IS2</td>
<td>036</td>
</tr>
<tr>
<td>RS</td>
<td>036</td>
<td>IS1</td>
<td>037</td>
</tr>
<tr>
<td>US</td>
<td>037</td>
<td>space</td>
<td></td>
</tr>
<tr>
<td>exclamation-mark</td>
<td>'!'</td>
<td>quotation-mark</td>
<td>'&quot;'</td>
</tr>
<tr>
<td>number-sign</td>
<td>'#'</td>
<td>dollar-sign</td>
<td>'$'</td>
</tr>
<tr>
<td>percent-sign</td>
<td>'%'</td>
<td>ampersand</td>
<td>'&amp;'</td>
</tr>
<tr>
<td>apostrophe</td>
<td>'''</td>
<td>left-parenthesis</td>
<td>'('</td>
</tr>
<tr>
<td>right-parenthesis</td>
<td>'}'</td>
<td>asterisk</td>
<td>'*'</td>
</tr>
<tr>
<td>plus-sign</td>
<td>'+'</td>
<td>comma</td>
<td>','</td>
</tr>
<tr>
<td>hyphen</td>
<td>'-'</td>
<td>hyphen-minus</td>
<td>'--'</td>
</tr>
<tr>
<td>period</td>
<td>'.'</td>
<td>full-stop</td>
<td>'.'</td>
</tr>
<tr>
<td>slash</td>
<td>'/'</td>
<td>solidus</td>
<td>'/'</td>
</tr>
<tr>
<td>zero</td>
<td>'0'</td>
<td>one</td>
<td>'1'</td>
</tr>
<tr>
<td>two</td>
<td>'2'</td>
<td>three</td>
<td>'3'</td>
</tr>
<tr>
<td>four</td>
<td>'4'</td>
<td>five</td>
<td>'5'</td>
</tr>
<tr>
<td>six</td>
<td>'6'</td>
<td>seven</td>
<td>'7'</td>
</tr>
<tr>
<td>eight</td>
<td>'8'</td>
<td>nine</td>
<td>'9'</td>
</tr>
<tr>
<td>colon</td>
<td>':'</td>
<td>semicolon</td>
<td>';'</td>
</tr>
<tr>
<td>less-than-sign</td>
<td>'&lt;'</td>
<td>equals-sign</td>
<td>'='</td>
</tr>
<tr>
<td>greater-than-sign</td>
<td>'&gt;'</td>
<td>question-mark</td>
<td>'?'</td>
</tr>
<tr>
<td>commercial-at</td>
<td>'@'</td>
<td>left-square-bracket</td>
<td>'[]'</td>
</tr>
<tr>
<td>backslash</td>
<td>''</td>
<td>reverse-solidus</td>
<td>'\'</td>
</tr>
</tbody>
</table>
### Regular Expressions

<table>
<thead>
<tr>
<th>Name</th>
<th>Character</th>
<th>Name</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>right-square-bracket</td>
<td>']'</td>
<td>circumflex</td>
<td>'^'</td>
</tr>
<tr>
<td>circumflex-accent</td>
<td>'^'</td>
<td>underscore</td>
<td>'_'</td>
</tr>
<tr>
<td>low-line</td>
<td>'_'</td>
<td>grave-accent</td>
<td>'&quot;'</td>
</tr>
<tr>
<td>left-brace</td>
<td>'{'</td>
<td>left-curly-bracket</td>
<td>'{'</td>
</tr>
<tr>
<td>vertical-line</td>
<td>'</td>
<td>'</td>
<td>right-brace</td>
</tr>
<tr>
<td>right-curly-bracket</td>
<td>'}'</td>
<td>tilda</td>
<td>'~'</td>
</tr>
</tbody>
</table>

| DEL | 177 |

- **[=character_class=]**

Within a bracket expression (written using `[]`), `=[character_class=]` represents an equivalence class. It matches all characters with the same collation value, including itself. For example, if `o` and `(+)` are the members of an equivalence class, `=[o=]`, `=[(+=]=]`, and `[o(+)]` are all synonymous. An equivalence class may not be used as an endpoint of a range.

- **[::character_class:]**

Within a bracket expression (written using `[]`), `::character_class:` represents a character class that matches all characters belonging to that class. The following table lists the standard class names. These names stand for the character classes defined in the `ctype(3)` manual page. A particular locale may provide other class names. A character class may not be used as an endpoint of a range.

<table>
<thead>
<tr>
<th>Character Class Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>alnum</td>
<td>Alphanumeric characters</td>
</tr>
<tr>
<td>alpha</td>
<td>Alphabetic characters</td>
</tr>
<tr>
<td>blank</td>
<td>Whitespace characters</td>
</tr>
<tr>
<td>cntrl</td>
<td>Control characters</td>
</tr>
<tr>
<td>digit</td>
<td>Digit characters</td>
</tr>
<tr>
<td>graph</td>
<td>Graphic characters</td>
</tr>
<tr>
<td>lower</td>
<td>Lowercase alphabetic characters</td>
</tr>
<tr>
<td>print</td>
<td>Graphic or space characters</td>
</tr>
<tr>
<td>punct</td>
<td>Punctuation characters</td>
</tr>
<tr>
<td>space</td>
<td>Space, tab, newline, and carriage return</td>
</tr>
<tr>
<td>upper</td>
<td>Uppercase alphabetic characters</td>
</tr>
<tr>
<td>xdigit</td>
<td>Hexadecimal digit characters</td>
</tr>
</tbody>
</table>

- `[[::<::]][[::>::]]`

```sql
mysql> SELECT '~' REGEXP '[[~.~]]';                                  -> 1
mysql> SELECT '~' REGEXP '[[.tilde.]]';                               -> 1
```

```sql
mysql> SELECT 'justalnums' REGEXP '[:alnum:]+';                      -> 1
mysql> SELECT '!!!' REGEXP '[:alnum:]+';                             -> 0
```
These markers stand for word boundaries. They match the beginning and end of words, respectively. A word is a sequence of word characters that is not preceded by or followed by word characters. A word character is an alphanumeric character in the `alnum` class or an underscore (`_`).

```sql
mysql> SELECT 'a word a' REGEXP '[[[:<:]\]word\[[[:>:]\]]\]'; -> 1
mysql> SELECT 'a xword a' REGEXP '[[[:<:]\]word\[[[:>:]\]]\]'; -> 0
```

To use a literal instance of a special character in a regular expression, precede it by two backslash (`\`) characters. The MySQL parser interprets one of the backslashes, and the regular expression library interprets the other. For example, to match the string `1+2` that contains the special `+` character, only the last of the following regular expressions is the correct one:

```sql
mysql> SELECT '1+2' REGEXP '1+2'; -> 0
mysql> SELECT '1+2' REGEXP '1\+2'; -> 0
mysql> SELECT '1+2' REGEXP '1\\+2'; -> 1
```

### 12.7.3 Character Set and Collation of Function Results

MySQL has many operators and functions that return a string. This section answers the question: What is the character set and collation of such a string?

For simple functions that take string input and return a string result as output, the output's character set and collation are the same as those of the principal input value. For example, `UPPER(X)` returns a string with the same character string and collation as `X`. The same applies for `INSTR()`, `LCASE()`, `LOWER()`, `LTRIM()`, `MID()`, `REPEAT()`, `REPLACE()`, `REVERSE()`, `RIGHT()`, `RPAD()`, `RTRIM()`, `SOUNDEX()`, `SUBSTRING()`, `TRIM()`, `UCASE()`, and `UPPER()`.

**Note**

The `REPLACE()` function, unlike all other functions, always ignores the collation of the string input and performs a case-sensitive comparison.

If a string input or function result is a binary string, the string has the `binary` character set and collation. This can be checked by using the `CHARSET()` and `COLLATION()` functions, both of which return `binary` for a binary string argument:

```sql
SELECT CHARSET(BINARY 'a'), COLLATION(BINARY 'a')
```

For operations that combine multiple string inputs and return a single string output, the “aggregation rules” of standard SQL apply for determining the collation of the result:

- If an explicit `COLLATE Y` occurs, use `Y`.
- If explicit `COLLATE Y` and `COLLATE Z` occur, raise an error.
- Otherwise, if all collations are `Y`, use `Y`.
- Otherwise, the result has no collation.

For example, with `CASE ... WHEN a THEN b WHEN b THEN c COLLATE X END`, the resulting collation is `X`. The same applies for `UNION`, `||`, `CONCAT()`, `ELT()`, `GREATEST()`, `IF()`, and `LEAST()`.

For operations that convert to character data, the character set and collation of the strings that result from the operations are defined by the `character_set_connection` and `collation_connection` system...
variables that determine the default connection character set and collation (see Section 10.4, “Connection Character Sets and Collations”). This applies only to CAST(), CONV(), FORMAT(), HEX(), and SPACE().

If there is any question about the character set or collation of the result returned by a string function, use the CHARSET() or COLLATION() function to find out:

```sql
mysql> SELECT USER(), CHARSET(USER()), COLLATION(USER());
+----------------+-----------------+-------------------+
| USER()         | CHARSET(USER()) | COLLATION(USER()) |
+----------------+-----------------+-------------------+
| test@localhost | utf8            | utf8_general_ci   |
+----------------+-----------------+-------------------+
mysql> SELECT CHARSET(COMPRESS('abc')), COLLATION(COMPRESS('abc'));
+--------------------------+----------------------------+
| CHARSET(COMPRESS('abc')) | COLLATION(COMPRESS('abc')) |
| binary                   | binary                     |
+--------------------------+----------------------------+
```

12.8 What Calendar Is Used By MySQL?

MySQL uses what is known as a proleptic Gregorian calendar.

Every country that has switched from the Julian to the Gregorian calendar has had to discard at least ten days during the switch. To see how this works, consider the month of October 1582, when the first Julian-to-Gregorian switch occurred.

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
<td>31</td>
</tr>
</tbody>
</table>

There are no dates between October 4 and October 15. This discontinuity is called the cutover. Any dates before the cutover are Julian, and any dates following the cutover are Gregorian. Dates during a cutover are nonexistent.

A calendar applied to dates when it was not actually in use is called proleptic. Thus, if we assume there was never a cutover and Gregorian rules always rule, we have a proleptic Gregorian calendar. This is what is used by MySQL, as is required by standard SQL. For this reason, dates prior to the cutover stored as MySQL DATE or DATETIME values must be adjusted to compensate for the difference. It is important to realize that the cutover did not occur at the same time in all countries, and that the later it happened, the more days were lost. For example, in Great Britain, it took place in 1752, when Wednesday September 2 was followed by Thursday September 14. Russia remained on the Julian calendar until 1918, losing 13 days in the process, and what is popularly referred to as its “October Revolution” occurred in November according to the Gregorian calendar.

12.9 Full-Text Search Functions

MATCH (col1, col2, ...) AGAINST (expr [search_modifier])

search_modifier:

```sql
{ 
    IN NATURAL LANGUAGE MODE
    | IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION
    | IN BOOLEAN MODE
    WITH QUERY EXPANSION
}
```
MySQL has support for full-text indexing and searching:

- A full-text index in MySQL is an index of type `FULLTEXT`.
- Full-text indexes can be used only with MyISAM tables. (In MySQL 5.6 and up, they can also be used with InnoDB tables.) Full-text indexes can be created only for CHAR, VARCHAR, or TEXT columns.
- A `FULLTEXT` index definition can be given in the `CREATE TABLE` statement when a table is created, or added later using `ALTER TABLE` or `CREATE INDEX`.
- For large data sets, it is much faster to load your data into a table that has no `FULLTEXT` index and then create the index after that, than to load data into a table that has an existing `FULLTEXT` index.

Full-text searching is performed using `MATCH()` ... `AGAINST` syntax. `MATCH()` takes a comma-separated list that names the columns to be searched. `AGAINST` takes a string to search for, and an optional modifier that indicates what type of search to perform. The search string must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.

There are three types of full-text searches:

- A natural language search interprets the search string as a phrase in natural human language (a phrase in free text). There are no special operators, with the exception of double quote (") characters. The stopword list applies. In addition, words that are present in 50% or more of the rows are considered common and do not match.

  Full-text searches are natural language searches if the `IN NATURAL LANGUAGE MODE` modifier is given or if no modifier is given. For more information, see Section 12.9.1, “Natural Language Full-Text Searches”.

- A boolean search interprets the search string using the rules of a special query language. The string contains the words to search for. It can also contain operators that specify requirements such that a word must be present or absent in matching rows, or that it should be weighted higher or lower than usual. Common words such as “some” or “then” are stopwords and do not match if present in the search string. The `IN BOOLEAN MODE` modifier specifies a boolean search. For more information, see Section 12.9.2, “Boolean Full-Text Searches”.

- A query expansion search is a modification of a natural language search. The search string is used to perform a natural language search. Then words from the most relevant rows returned by the search are added to the search string and the search is done again. The query returns the rows from the second search. The `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` or `WITH QUERY EXPANSION` modifier specifies a query expansion search. For more information, see Section 12.9.3, “Full-Text Searches with Query Expansion”.

Constraints on full-text searching are listed in Section 12.9.5, “Full-Text Restrictions”.

The `myisam_ftdump` utility can be used to dump the contents of a full-text index. This may be helpful for debugging full-text queries. See Section 4.6.2, "`myisam_ftdump` — Display Full-Text Index information".

### 12.9.1 Natural Language Full-Text Searches

By default or with the `IN NATURAL LANGUAGE MODE` modifier, the `MATCH()` function performs a natural language search for a string against a `text collection`. A collection is a set of one or more columns included in a `FULLTEXT` index. The search string is given as the argument to `AGAINST()`. For each row in the table, `MATCH()` returns a relevance value; that is, a similarity measure between the search string and the text in that row in the columns named in the `MATCH()` list.

```
mysql> CREATE TABLE articles ( 
```
By default, the search is performed in case-insensitive fashion. However, you can perform a case-sensitive full-text search by using a binary collation for the indexed columns. For example, a column that uses the latin1 character set can be assigned a collation of latin1_bin to make it case-sensitive for full-text searches.

When MATCH() is used in a WHERE clause, as in the example shown earlier, the rows returned are automatically sorted with the highest relevance first. Relevance values are nonnegative floating-point numbers. Zero relevance means no similarity. Relevance is computed based on the number of words in the row (document), the number of unique words in the row, the total number of words in the collection, and the number of rows that contain a particular word.

To simply count matches, you could use a query like this:

```sql
mysql> SELECT COUNT(*) FROM articles
    WHERE MATCH (title, body)
    AGAINST ('database' IN NATURAL LANGUAGE MODE);
```

However, you might find it quicker to rewrite the query as follows:

```sql
mysql> SELECT COUNT(IF(MATCH (title, body) AGAINST ('database' IN NATURAL LANGUAGE MODE), 1, NULL)) AS count FROM articles;
```
The first query sorts the results by relevance whereas the second does not. However, the second query performs a full table scan and the first does not. The first may be faster if the search matches few rows; otherwise, the second may be faster because it would read many rows anyway.

For natural-language full-text searches, it is a requirement that the columns named in the MATCH() function be the same columns included in some FULLTEXT index in your table. For the preceding query, note that the columns named in the MATCH() function (title and body) are the same as those named in the definition of the article table's FULLTEXT index. If you wanted to search the title or body separately, you would need to create separate FULLTEXT indexes for each column.

It is also possible to perform a boolean search or a search with query expansion. These search types are described in Section 12.9.2, "Boolean Full-Text Searches", and Section 12.9.3, "Full-Text Searches with Query Expansion".

A full-text search that uses an index can name columns only from a single table in the MATCH() clause because an index cannot span multiple tables. A boolean search can be done in the absence of an index (albeit more slowly), in which case it is possible to name columns from multiple tables.

The preceding example is a basic illustration that shows how to use the MATCH() function where rows are returned in order of decreasing relevance. The next example shows how to retrieve the relevance values explicitly. Returned rows are not ordered because the SELECT statement includes neither WHERE nor ORDER BY clauses:

```
mysql> SELECT id, MATCH (title,body) AGAINST ('Tutorial' IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles;
+----+------------------+
| id | score            |
+----+------------------+
|  1 | 0.65545833110809 |
|  2 |                0 |
|  3 | 0.66266459226608 |
|  4 |                0 |
|  5 |                0 |
|  6 |                0 |
+----+------------------+
6 rows in set (0.00 sec)
```

The following example is more complex. The query returns the relevance values and it also sorts the rows in order of decreasing relevance. To achieve this result, specify MATCH() twice: once in the SELECT list and once in the WHERE clause. This causes no additional overhead, because the MySQL optimizer notices that the two MATCH() calls are identical and invokes the full-text search code only once.

```
mysql> SELECT id, body, MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles WHERE MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE);
+----+-------------------------------------+-----------------+
| id | body                                | score           |
+----+-------------------------------------+-----------------+
|  4 | 1. Never run mysqld as root. 2. ... | 1.5219271183014 |
|  6 | When configured properly, MySQL ... | 1.3114095926285 |
+----+-------------------------------------+-----------------+
2 rows in set (0.00 sec)
```
A phrase that is enclosed within double quote (") characters matches only rows that contain the phrase literally, as it was typed. The full-text engine splits the phrase into words and performs a search in the FULLTEXT index for the words. Nonword characters need not be matched exactly: Phrase searching requires only that matches contain exactly the same words as the phrase and in the same order. For example, "test phrase" matches "test, phrase". If the phrase contains no words that are in the index, the result is empty. For example, if all words are either stopwords or shorter than the minimum length of indexed words, the result is empty.

The MySQL FULLTEXT implementation regards any sequence of true word character (letters, digits, and underscores) as a word. That sequence may also contain apostrophes ('), but not more than one in a row. This means that aaa'bbb is regarded as one word, but aaa''bbb is regarded as two words. Apostrophes at the beginning or the end of a word are stripped by the FULLTEXT parser; 'aaa'bbb' would be parsed as aaa'bbb.

The FULLTEXT parser determines where words start and end by looking for certain delimiter characters; for example,  (space), , (comma), and . (period). If words are not separated by delimiters (as in, for example, Chinese), the FULLTEXT parser cannot determine where a word begins or ends. To be able to add words or other indexed terms in such languages to a FULLTEXT index, you must preprocess them so that they are separated by some arbitrary delimiter.

It is possible to write a plugin that replaces the built-in full-text parser. For details, see Section 24.2, “The MySQL Plugin API”. For example parser plugin source code, see the plugin/fulltext directory of a MySQL source distribution.

Some words are ignored in full-text searches:

- Any word that is too short is ignored. The default minimum length of words that are found by full-text searches is four characters.

- Words in the stopword list are ignored. A stopword is a word such as “the” or “some” that is so common that it is considered to have zero semantic value. There is a built-in stopword list, but it can be overwritten by a user-defined list.

The default stopword list is given in Section 12.9.4, “Full-Text Stopwords”. The default minimum word length and stopword list can be changed as described in Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”.

Every correct word in the collection and in the query is weighted according to its significance in the collection or query. Consequently, a word that is present in many documents has a lower weight (and may even have a zero weight), because it has lower semantic value in this particular collection. Conversely, if the word is rare, it receives a higher weight. The weights of the words are combined to compute the relevance of the row.

Such a technique works best with large collections (in fact, it was carefully tuned this way). For very small tables, word distribution does not adequately reflect their semantic value, and this model may sometimes produce bizarre results. For example, although the word “MySQL” is present in every row of the articles table shown earlier, a search for the word produces no results:

```
mysql> SELECT * FROM articles
    -> WHERE MATCH (title, body)
    -> AGAINST ('MySQL' IN NATURAL LANGUAGE MODE);
Empty set (0.00 sec)
```

The search result is empty because the word “MySQL” is present in at least 50% of the rows. As such, it is effectively treated as a stopword. For large data sets, this is the most desirable behavior: A natural language query should not return every second row from a 1GB table. For small data sets, it may be less desirable.
A word that matches half of the rows in a table is less likely to locate relevant documents. In fact, it most likely finds plenty of irrelevant documents. We all know this happens far too often when we are trying to find something on the Internet with a search engine. It is with this reasoning that rows containing the word are assigned a low semantic value for the particular data set in which they occur. A given word may reach the 50% threshold in one data set but not another.

The 50% threshold has a significant implication when you first try full-text searching to see how it works: If you create a table and insert only one or two rows of text into it, every word in the text occurs in at least 50% of the rows. As a result, no search returns any results. Be sure to insert at least three rows, and preferably many more. Users who need to bypass the 50% limitation can use the boolean search mode; see Section 12.9.2, “Boolean Full-Text Searches”.

### 12.9.2 Boolean Full-Text Searches

MySQL can perform boolean full-text searches using the `IN BOOLEAN MODE` modifier. With this modifier, certain characters have special meaning at the beginning or end of words in the search string. In the following query, the `+` and `-` operators indicate that a word is required to be present or absent, respectively, for a match to occur. Thus, the query retrieves all the rows that contain the word “MySQL” but that do not contain the word “YourSQL”:

```sql
mysql> SELECT * FROM articles WHERE MATCH (title,body) AGAINST ('+MySQL -YourSQL' IN BOOLEAN MODE);
```

<table>
<thead>
<tr>
<th>id</th>
<th>title</th>
<th>body</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MySQL Tutorial</td>
<td>DBMS stands for DataBase ...</td>
</tr>
<tr>
<td>2</td>
<td>How To Use MySQL Well</td>
<td>After you went through a ...</td>
</tr>
<tr>
<td>3</td>
<td>Optimizing MySQL</td>
<td>In this tutorial we will show ...</td>
</tr>
<tr>
<td>4</td>
<td>1001 MySQL Tricks</td>
<td>1. Never run mysqld as root. 2. ...</td>
</tr>
<tr>
<td>6</td>
<td>MySQL Security</td>
<td>When configured properly, MySQL ...</td>
</tr>
</tbody>
</table>

**Note**

In implementing this feature, MySQL uses what is sometimes referred to as implied Boolean logic, in which

- `+` stands for **AND**
- `-` stands for **NOT**
- `[no operator]` implies **OR**

Boolean full-text searches have these characteristics:

- They do not use the 50% threshold.
- They do not automatically sort rows in order of decreasing relevance. You can see this from the preceding query result: The row with the highest relevance is the one that contains “MySQL” twice, but it is listed last, not first.
- They can work even without a `FULLTEXT` index, although a search executed in this fashion would be quite slow.
- The minimum and maximum word length full-text parameters apply.
- The stopwords list applies.

The boolean full-text search capability supports the following operators:
• +

A leading plus sign indicates that this word must be present in each row that is returned.

• –

A leading minus sign indicates that this word must not be present in any of the rows that are returned.

Note: The – operator acts only to exclude rows that are otherwise matched by other search terms. Thus, a boolean-mode search that contains only terms preceded by – returns an empty result. It does not return “all rows except those containing any of the excluded terms.”

• (no operator)

By default (when neither + nor – is specified) the word is optional, but the rows that contain it are rated higher. This mimics the behavior of MATCH() ... AGAINST() without the IN BOOLEAN MODE modifier.

• > <

These two operators are used to change a word’s contribution to the relevance value that is assigned to a row. The > operator increases the contribution and the < operator decreases it. See the example following this list.

• ( )

Parentheses group words into subexpressions. Parenthesized groups can be nested.

• ~

A leading tilde acts as a negation operator, causing the word’s contribution to the row’s relevance to be negative. This is useful for marking “noise” words. A row containing such a word is rated lower than others, but is not excluded altogether, as it would be with the – operator.

• *

The asterisk serves as the truncation (or wildcard) operator. Unlike the other operators, it should be appended to the word to be affected. Words match if they begin with the word preceding the * operator.

If a word is specified with the truncation operator, it is not stripped from a boolean query, even if it is too short (as determined from the ft_min_word_len setting) or a stopword. This occurs because the word is not seen as too short or a stopword, but as a prefix that must be present in the document in the form of a word that begins with the prefix. Suppose that ft_min_word_len=4. Then a search for '+word +the*' will likely return fewer rows than a search for '+word +the':

• The former query remains as is and requires both word and the* (a word starting with the) to be present in the document.

• The latter query is transformed to +word (requiring only word to be present). the is both too short and a stopword, and either condition is enough to cause it to be ignored.

• "

A phrase that is enclosed within double quote (") characters matches only rows that contain the phrase literally, as it was typed. The full-text engine splits the phrase into words and performs a search in the FULLTEXT index for the words. Nonword characters need not be matched exactly: Phrase searching requires only that matches contain exactly the same words as the phrase and in the same order. For example, "test phrase" matches "test, phrase".
If the phrase contains no words that are in the index, the result is empty. For example, if all words are either stopwords or shorter than the minimum length of indexed words, the result is empty.

The following examples demonstrate some search strings that use boolean full-text operators:

- 'apple banana'
  Find rows that contain at least one of the two words.

- '+apple +juice'
  Find rows that contain both words.

- '+apple macintosh'
  Find rows that contain the word “apple”, but rank rows higher if they also contain “macintosh”.

- '+apple -macintosh'
  Find rows that contain the word “apple” but not “macintosh”.

- '+apple ~macintosh'
  Find rows that contain the word “apple”, but if the row also contains the word “macintosh”, rate it lower than if row does not. This is “softer” than a search for '+apple -macintosh', for which the presence of “macintosh” causes the row not to be returned at all.

- '+apple + (>turnover <strudel)'
  Find rows that contain the words “apple” and “turnover”, or “apple” and “strudel” (in any order), but rank “apple turnover” higher than “apple strudel”.

- 'apple*'
  Find rows that contain words such as “apple”, “apples”, “applesauce”, or “applet”.

- ‘"some words"'
  Find rows that contain the exact phrase “some words” (for example, rows that contain “some words of wisdom” but not “some noise words”). Note that the " characters that enclose the phrase are operator characters that delimit the phrase. They are not the quotation marks that enclose the search string itself.

### 12.9.3 Full-Text Searches with Query Expansion

Full-text search supports query expansion (and in particular, its variant “blind query expansion”). This is generally useful when a search phrase is too short, which often means that the user is relying on implied knowledge that the full-text search engine lacks. For example, a user searching for “database” may really mean that “MySQL”, “Oracle”, “DB2”, and “RDBMS” all are phrases that should match “databases” and should be returned, too. This is implied knowledge.

Blind query expansion (also known as automatic relevance feedback) is enabled by adding WITH QUERY EXPANSION or IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION following the search phrase. It works by performing the search twice, where the search phrase for the second search is the original search phrase concatenated with the few most highly relevant documents from the first search. Thus, if one of these documents contains the word “databases” and the word “MySQL”, the second search finds the documents that contain the word “MySQL” even if they do not contain the word “database”. The following example shows this difference:
Another example could be searching for books by Georges Simenon about Maigret, when a user is not sure how to spell “Maigret”. A search for “Megre and the reluctant witnesses” finds only “Maigret and the Reluctant Witnesses” without query expansion. A search with query expansion finds all books with the word “Maigret” on the second pass.

**Note**

Because blind query expansion tends to increase noise significantly by returning nonrelevant documents, it is meaningful to use only when a search phrase is rather short.

### 12.9.4 Full-Text Stopwords

The stopword list is loaded and searched for full-text queries using the server character set and collation (the values of the `character_set_server` and `collation_server` system variables). False hits or misses may occur for stopword lookups if the stopword file or columns used for full-text indexing or searches have a character set or collation different from `character_set_server` or `collation_server`.

Case sensitivity of stopword lookups depends on the server collation. For example, lookups are case-insensitive if the collation is `latin1_swedish_ci`, whereas lookups are case-sensitive if the collation is `latin1_general_cs` or `latin1_bin`.

The stopword file is loaded and searched using `latin1` if `character_set_server` is `ucs2`, `utf16`, or `utf32`.

The following list shows the default full-text stopwords. In a MySQL source distribution, you can find this list in the `storage/myisam/ft_static.c` file.

<table>
<thead>
<tr>
<th>a's</th>
<th>able</th>
<th>about</th>
<th>above</th>
<th>according</th>
<th>afterwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>accordingly</td>
<td>across</td>
<td>actually</td>
<td>after</td>
<td>allow</td>
<td></td>
</tr>
<tr>
<td>against</td>
<td>ain't</td>
<td>all</td>
<td>already</td>
<td></td>
<td></td>
</tr>
<tr>
<td>allows</td>
<td>almost</td>
<td>alone</td>
<td>am</td>
<td>among</td>
<td></td>
</tr>
<tr>
<td>also</td>
<td>although</td>
<td>always</td>
<td>along</td>
<td></td>
<td></td>
</tr>
<tr>
<td>amongst</td>
<td>an</td>
<td>and</td>
<td>another</td>
<td>any</td>
<td></td>
</tr>
<tr>
<td>anybody</td>
<td>anyhow</td>
<td>anyone</td>
<td>anything</td>
<td>anyway</td>
<td></td>
</tr>
<tr>
<td>anyways</td>
<td>anywhere</td>
<td>apart</td>
<td>appear</td>
<td>appreciate</td>
<td></td>
</tr>
<tr>
<td>appropriate</td>
<td>are</td>
<td>aren't</td>
<td>around</td>
<td>as</td>
<td></td>
</tr>
<tr>
<td>aside</td>
<td>ask</td>
<td>asking</td>
<td>associated</td>
<td>at</td>
<td></td>
</tr>
</tbody>
</table>
12.9.5 Full-Text Restrictions

- Full-text searches are supported for MyISAM tables only. (In MySQL 5.6 and up, they can also be used with InnoDB tables.)

- Full-text searches are not supported for partitioned tables. See Section 19.5, “Restrictions and Limitations on Partitioning”.

- Full-text searches can be used with most multibyte character sets. The exception is that for Unicode, the utf8 character set can be used, but not the ucs2 character set. However, although FULLTEXT indexes on ucs2 columns cannot be used, you can perform IN BOOLEAN MODE searches on a ucs2 column that has no such index.

The remarks for utf8 also apply to utf8mb4, and the remarks for ucs2 also apply to utf16 and utf32.

- Ideographic languages such as Chinese and Japanese do not have word delimiters. Therefore, the FULLTEXT parser cannot determine where words begin and end in these and other such languages. The implications of this and some workarounds for the problem are described in Section 12.9, “Full-Text Search Functions”.

- Although the use of multiple character sets within a single table is supported, all columns in a FULLTEXT index must use the same character set and collation.

- The MATCH() column list must match exactly the column list in some FULLTEXT index definition for the table, unless this MATCH() is IN BOOLEAN MODE. Boolean-mode searches can be done on nonindexed columns, although they are likely to be slow.
• The argument to \texttt{AGAINST()} must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.

• Index hints are more limited for \texttt{FULLTEXT} searches than for non-\texttt{FULLTEXT} searches. See Section 8.9.3, “Index Hints”.

• The ‘%’ character is not a supported wildcard character for full-text searches.

\section*{12.9.6 Fine-Tuning MySQL Full-Text Search}

MySQL’s full-text search capability has few user-tunable parameters. You can exert more control over full-text searching behavior if you have a MySQL source distribution because some changes require source code modifications. See Section 2.9, “Installing MySQL from Source”.

Full-text search is carefully tuned for the most effectiveness. Modifying the default behavior in most cases can actually decrease effectiveness. \textit{Do not alter the MySQL sources unless you know what you are doing.}

Most full-text variables described in this section must be set at server startup time. A server restart is required to change them; they cannot be modified while the server is running.

Some variable changes require that you rebuild the \texttt{FULLTEXT} indexes in your tables. Instructions for doing so are given later in this section.

• The minimum and maximum lengths of words to be indexed are defined by the \texttt{ft_min_word_len} and \texttt{ft_max_word_len} system variables. (See Section 5.1.7, “Server System Variables”.) The default minimum value is four characters; the default maximum is version dependent. If you change either value, you must rebuild your \texttt{FULLTEXT} indexes. For example, if you want three-character words to be searchable, you can set the \texttt{ft_min_word_len} variable by putting the following lines in an option file:

\begin{verbatim}
[mysqld]
ft_min_word_len=3
\end{verbatim}

Then restart the server and rebuild your \texttt{FULLTEXT} indexes. Note particularly the remarks regarding \texttt{myisamchk} in the instructions following this list.

• To override the default stopword list, set the \texttt{ft_stopword_file} system variable. (See Section 5.1.7, “Server System Variables”.) The variable value should be the path name of the file containing the stopword list, or the empty string to disable stopword filtering. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. After changing the value of this variable or the contents of the stopword file, restart the server and rebuild your \texttt{FULLTEXT} indexes.

The stopword list is free-form. That is, you may use any nonalphanumeric character such as newline, space, or comma to separate stopwords. Exceptions are the underscore character (\_\_) and a single apostrophe (‘’) which are treated as part of a word. The character set of the stopword list is the server's default character set; see Section 10.3.2, “Server Character Set and Collation”.

• The 50\% threshold for natural language searches is determined by the particular weighting scheme chosen. To disable it, look for the following line in \texttt{storage/myisam/ftdefs.h}:

\begin{verbatim}
#define GWS_IN_USE GWS_PROB
\end{verbatim}

Change that line to this:

\begin{verbatim}
#define GWS_IN_USE GWS_FREQ
\end{verbatim}

Then recompile MySQL. There is no need to rebuild the indexes in this case.
Note

By making this change, you severely decrease MySQL's ability to provide adequate relevance values for the `MATCH()` function. If you really need to search for such common words, it would be better to search using `IN BOOLEAN MODE` instead, which does not observe the 50% threshold.

- To change the operators used for boolean full-text searches, set the `ft_boolean_syntax` system variable. This variable can be changed while the server is running, but you must have privileges sufficient to set global system variables (see Section 5.1.8.1, “System Variable Privileges”). No rebuilding of indexes is necessary in this case. See Section 5.1.7, “Server System Variables”, which describes the rules governing how to set this variable.

- If you want to change the set of characters that are considered word characters, you can do so in several ways, as described in the following list. After making the modification, you must rebuild the indexes for each table that contains any FULLTEXT indexes. Suppose that you want to treat the hyphen character (‘-’) as a word character. Use one of these methods:

  - Modify the MySQL source: In `storage/myisam/ftdefs.h`, see the `true_word_char()` and `misc_word_char()` macros. Add ‘-’ to one of those macros and recompile MySQL.
  
  - Modify a character set file: This requires no recompilation. The `true_word_char()` macro uses a "character type" table to distinguish letters and numbers from other characters. You can edit the contents of the `<ctype><map>` array in one of the character set XML files to specify that ‘-’ is a “letter.” Then use the given character set for your FULLTEXT indexes. For information about the `<ctype><map>` array format, see Section 10.13.1, “Character Definition Arrays”.

  - Add a new collation for the character set used by the indexed columns, and alter the columns to use that collation. For general information about adding collations, see Section 10.14, “Adding a Collation to a Character Set”. For an example specific to full-text indexing, see Section 12.9.7, “Adding a Collation for Full-Text Indexing”.

If you modify full-text variables that affect indexing (`ft_min_word_len`, `ft_max_word_len`, or `ft_stopword_file`), or if you change the stopword file itself, you must rebuild your FULLTEXT indexes after making the changes and restarting the server. To rebuild the indexes in this case, it is sufficient to do a QUICK repair operation:

```
mysql> REPAIR TABLE tbl_name QUICK;
```

Alternatively, use `ALTER TABLE` with the `DROP INDEX` and `ADD INDEX` options to drop and re-create each FULLTEXT index. In some cases, this may be faster than a repair operation.

Each table that contains any FULLTEXT index must be repaired as just shown. Otherwise, queries for the table may yield incorrect results, and modifications to the table will cause the server to see the table as corrupt and in need of repair.

If you use `myisamchk` to perform an operation that modifies table indexes (such as repair or analyze), the FULLTEXT indexes are rebuilt using the `default` full-text parameter values for minimum word length, maximum word length, and stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in MyISAM index files. To avoid the problem if you have modified the minimum or maximum word length or stopword file values used by the server, specify the same `ft_min_word_len`, `ft_max_word_len`, and `ft_stopword_file` values for `myisamchk` that you use for `mysqld`. For example, if you have set the minimum word length to 3, you can repair a table with `myisamchk` like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```
To ensure that `myisamchk` and the server use the same values for full-text parameters, place each one in both the `[mysqld]` and `[myisamchk]` sections of an option file:

```ini
[mysqld]
ft_min_word_len=3

[myisamchk]
ft_min_word_len=3
```

An alternative to using `myisamchk` for index modification is to use the `REPAIR TABLE`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, or `ALTER TABLE` statements. These statements are performed by the server, which knows the proper full-text parameter values to use.

### 12.9.7 Adding a Collation for Full-Text Indexing

This section describes how to add a new collation for full-text searches. The sample collation is like `latin1_swedish_ci` but treats the ‘-’ character as a letter rather than as a punctuation character so that it can be indexed as a word character. General information about adding collations is given in Section 10.14, “Adding a Collation to a Character Set”; it is assumed that you have read it and are familiar with the files involved.

To add a collation for full-text indexing, use the following procedure. The instructions here add a collation for a simple character set, which as discussed in Section 10.14, “Adding a Collation to a Character Set”, can be created using a configuration file that describes the character set properties. For a complex character set such as Unicode, create collations using C source files that describe the character set properties.

1. Add a collation to the `Index.xml` file. The collation ID must be unused, so choose a value different from 62 if that ID is already taken on your system.

   ```xml
   <charset name="latin1">
   ...
   <collation name="latin1_fulltext_ci" id="62"/>
   </charset>
   ```

2. Declare the sort order for the collation in the `latin1.xml` file. In this case, the order can be copied from `latin1_swedish_ci`:

   ```xml
   <collation name="latin1_fulltext_ci">
   <map>
   00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
   10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
   20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
   30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
   40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
   60 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   70 71 72 73 74 75 76 77 78 79 7A 7B 7C 7D 7E 7F
   80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
   90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
   A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
   B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
   40 41 41 41 5C 5B 5C 43 45 45 45 45 45 45 45 49 49 49 49
   44 4E 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F 4F
   </map>
   </collation>
   ```

3. Modify the `ctype` array in `latin1.xml`. Change the value corresponding to 0x2D (which is the code for the ‘-’ character) from 10 (punctuation) to 01 (uppercase letter). In the following array, this is the element in the fourth row down, third value from the end.
4. Restart the server.

5. To employ the new collation, include it in the definition of columns that are to use it:

```sql
mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected (0.13 sec)

mysql> CREATE TABLE t1 (  
-> a TEXT CHARACTER SET latin1 COLLATE latin1_fulltext_ci,
-> FULLTEXT INDEX(a)
-> ) ENGINE=MyISAM;
Query OK, 0 rows affected (0.47 sec)
```

6. Test the collation to verify that hyphen is considered as a word character:

```sql
mysql> INSERT INTO t1 VALUES ('----'),('....'),('abcd');
Query OK, 3 rows affected (0.22 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1 WHERE MATCH a AGAINST ('----' IN BOOLEAN MODE);
+------+
| a    |
+------+
| ---- |
+------+
1 row in set (0.00 sec)
```

## 12.10 Cast Functions and Operators

### Table 12.14 Cast Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINARY</td>
<td>Cast a string to a binary string</td>
</tr>
<tr>
<td>CAST()</td>
<td>Cast a value as a certain type</td>
</tr>
<tr>
<td>CONVERT()</td>
<td>Cast a value as a certain type</td>
</tr>
</tbody>
</table>

Cast functions and operators enable conversion of values from one data type to another.

`CONVERT()` with a `USING` clause converts data between different character sets:
CONVERT(\textit{expr} \text{ USING} \ \textit{transcoding\_name})

In MySQL, transcoding names are the same as the corresponding character set names.

Examples:

\begin{verbatim}
SELECT CONVERT('test' USING utf8);
SELECT CONVERT(_latin1'Müller' USING utf8);
INSERT INTO utf8\_table (utf8\_column)
  SELECT CONVERT(latin1\_column USING utf8) FROM latin1\_table;
\end{verbatim}

To convert strings between different character sets, you can also use \texttt{CONVERT()} without \texttt{USING}, or \texttt{CAST()}:

\begin{verbatim}
CONVERT\texttt{(string, CHAR(\{N\}) CHARACTER SET charset\_name)}
CAST\texttt{(string AS CHAR(\{N\}) CHARACTER SET charset\_name)}
\end{verbatim}

Examples:

\begin{verbatim}
SELECT CONVERT('test', CHAR CHARACTER SET utf8);
SELECT CAST('test' AS CHAR CHARACTER SET utf8);
\end{verbatim}

If you specify \texttt{CHARACTER SET charset\_name} as just shown, the character set and collation of the result are \texttt{charset\_name} and the default collation of \texttt{charset\_name}. If you omit \texttt{CHARACTER SET charset\_name}, the character set and collation of the result are defined by the \texttt{character\_set\_connection} and \texttt{collation\_connection} system variables that determine the default connection character set and collation (see Section 10.4, “Connection Character Sets and Collations”).

A \texttt{COLLATE} clause is not permitted within a \texttt{CONVERT()} or \texttt{CAST()} call, but you can apply it to the function result. For example, these are legal:

\begin{verbatim}
SELECT CONVERT('test' USING utf8) COLLATE utf8\_bin;
SELECT CONVERT('test', CHAR CHARACTER SET utf8) COLLATE utf8\_bin;
SELECT CAST('test' AS CHAR CHARACTER SET utf8) COLLATE utf8\_bin;
\end{verbatim}

But these are illegal:

\begin{verbatim}
SELECT CONVERT('test' USING utf8 COLLATE utf8\_bin);
SELECT CONVERT('test', CHAR CHARACTER SET utf8 COLLATE utf8\_bin);
SELECT CAST('test' AS CHAR CHARACTER SET utf8 COLLATE utf8\_bin);
\end{verbatim}

Normally, you cannot compare a \texttt{BLOB} value or other binary string in case-insensitive fashion because binary strings use the \texttt{binary} character set, which has no collation with the concept of lettercase. To perform a case-insensitive comparison, first use the \texttt{CONVERT()} or \texttt{CAST()} function to convert the value to a nonbinary string. Comparisons of the resulting string use its collation. For example, if the conversion result character set has a case-insensitive collation, a \texttt{LIKE} operation is not case-sensitive. That is true for the following operation because the default \texttt{latin1} collation (\texttt{latin1\_swedish\_ci}) is not case-sensitive:

\begin{verbatim}
SELECT 'A' LIKE CONVERT\texttt{(blob\_col USING latin1)
  FROM tbl\_name;}
\end{verbatim}

To specify a particular collation for the converted string, use a \texttt{COLLATE} clause following the \texttt{CONVERT()} call:

\begin{verbatim}
SELECT 'A' LIKE CONVERT\texttt{(blob\_col USING latin1) COLLATE latin1\_german1\_ci
  FROM tbl\_name;}
\end{verbatim}

To use a different character set, substitute its name for \texttt{latin1} in the preceding statements (and similarly to use a different collation).
CONVERT() and CAST() can be used more generally for comparing strings represented in different character sets. For example, a comparison of these strings results in an error because they have different character sets:

```sql
mysql> SET @s1 = _latin1 'abc', @s2 = _latin2 'abc';
mysql> SELECT @s1 = @s2;
ERROR 1267 (HY000): Illegal mix of collations (latin1_swedish_ci,IMPLICIT) and (latin2_general_ci,IMPLICIT) for operation '='
```

Converting one of the strings to a character set compatible with the other enables the comparison to occur without error:

```sql
mysql> SELECT @s1 = CONVERT(@s2 USING latin1);
```

For string literals, another way to specify the character set is to use a character set introducer. `_latin1` and `_latin2` in the preceding example are instances of introducers. Unlike conversion functions such as CAST(), or CONVERT(), which convert a string from one character set to another, an introducer designates a string literal as having a particular character set, with no conversion involved. For more information, see Section 10.3.8, “Character Set Introducers”.

Character set conversion is also useful preceding lettercase conversion of binary strings. LOWER() and UPPER() are ineffective when applied directly to binary strings because the concept of lettercase does not apply. To perform lettercase conversion of a binary string, first convert it to a nonbinary string using a character set appropriate for the data stored in the string:

```sql
mysql> SET @str = BINARY 'New York';
mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
```

Be aware that if you convert an indexed column using BINARY, CAST(), or CONVERT(), MySQL may not be able to use the index efficiently.

The cast functions are useful for creating a column with a specific type in a CREATE TABLE ... SELECT statement:

```sql
mysql> CREATE TABLE new_table SELECT CAST('2000-01-01' AS DATE) AS c1;
```

The cast functions are useful for sorting ENUM columns in lexical order. Normally, sorting of ENUM columns occurs using the internal numeric values. Casting the values to CHAR results in a lexical sort:

```sql
SELECT enum_col FROM tbi_name ORDER BY CAST(enum_col AS CHAR);
```

CAST() also changes the result if you use it as part of a more complex expression such as

```
CONCAT('Date: ',CAST(NOW() AS DATE)).
```
For temporal values, there is little need to use \texttt{CAST()} to extract data in different formats. Instead, use a function such as \texttt{EXTRACT()}, \texttt{DATE\_FORMAT()}, or \texttt{TIME\_FORMAT()}. See Section 12.6, “Date and Time Functions”.

To cast a string to a number, you normally need do nothing other than use the string value in numeric context:

\begin{verbatim}
mysql> SELECT 1+'1';
-> 2
\end{verbatim}

That is also true for hexadecimal and bit literals, which are binary strings by default:

\begin{verbatim}
mysql> SELECT X'41', X'41'+0;
-> 'A', 65
mysql> SELECT b'1100001', b'1100001'+0;
-> 'a', 97
\end{verbatim}

A string used in an arithmetic operation is converted to a floating-point number during expression evaluation.

A number used in string context is converted to a string:

\begin{verbatim}
mysql> SELECT CONCAT('hello you ',2);
-> 'hello you 2'
\end{verbatim}

For information about implicit conversion of numbers to strings, see Section 12.2, “Type Conversion in Expression Evaluation”.

When using an explicit \texttt{CAST()} on a \texttt{TIMESTAMP} value in a statement that does not select from any tables, the value is treated by MySQL as a string prior to performing any conversion. This results in the value being truncated when casting to a numeric type, as shown here:

\begin{verbatim}
mysql> SELECT CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED);
+-------------------------------------------------+
| CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED) |
+-------------------------------------------------+
|                                            2014 |
+-------------------------------------------------+
1 row in set, 1 warning (0.00 sec)
mysql> SHOW WARNINGS;
+---------+------+----------------------------------------------------------+
| Level   | Code | Message                                                  |
+---------+------+----------------------------------------------------------+
| Warning | 1292 | Truncated incorrect INTEGER value: '2014-09-08 18:07:54' |
+---------+------+----------------------------------------------------------+
1 row in set (0.00 sec)
\end{verbatim}

This does not apply when selecting rows from a table, as shown here:

\begin{verbatim}
mysql> USE test;
Database changed
mysql> CREATE TABLE c_test (col TIMESTAMP);
Query OK, 0 rows affected (0.07 sec)
mysql> INSERT INTO c_test VALUES ('2014-09-08 18:07:54');
Query OK, 1 row affected (0.05 sec)
mysql> SELECT col, CAST(col AS UNSIGNED) AS c_col FROM c_test;
+---------------------+----------------+
| col                 | c_col          |
|---------------------+----------------|
| 2014                | 2014           |
+---------------------+----------------+
1 row in set (0.00 sec)
\end{verbatim}
Cast Functions and Operators

MySQL supports arithmetic with both signed and unsigned 64-bit values. For numeric operators (such as + or -) where one of the operands is an unsigned integer, the result is unsigned by default (see Section 12.5.1, “Arithmetic Operators”). To override this, use the SIGNED or UNSIGNED cast operator to cast a value to a signed or unsigned 64-bit integer, respectively.

```sql
mysql> SELECT 1 - 2;
-> -1
```

```sql
mysql> SELECT CAST(1 - 2 AS UNSIGNED);
-> 18446744073709551615
```

```sql
mysql> SELECT CAST(CAST(1 - 2 AS UNSIGNED) AS SIGNED);
-> -1
```

If either operand is a floating-point value, the result is a floating-point value and is not affected by the preceding rule. (In this context, DECIMAL column values are regarded as floating-point values.)

```sql
mysql> SELECT CAST(1 AS UNSIGNED) - 2.0;
-> -1.0
```

The SQL mode affects the result of conversion operations (see Section 5.1.10, “Server SQL Modes”). Examples:

- For conversion of a “zero” date string to a date, CONVERT() and CAST() return NULL and produce a warning when the NO_ZERO_DATE SQL mode is enabled.
- For integer subtraction, if the NO_UNSIGNED_SUBTRACTION SQL mode is enabled, the subtraction result is signed even if any operand is unsigned.

The following list describes the available cast functions and operators:

- **BINARY expr**

  The BINARY operator converts the expression to a binary string (a string that has the binary character set and binary collation). A common use for BINARY is to force a character string comparison to be done byte by byte using numeric byte values rather than character by character. The BINARY operator also causes trailing spaces in comparisons to be significant. For information about the differences between the binary collation of the binary character set and the _bin collations of nonbinary character sets, see Section 10.8.5, “The binary Collation Compared to _bin Collations”.

```sql
mysql> SELECT 'a' = 'A';
-> 1
```

```sql
mysql> SELECT BINARY 'a' = 'A';
-> 0
```

```sql
mysql> SELECT 'a' = 'a ';
-> 1
```

```sql
mysql> SELECT BINARY 'a' = 'a ';
-> 0
```

In a comparison, BINARY affects the entire operation; it can be given before either operand with the same result.

To convert a string expression to a binary string, these constructs are equivalent:

```
BINARY expr
CAST(expr AS BINARY)
```
CAST Functions and Operators

CONVERT(expr USING BINARY)

If a value is a string literal, it can be designated as a binary string without performing any conversion by using the _binary character set introducer:

mysql> SELECT 'a' = 'A';
-> 1
mysql> SELECT _binary 'a' = 'A';
-> 0

For information about introducers, see Section 10.3.8, "Character Set Introducers".

The BINARY operator in expressions differs in effect from the BINARY attribute in character column definitions. A character column defined with the BINARY attribute is assigned the table default character set and the binary (_bin) collation of that character set. Every nonbinary character set has a _bin collation. For example, if the table default character set is utf8, these two column definitions are equivalent:

CHAR(10) BINARY
CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin

The use of CHARACTER SET binary in the definition of a CHAR, VARCHAR, or TEXT column causes the column to be treated as the corresponding binary string data type. For example, the following pairs of definitions are equivalent:

CHAR(10) CHARACTER SET binary
BINARY(10)

VARCHAR(10) CHARACTER SET binary
VARBINARY(10)

TEXT CHARACTER SET binary
BLOB

- CAST(expr AS type)

The CAST() function takes an expression of any type and produces a result value of the specified type, similar to CONVERT(). For more information, see the description of CONVERT().

CAST() is standard SQL syntax.

- CONVERT(expr,type), CONVERT(expr USING transcoding_name)

The CONVERT() function takes an expression of any type and produces a result value of the specified type.

Discussion of CONVERT(expr, type) syntax here also applies to CAST(expr AS type), which is equivalent.

CONVERT(... USING ...) is standard SQL syntax. The non-USING form of CONVERT() is ODBC syntax.

CONVERT() with USING converts data between different character sets. In MySQL, transcoding names are the same as the corresponding character set names. For example, this statement converts the string 'abc' in the default character set to the corresponding string in the utf8 character set:

SELECT CONVERT('abc' USING utf8);

CONVERT() without USING and CAST() take an expression and a type value specifying the result type. These type values are permitted:
• **BINARY**\([N]\)**

  Produces a string with the `BINARY` data type. For a description of how this affects comparisons, see Section 11.3.3, “The BINARY and VARBINARY Types”. If the optional length \(N\) is given, `BINARY(N)` causes the cast to use no more than \(N\) bytes of the argument. Values shorter than \(N\) bytes are padded with `0x00` bytes to a length of \(N\).

• **CHAR**\([N]\) [charset_info]

  Produces a string with the `CHAR` data type. If the optional length \(N\) is given, `CHAR(N)` causes the cast to use no more than \(N\) characters of the argument. No padding occurs for values shorter than \(N\) characters.

  With no `charset_info` clause, `CHAR` produces a string with the default character set. To specify the character set explicitly, these `charset_info` values are permitted:

  • **CHARACTER SET** charset_name: Produces a string with the given character set.
  
  • **ASCII**:: Shorthand for `CHARACTER SET latin1`.
  
  • **UNICODE**: Shorthand for `CHARACTER SET ucs2`.

  In all cases, the string has the character set default collation.

• **DATE**

  Produces a `DATE` value.

• **DATETIME**

  Produces a `DATETIME` value.

• **DECIMAL**\([M[,D]]\)**

  Produces a `DECIMAL` value. If the optional \(M\) and \(D\) values are given, they specify the maximum number of digits (the precision) and the number of digits following the decimal point (the scale).

• **NCHAR**\([N]\)**

  Like `CHAR`, but produces a string with the national character set. See Section 10.3.7, “The National Character Set”.

  Unlike `CHAR`, `NCHAR` does not permit trailing character set information to be specified.

• **SIGNED [INTEGER]**

  Produces a signed integer value.

• **TIME**

  Produces a `TIME` value.

• **UNSIGNED [INTEGER]**

  Produces an unsigned integer value.
12.11 XML Functions

Table 12.15 XML Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExtractValue()</td>
<td>Extract a value from an XML string using XPath notation</td>
</tr>
<tr>
<td>UpdateXML()</td>
<td>Return replaced XML fragment</td>
</tr>
</tbody>
</table>

This section discusses XML and related functionality in MySQL.

**Note**

It is possible to obtain XML-formatted output from MySQL in the `mysql` and `mysqldump` clients by invoking them with the `--xml` option. See Section 4.5.1, "mysql — The MySQL Command-Line Client", and Section 4.5.4, "mysqldump — A Database Backup Program".

Two functions providing basic XPath 1.0 (XML Path Language, version 1.0) capabilities are available. Some basic information about XPath syntax and usage is provided later in this section; however, an in-depth discussion of these topics is beyond the scope of this manual, and you should refer to the XML Path Language (XPath) 1.0 standard for definitive information. A useful resource for those new to XPath or who desire a refresher in the basics is the Zvon.org XPath Tutorial, which is available in several languages.

**Note**

These functions remain under development. We continue to improve these and other aspects of XML and XPath functionality in MySQL 5.5 and onwards. You may discuss these, ask questions about them, and obtain help from other users with them in the MySQL XML User Forum.

XPath expressions used with these functions support user variables and local stored program variables. User variables are weakly checked; variables local to stored programs are strongly checked (see also Bug #26518):

- **User variables (weak checking).** Variables using the syntax `$@variable_name` (that is, user variables) are not checked. No warnings or errors are issued by the server if a variable has the wrong type or has previously not been assigned a value. This also means the user is fully responsible for any typographical errors, since no warnings will be given if (for example) `$@myvariable` is used where `$@myvariable` was intended.

Example:

```
mysql> SET @xml = '<a><b>X</b><b>Y</b></a>';  
Query OK, 0 rows affected (0.00 sec)

mysql> SET @i =1, @j = 2;  
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @i, ExtractValue(@xml, '/b[$@i]');  
+-------+----------------------------------+
<table>
<thead>
<tr>
<th>@i</th>
<th>ExtractValue(@xml, '/b[$@i]')</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
</tr>
</tbody>
</table>
+-------+----------------------------------+

mysql> SELECT @j, ExtractValue(@xml,'/b[$@j]');  
+-------+----------------------------------+
<table>
<thead>
<tr>
<th>@j</th>
<th>ExtractValue(@xml,'/b[$@j]')</th>
</tr>
</thead>
</table>
```

1317
XML Functions

Variables in stored programs (strong checking). Variables using the syntax $\text{variable_name}$ can be declared and used with these functions when they are called inside stored programs. Such variables are local to the stored program in which they are defined, and are strongly checked for type and value.

Example:

```sql
mysql> CREATE PROCEDURE myproc ()
    -> BEGIN
    -> DECLARE i INT DEFAULT 1;
    -> DECLARE xml VARCHAR(25) DEFAULT '<a>X</a><a>Y</a><a>Z</a>';
    -> WHILE i < 4 DO
    ->     SELECT xml, i, ExtractValue(xml, '//a[$i]');
    ->     SET i = i+1;
    -> END WHILE;
    -> END |
Query OK, 0 rows affected (0.01 sec)
```

Parameters. Variables used in XPath expressions inside stored routines that are passed in as parameters are also subject to strong checking.

Expressions containing user variables or variables local to stored programs must otherwise (except for notation) conform to the rules for XPath expressions containing variables as given in the XPath 1.0 specification.
Note
A user variable used to store an XPath expression is treated as an empty string. Because of this, it is not possible to store an XPath expression as a user variable. (Bug #32911)

- ExtractValue(xml_frag, xpath_expr)

ExtractValue() takes two string arguments, a fragment of XML markup xml_frag and an XPath expression xpath_expr (also known as a locator); it returns the text (CDATA) of the first text node which is a child of the element or elements matched by the XPath expression. In MySQL 5.5, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

Using this function is the equivalent of performing a match using the xpath_expr after appending /text(). In other words, ExtractValue(''<a><b>Sakila</b></a>'', '/a/b') and ExtractValue(''<a><b>Sakila</b></a>'', '/a/b/text()') produce the same result.

If multiple matches are found, the content of the first child text node of each matching element is returned (in the order matched) as a single, space-delimited string.

If no matching text node is found for the expression (including the implicit /text())—for whatever reason, as long as xpath_expr is valid, and xml_frag consists of elements which are properly nested and closed—an empty string is returned. No distinction is made between a match on an empty element and no match at all. This is by design.

If you need to determine whether no matching element was found in xml_frag or such an element was found but contained no child text nodes, you should test the result of an expression that uses the XPath count() function. For example, both of these statements return an empty string, as shown here:

```
mysql> SELECT ExtractValue(''<a><b/></a>'', '/a/b');
+-------------------------------------+
| ExtractValue(''<a><b/></a>'', '/a/b') |
+-------------------------------------+
|                                     |
+-------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(''<a><c/></a>'', '/a/b');
+-------------------------------------+
| ExtractValue(''<a><c/></a>'', '/a/b') |
+-------------------------------------+
|                                     |
+-------------------------------------+
1 row in set (0.00 sec)
```

However, you can determine whether there was actually a matching element using the following:

```
mysql> SELECT ExtractValue(''<a><b/></a>'', 'count(/a/b)');
+---------------------------------+
| ExtractValue(''<a><b/></a>'', 'count(/a/b)') |
+---------------------------------+
| 1                               |
+---------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(''<a><c/></a>'', 'count(/a/b)');
+---------------------------------+
| ExtractValue(''<a><c/></a>'', 'count(/a/b)') |
+---------------------------------+
| 0                               |
+---------------------------------+
```
Important

`ExtractValue()` returns only CDATA, and does not return any tags that might be contained within a matching tag, nor any of their content (see the result returned as `val1` in the following example).

```sql
mysql> SELECT
  -> ExtractValue('<a>ccc<b>ddd</b></a>', '/a') AS val1,
  -> ExtractValue('<a>ccc<b>ddd</b></a>', '/a/b') AS val2,
  -> ExtractValue('<a>ccc<b>ddd</b></a>', '//b') AS val3,
  -> ExtractValue('<a>ccc<b>ddd</b><b>eee</b></a>', '//b') AS val4,
  -> ExtractValue('<a>ccc<b>ddd</b><b>eee</b></a>', '//b') AS val5;
+------+------+------+------+---------+
| val1 | val2 | val3 | val4 | val5    |
+------+------+------+------+---------+
| ccc  | ddd  | ddd  |      | ddd eee |
+------+------+------+------+---------+
```

This function uses the current SQL collation for making comparisons with `contains()`, performing the same collation aggregation as other string functions (such as `CONCAT()`), in taking into account the collation coercibility of their arguments; see Section 10.8.4, “Collation Coercibility in Expressions”, for an explanation of the rules governing this behavior.

(Previously, binary—that is, case-sensitive—comparison was always used.)

`NULL` is returned if `xml_frag` contains elements which are not properly nested or closed, and a warning is generated, as shown in this example:

```sql
mysql> SELECT ExtractValue('<a>c</a><b', '//a');
+-----------------------------------+
| ExtractValue('<a>c</a><b', '//a') |
+-----------------------------------+
| NULL                              |
+-----------------------------------+
1 row in set, 1 warning (0.00 sec)
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
  Code: 1525
  Message: Incorrect XML value: 'parse error at line 1 pos 11: END-OF-INPUT unexpected ('>' wanted')
1 row in set (0.00 sec)
mysql> SELECT ExtractValue('<a>c</a><b/>', '//a');
+-------------------------------------+
| ExtractValue('<a>c</a><b/>', '//a') |
+-------------------------------------+
| c                                   |
+-------------------------------------+
1 row in set (0.00 sec)
```

• `UpdateXML(xml_target, xpath_expr, new_xml)`

This function replaces a single portion of a given fragment of XML markup `xml_target` with a new XML fragment `new_xml`, and then returns the changed XML. The portion of `xml_target` that is replaced...
matches an XPath expression `xpath_expr` supplied by the user. In MySQL 5.5, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

If no expression matching `xpath_expr` is found, or if multiple matches are found, the function returns the original `xml_target` XML fragment. All three arguments should be strings.

```sql
mysql> SELECT UpdateXML('<a><b>ccc</b><d></d></a>', '/a', '<e>fff</e>') AS val1, UpdateXML('<a><b>ccc</b><d></d></a>', '/b', '<e>fff</e>') AS val2, UpdateXML('<a><b>ccc</b><d></d></a>', '//b', '<e>fff</e>') AS val3, UpdateXML('<a><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val4, UpdateXML('<a><d></d><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val5;

+----------+----------+----------+----------+----------+
|          |          |          |          |          |
| val1:    | <e>fff</e>|          |          |          |
| val2:    | <a><b>ccc</b><d></d></a> |          |          |          |
| val3:    | <a><e>fff</e><d></d></a> |          |          |          |
| val4:    | <a><b>ccc</b><e>fff</e></a> |          |          |          |
| val5:    | <a><d></d><b>ccc</b><d></d></a> |          |          |          |
+----------+----------+----------+----------+----------+
```

**Note**

A discussion in depth of XPath syntax and usage are beyond the scope of this manual. Please see the [XML Path Language (XPath) 1.0 specification](https://www.w3.org/TR/xpath10/) for definitive information. A useful resource for those new to XPath or who are wishing a refresher in the basics is the [Zvon.org XPath Tutorial](https://zvon.org/XPath/), which is available in several languages.

Descriptions and examples of some basic XPath expressions follow:

- `/tag`

  Matches `<tag/>` if and only if `<tag/>` is the root element.

  Example: `/a` has a match in `<a><b/></a>` because it matches the outermost (root) tag. It does not match the inner `<a>` element in `<b><a/></b>` because in this instance it is the child of another element.

- `/tag1/tag2`

  Matches `<tag2/>` if and only if it is a child of `<tag1/>`, and `<tag1/>` is the root element.

  Example: `/a/b` matches the `<b>` element in the XML fragment `<a><b/></a>` because it is a child of the root element `<a>`. It does not have a match in `<b><a/></b>` because in this case, `<b>` is the root element (and hence the child of no other element). Nor does the XPath expression have a match in `<a><c><b/></c></a>`; here, `<b>` is a descendant of `<a>`, but not actually a child of `<a>`.

  This construct is extendable to three or more elements. For example, the XPath expression `/a/b/c` matches the `<c>` element in the fragment `<a><b><c/></b></a>`.

- `//tag`

  Matches any instance of `<tag/>`.

  Example: `//a` matches the `<a>` element in any of the following: `<a><b><c/></b></a>`; `<a><b/></a>`; `<c><a><b/></a></c>`; `<c><b><a/></b></c>`.

  `//` can be combined with `/`. For example, `//a/b` matches the `<b>` element in either of the fragments `<a><b/></a>` or `<c><a><b/></a></c>`.
Note

//tag is the equivalent of /descendant-or-self::*/tag. A common error is to confuse this with /descendant-or-self::tag, although the latter expression can actually lead to very different results, as can be seen here:

```sql
mysql> SET @xml = '<a><b><c>w</c><b>x</b><d>y</d>z</b></a>);
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT @xml;
+-----------------------------------------+
| @xml                                    |
+-----------------------------------------+
| <a><b><c>w</c><b>x</b><d>y</d>z</b></a> |
+-----------------------------------------+
1 row in set (0.00 sec)
mysql> SELECT ExtractValue(@xml, '//b[1]');
+------------------------------+
| ExtractValue(@xml, '//b[1]') |
| x z                          |
+------------------------------+
1 row in set (0.00 sec)
mysql> SELECT ExtractValue(@xml, '//b[2]');
+------------------------------+
| ExtractValue(@xml, '//b[2]') |
|                              |
+------------------------------+
1 row in set (0.01 sec)
mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[1]');
+---------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[1]') |
| x z                                               |
+---------------------------------------------------+
1 row in set (0.06 sec)
mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[2]');
+---------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[2]') |
|                                                   |
+---------------------------------------------------+
1 row in set (0.00 sec)
mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[1]');
+-------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[1]') |
| z                                               |
+-------------------------------------------------+
1 row in set (0.00 sec)
mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[2]');
+-------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[2]') |
| x                                               |
+-------------------------------------------------+
1 row in set (0.00 sec)
```
• The * operator acts as a “wildcard” that matches any element. For example, the expression /*/b matches the b element in either of the XML fragments <a><b/></a> or <c><b/></c>. However, the expression does not produce a match in the fragment <b><a/></b> because b must be a child of some other element. The wildcard may be used in any position: The expression */b/* will match any child of a b element that is itself not the root element.

• You can match any of several locators using the | (UNION) operator. For example, the expression //b|//c matches all b and c elements in the XML target.

• It is also possible to match an element based on the value of one or more of its attributes. This done using the syntax tag[@attribute="value"]. For example, the expression //b[@id="idB"] matches the second b element in the fragment <a><b id="idA"/></a><c/><b id="idB"/></a>. To match against any element having attribute="value", use the XPath expression //*[attribute="value"].

To filter multiple attribute values, simply use multiple attribute-comparison clauses in succession. For example, the expression //b[@c="x"][@d="y"] matches the element <b c="x" d="y"/> occurring anywhere in a given XML fragment.

To find elements for which the same attribute matches any of several values, you can use multiple locators joined by the | operator. For example, to match all b elements whose c attributes have either of the values 23 or 17, use the expression //b[@c="23"]|//b[@c="17"]). You can also use the logical or operator for this purpose: //b[@c="23" or @c="17"]).

Note
The difference between or and | is that or joins conditions, while | joins result sets.

XPath Limitations. The XPath syntax supported by these functions is currently subject to the following limitations:

• Nodeset-to-nodeset comparison (such as 'a/b[@c=@d]') is not supported.

• All of the standard XPath comparison operators are supported. (Bug #22823)

• Relative locator expressions are resolved in the context of the root node. For example, consider the following query and result:

```sql
mysql> SELECT ExtractValue(
    >    '<a><b c="1">X</b><b c="2">Y</b></a>',
    >    'a/b'
    > ) AS result;
+--------+
| result |
+--------+
| X Y    |
+--------+
1 row in set (0.03 sec)
```

In this case, the locator a/b resolves to /a/b.

Relative locators are also supported within predicates. In the following example, d[../@c="1"] is resolved as /a/b[@c="1"]/d:

```sql
mysql> SELECT ExtractValue(
    >    '<a>
    >    <b c="1">d<X</b></b>
    >    <b c="2">d<X</b></b>
    >    </a>',
    >    'a/b[@c="1"]/d'
    > ) AS result;
+--------+
| result |
+--------+
| X Y    |
+--------+
1 row in set (0.03 sec)
```
• Locators prefixed with expressions that evaluate as scalar values—including variable references, literals, numbers, and scalar function calls—are not permitted, and their use results in an error.

• The :: operator is not supported in combination with node types such as the following:
  • axis::comment()
  • axis::text()
  • axis::processing-instructions()
  • axis::node()

However, name tests (such as axis::name and axis::* ) are supported, as shown in these examples:

mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b');
+-------------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b') |
| x                                                     |
+-------------------------------------------------------+
1 row in set (0.02 sec)

mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*');
+-------------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*') |
| x y                                                   |
+-------------------------------------------------------+
1 row in set (0.01 sec)

• “Up-and-down” navigation is not supported in cases where the path would lead “above” the root element. That is, you cannot use expressions which match on descendants of ancestors of a given element, where one or more of the ancestors of the current element is also an ancestor of the root element (see Bug #16321).

• The following XPath functions are not supported, or have known issues as indicated:
  • id()
  • lang()
  • local-name()
  • name()
  • namespace-uri()
  • normalize-space()
  • starts-with()
  • string()
• substring-after()
• substring-before()
• translate()

• The following axes are not supported:
  • following-sibling
  • following
  • preceding-sibling
  • preceding

XPath expressions passed as arguments to ExtractValue() and UpdateXML() may contain the colon character (:) in element selectors, which enables their use with markup employing XML namespaces notation. For example:

```sql
mysql> SET @xml = '<a>111<b:c>222<d>333</d><e:f>444</e:f></b:c></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT ExtractValue(@xml, '//e:f');
  +-----------------------------+
  | ExtractValue(@xml, '//e:f') |
  | 444                         |
  +-----------------------------+
1 row in set (0.00 sec)

mysql> SELECT UpdateXML(@xml, '//b:c', '<g:h>555</g:h>');
  +--------------------------------------------+
  | UpdateXML(@xml, '//b:c', '<g:h>555</g:h>') |
  | <a>111<g:h>555</g:h></a>                  |
  +--------------------------------------------+
1 row in set (0.00 sec)
```

This is similar in some respects to what is permitted by Apache Xalan and some other parsers, and is much simpler than requiring namespace declarations or the use of the namespace-uri() and local-name() functions.

Error handling. For both ExtractValue() and UpdateXML(), the XPath locator used must be valid and the XML to be searched must consist of elements which are properly nested and closed. If the locator is invalid, an error is generated:

```sql
mysql> SELECT ExtractValue('<a>c</a><b/>', '/&a');
ERROR 1105 (HY000): XPATH syntax error: '&a'
```

If xml_frag does not consist of elements which are properly nested and closed, NULL is returned and a warning is generated, as shown in this example:

```sql
mysql> SELECT ExtractValue('<a>c</a><b>', '//a');
```

If xml_frag does not consist of elements which are properly nested and closed, NULL is returned and a warning is generated, as shown in this example:
Important

The replacement XML used as the third argument to `UpdateXML()` is not checked to determine whether it consists solely of elements which are properly nested and closed.

**XPath Injection.** *Code injection* occurs when malicious code is introduced into the system to gain unauthorized access to privileges and data. It is based on exploiting assumptions made by developers about the type and content of data input from users. XPath is no exception in this regard.

A common scenario in which this can happen is the case of application which handles authorization by matching the combination of a login name and password with those found in an XML file, using an XPath expression like this one:

```
//user[login/text()='neapolitan' and password/text()='1c3cr34m']/attribute::id
```

This is the XPath equivalent of an SQL statement like this one:

```
SELECT id FROM users WHERE login='neapolitan' AND password='1c3cr34m';
```

A PHP application employing XPath might handle the login process like this:

```php
<?php
$file     =   "users.xml";
$login    =   $POST["login"];
$password =   $POST["password"];
$xpath = "//user[login/text()="$login" and password/text()="$password"]/attribute::id";
if( file_exists($file) )
{
    $xml = simplexml_load_file($file);
    if($result = $xml->xpath($xpath))
        echo "You are now logged in as user $result[0].";
    else
        echo "Invalid login name or password.";
}else
    exit("Failed to open $file.");
?>
```

No checks are performed on the input. This means that a malevolent user can "short-circuit" the test by entering ' or 1=1 for both the login name and password, resulting in `$xpath` being evaluated as shown here:

```
//user[login/text()=' or 1=1 and password/text()=' or 1=1]/attribute::id
```
Since the expression inside the square brackets always evaluates as `true`, it is effectively the same as this one, which matches the `id` attribute of every `user` element in the XML document:

```
//user/attribute::id
```

One way in which this particular attack can be circumvented is simply by quoting the variable names to be interpolated in the definition of `$xpath`, forcing the values passed from a Web form to be converted to strings:

```
zego = "//user[login/text()='$login' and password/text()='$password']/attribute::id";
```

This is the same strategy that is often recommended for preventing SQL injection attacks. In general, the practices you should follow for preventing XPath injection attacks are the same as for preventing SQL injection:

- Never accepted untested data from users in your application.
- Check all user-submitted data for type; reject or convert data that is of the wrong type.
- Test numeric data for out of range values; truncate, round, or reject values that are out of range. Test strings for illegal characters and either strip them out or reject input containing them.
- Do not output explicit error messages that might provide an unauthorized user with clues that could be used to compromise the system; log these to a file or database table instead.

Just as SQL injection attacks can be used to obtain information about database schemas, so can XPath injection be used to traverse XML files to uncover their structure, as discussed in Amit Klein's paper **Blind XPath Injection** (PDF file, 46KB).

It is also important to check the output being sent back to the client. Consider what can happen when we use the MySQL `ExtractValue()` function:

```
mysql> SELECT ExtractValue(
  ->  LOAD_FILE('users.xml'),
  ->  '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
  ->  AS id;
+-------------------------------+
| id                            |
+-------------------------------+
| 00327 13579 02403 42354 28570 |
+-------------------------------+
1 row in set (0.01 sec)
```

Because `ExtractValue()` returns multiple matches as a single space-delimited string, this injection attack provides every valid ID contained within `users.xml` to the user as a single row of output. As an extra safeguard, you should also test output before returning it to the user. Here is a simple example:

```
mysql> SELECT @id = ExtractValue(
  ->  LOAD_FILE('users.xml'),
  ->  '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
  ->  AS id;
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SELECT IF(  
  ->  INSTR(@id, ' ') = 0,  
  ->  @id,  
  ->  'Unable to retrieve user ID')  
  ->  AS singleID;
+----------------------------+
| singleID                   |
+----------------------------+
| Unable to retrieve user ID |
+----------------------------+
1 row in set (0.00 sec)
```
In general, the guidelines for returning data to users securely are the same as for accepting user input. These can be summed up as:

- Always test outgoing data for type and permissible values.
- Never permit unauthorized users to view error messages that might provide information about the application that could be used to exploit it.

## 12.12 Bit Functions and Operators

### Table 12.16 Bit Functions and Operators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;</td>
<td>Bitwise AND</td>
</tr>
<tr>
<td>&gt;&gt;</td>
<td>Right shift</td>
</tr>
<tr>
<td>&lt;&lt;</td>
<td>Left shift</td>
</tr>
<tr>
<td>^</td>
<td>Bitwise XOR</td>
</tr>
<tr>
<td>BIT_COUNT()</td>
<td>Return the number of bits that are set</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>~</td>
<td>Bitwise inversion</td>
</tr>
</tbody>
</table>

Bit functions and operators comprise `BIT_COUNT()`, `BIT_AND()`, `BIT_OR()`, `BIT_XOR()`, `&`, `|`, `^`, `~`, `<<`, and `>>`. `BIT_AND()`, `BIT_OR()`, and `BIT_XOR()` are aggregate functions described at Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions.” Bit functions and operators require `BIGINT` (64-bit integer) arguments and return `BIGINT` values, so they have a maximum range of 64 bits. Arguments of other types (such as the `BINARY` and `VARBINARY` binary string types) are converted to `BIGINT` and truncation might occur.

The following list describes available bit functions and operators:

- |  
  Bitwise OR.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 29 | 15;
  -> 31
  ```

- &  
  Bitwise AND.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 29 & 15;
  -> 13
  ```

- ^  
  Bitwise XOR.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 1 ^ 1;
  -> 0
  ```
Encryption and Compression Functions

12.13 Encryption and Compression Functions

Table 12.17 Encryption Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES_DECRYPT()</td>
<td>Decrypt using AES</td>
</tr>
<tr>
<td>AES_ENCRYPT()</td>
<td>Encrypt using AES</td>
</tr>
<tr>
<td>COMPRESS()</td>
<td>Return result as a binary string</td>
</tr>
<tr>
<td>DECODE()</td>
<td>Decode a string encrypted using ENCODE()</td>
</tr>
<tr>
<td>DES_DECRYPT()</td>
<td>Decrypt a string</td>
</tr>
<tr>
<td>DES_ENCRYPT()</td>
<td>Encrypt a string</td>
</tr>
<tr>
<td>ENCODE()</td>
<td>Encode a string</td>
</tr>
<tr>
<td>ENCRYPT()</td>
<td>Encrypt a string</td>
</tr>
<tr>
<td>MD5()</td>
<td>Calculate MD5 checksum</td>
</tr>
</tbody>
</table>
Encryption and Compression Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLD_PASSWORD()</td>
<td>Return the value of the pre-4.1 implementation of PASSWORD</td>
</tr>
<tr>
<td>PASSWORD()</td>
<td>Calculate and return a password string</td>
</tr>
<tr>
<td>SHA1(), SHA()</td>
<td>Calculate an SHA-1 160-bit checksum</td>
</tr>
<tr>
<td>SHA2()</td>
<td>Calculate an SHA-2 checksum</td>
</tr>
<tr>
<td>UNCOMPRESS()</td>
<td>Uncompress a string compressed</td>
</tr>
<tr>
<td>UNCOMPRESSED_LENGTH()</td>
<td>Return the length of a string before compression</td>
</tr>
</tbody>
</table>

Many encryption and compression functions return strings for which the result might contain arbitrary byte values. If you want to store these results, use a column with a `VARBINARY` or `BLOB` binary string data type. This will avoid potential problems with trailing space removal or character set conversion that would change data values, such as may occur if you use a nonbinary string data type (`CHAR`, `VARCHAR`, `TEXT`).

Some encryption functions return strings of ASCII characters: `MD5()`, `OLD_PASSWORD()`, `PASSWORD()`, `SHA()`, `SHA1()`. Their return value is a string that has a character set and collation determined by the `character_set_connection` and `collation_connection` system variables. This is a nonbinary string unless the character set is `binary`.

If an application stores values from a function such as `MD5()` or `SHA1()` that returns a string of hex digits, more efficient storage and comparisons can be obtained by converting the hex representation to binary using `UNHEX()` and storing the result in a `BINARY(N)` column. Each pair of hexadecimal digits requires one byte in binary form, so the value of `N` depends on the length of the hex string. `N` is 16 for an `MD5()` value and 20 for a `SHA1()` value. For `SHA2()`, `N` ranges from 28 to 32 depending on the argument specifying the desired bit length of the result.

The size penalty for storing the hex string in a `CHAR` column is at least two times, up to eight times if the value is stored in a column that uses the `utf8` character set (where each character uses 4 bytes). Storing the string also results in slower comparisons because of the larger values and the need to take character set collation rules into account.

Suppose that an application stores `MD5()` string values in a `CHAR(32)` column:

```sql
CREATE TABLE md5_tbl (md5_val CHAR(32), ...);
INSERT INTO md5_tbl (md5_val, ...) VALUES(MD5('abcdef'), ...);
```

To convert hex strings to more compact form, modify the application to use `UNHEX()` and `BINARY(16)` instead as follows:

```sql
CREATE TABLE md5_tbl (md5_val BINARY(16), ...);
INSERT INTO md5_tbl (md5_val, ...) VALUES(UNHEX(MD5('abcdef')), ...);
```

Applications should be prepared to handle the very rare case that a hashing function produces the same value for two different input values. One way to make collisions detectable is to make the hash column a primary key.

**Note**

Exploits for the MD5 and SHA-1 algorithms have become known. You may wish to consider using another one-way encryption function described in this section instead, such as `SHA2()`.

**Caution**

Passwords or other sensitive values supplied as arguments to encryption functions are sent as cleartext to the MySQL server unless an SSL connection is used. Also, such values will appear in any MySQL logs to which they are written. To avoid
these types of exposure, applications can encrypt sensitive values on the client side before sending them to the server. The same considerations apply to encryption keys. To avoid exposing these, applications can use stored procedures to encrypt and decrypt values on the server side.

- **AES_DECRYPT(crypt_str, key_str)**
  This function decrypts data using the official AES (Advanced Encryption Standard) algorithm. For more information, see the description of AES_ENCRYPT().

- **AES_ENCRYPT(str, key_str)**
  AES_ENCRYPT() and AES_DECRYPT() implement encryption and decryption of data using the official AES (Advanced Encryption Standard) algorithm, previously known as “Rijndael.” The AES standard permits various key lengths. These functions implement AES with a 128-bit key length, but you can extend them to 256 bits by modifying the source. The key length is a trade off between performance and security.

  AES_ENCRYPT() encrypts the string \( str \) using the key string \( key\_str \) and returns a binary string containing the encrypted output. AES_DECRYPT() decrypts the encrypted string \( crypt\_str \) using the key string \( key\_str \) and returns the original plaintext string. If either function argument is NULL, the function returns NULL.

  The \( str \) and \( crypt\_str \) arguments can be any length, and padding is automatically added to \( str \) so it is a multiple of a block as required by block-based algorithms such as AES. This padding is automatically removed by the AES_DECRYPT() function. The length of \( crypt\_str \) can be calculated using this formula:

  \[
  16 \times (\text{trunc}(\text{string\_length} / 16) + 1)
  \]

  For a key length of 128 bits, the most secure way to pass a key to the \( key\_str \) argument is to create a truly random 128-bit value and pass it as a binary value. For example:

  ```sql
  INSERT INTO t
  VALUES (1, AES_ENCRYPT('text', UNHEX('F3229A0B371ED2D9441B830D21A390C3')));
  ```

  A passphrase can be used to generate an AES key by hashing the passphrase. For example:

  ```sql
  INSERT INTO t
  VALUES (1, AES_ENCRYPT('text', UNHEX(SHA2('My secret passphrase', 512))));
  ```

  Do not pass a password or passphrase directly to \( crypt\_str \), hash it first. Previous versions of this documentation suggested the former approach, but it is no longer recommended as the examples shown here are more secure.

  If AES_DECRYPT() detects invalid data or incorrect padding, it returns NULL. However, it is possible for AES_DECRYPT() to return a non-NUL value (possibly garbage) if the input data or the key is invalid.

- **COMPRESS(string_to_compress)**
  Compresses a string and returns the result as a binary string. This function requires MySQL to have been compiled with a compression library such as zlib. Otherwise, the return value is always NULL. The compressed string can be uncompressed with UNCOMPRESS().

  ```sql
  mysql> SELECT LENGTH(COMPRESS(REPEAT('a', 1000))); -> 21
  mysql> SELECT LENGTH(COMPRESS('')); -> 0
  mysql> SELECT LENGTH(COMPRESS('a'));
  ```
Encryption and Compression Functions

mysql> SELECT LENGTH(COMPRESS(REPEAT('a',16)));
-> 15

The compressed string contents are stored the following way:

- Empty strings are stored as empty strings.
- Nonempty strings are stored as a 4-byte length of the uncompressed string (low byte first), followed by the compressed string. If the string ends with space, an extra . character is added to avoid problems with endspace trimming should the result be stored in a CHAR or VARCHAR column. (However, use of nonbinary string data types such as CHAR or VARCHAR to store compressed strings is not recommended anyway because character set conversion may occur. Use a VARBINARY or BLOB binary string column instead.)

- `DECODE(crypt_str, pass_str)`
  Decrypts the encrypted string `crypt_str` using `pass_str` as the password. `crypt_str` should be a string returned from `ENCODE()`.

- `DES_DECRYPT(crypt_str[, key_str])`
  Decrypts a string encrypted with `DES_ENCRYPT()`. If an error occurs, this function returns NULL.
  This function works only if MySQL has been configured with SSL support. See Section 6.3, "Using Encrypted Connections".
  If no `key_str` argument is given, `DES_DECRYPT()` examines the first byte of the encrypted string to determine the DES key number that was used to encrypt the original string, and then reads the key from the DES key file to decrypt the message. For this to work, the user must have the SUPER privilege. The key file can be specified with the `--des-key-file` server option.
  If you pass this function a `key_str` argument, that string is used as the key for decrypting the message.
  If the `crypt_str` argument does not appear to be an encrypted string, MySQL returns the given `crypt_str`.

- `DES_ENCRYPT(str[, {key_num|key_str}])`
  Encrypts the string with the given key using the Triple-DES algorithm.
  This function works only if MySQL has been configured with SSL support. See Section 6.3, "Using Encrypted Connections".
  The encryption key to use is chosen based on the second argument to `DES_ENCRYPT()`, if one was given. With no argument, the first key from the DES key file is used. With a `key_num` argument, the given key number (0 to 9) from the DES key file is used. With a `key_str` argument, the given key string is used to encrypt `str`.
  The key file can be specified with the `--des-key-file` server option.
  The return string is a binary string where the first character is `CHAR(128 | key_num)`. If an error occurs, `DES_ENCRYPT()` returns NULL.
  The 128 is added to make it easier to recognize an encrypted key. If you use a string key, `key_num` is 127.
  The string length for the result is given by this formula:
Encryption and Compression Functions

new_len = orig_len + (8 - (orig_len % 8)) + 1

Each line in the DES key file has the following format:

key_num des_key_str

Each key_num value must be a number in the range from 0 to 9. Lines in the file may be in any order. des_key_str is the string that is used to encrypt the message. There should be at least one space between the number and the key. The first key is the default key that is used if you do not specify any key argument to DES_ENCRYPT().

You can tell MySQL to read new key values from the key file with the FLUSH DES_KEY_FILE statement. This requires the RELOAD privilege.

One benefit of having a set of default keys is that it gives applications a way to check for the existence of encrypted column values, without giving the end user the right to decrypt those values.

mysql> SELECT customer_address FROM customer_table > WHERE crypted_credit_card = DES_ENCRYPT('credit_card_number');

• ENCODE(str, pass_str)

Encrypt str using pass_str as the password. The result is a binary string of the same length as str. To decrypt the result, use DECODE().

The ENCODE() function should no longer be used. If you still need to use ENCODE(), a salt value must be used with it to reduce risk. For example:

ENCODE('cleartext', CONCAT('my_random_salt','my_secret_password'))

A new random salt value must be used whenever a password is updated.

• ENCRYPT(str[, salt])

Encrypts str using the Unix crypt() system call and returns a binary string. The salt argument must be a string with at least two characters or the result will be NULL. If no salt argument is given, a random value is used.

mysql> SELECT ENCRYPT('hello');
-> 'VxuFAJXVARROc'

ENCRYPT() ignores all but the first eight characters of str, at least on some systems. This behavior is determined by the implementation of the underlying crypt() system call.

The use of ENCRYPT() with the ucs2, utf16, or utf32 multibyte character sets is not recommended because the system call expects a string terminated by a zero byte.

If crypt() is not available on your system (as is the case with Windows), ENCRYPT() always returns NULL.
• **MD5(str)**

Calculates an MD5 128-bit checksum for the string. The value is returned as a string of 32 hexadecimal digits, or **NULL** if the argument was **NULL**. The return value can, for example, be used as a hash key. See the notes at the beginning of this section about storing hash values efficiently.

The return value is a string in the connection character set.

```sql
mysql> SELECT MD5('testing');
-> 'ae2b1fca513949e5d54fb22b8ed95575'
```

This is the “RSA Data Security, Inc. MD5 Message-Digest Algorithm.”

See the note regarding the MD5 algorithm at the beginning this section.

• **OLD_PASSWORD(str)**

`OLD_PASSWORD()` was added when the implementation of `PASSWORD()` was changed in MySQL 4.1 to improve security. `OLD_PASSWORD()` returns the value of the pre-4.1 implementation of `PASSWORD()` as a string, and is intended to permit you to reset passwords for any pre-4.1 clients that need to connect to your MySQL server without locking them out. See Section 6.1.2.4, “Password Hashing in MySQL.”

The return value is a string in the connection character set.

![Note](image)

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

• **PASSWORD(str)**

Returns a hashed password string calculated from the cleartext password `str`. The return value is a string in the connection character set, or **NULL** if the argument is **NULL**. This function is the SQL interface to the algorithm used by the server to encrypt MySQL passwords for storage in the `mysql.user` grant table.

The `old_passwords` system variable controls the password hashing method used by the `PASSWORD()` function. It also influences password hashing performed by `CREATE USER` and `GRANT` statements that specify a password using an `IDENTIFIED BY` clause.

The following table shows, for each password hashing method, the permitted value of `old_passwords` and which authentication plugins use the hashing method.

<table>
<thead>
<tr>
<th>Password Hashing Method</th>
<th>old_passwords Value</th>
<th>Associated Authentication Plugin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MySQL 4.1 native hashing</td>
<td>0 or OFF</td>
<td><code>mysql_native_password</code></td>
</tr>
<tr>
<td>Pre-4.1 (“old”) hashing</td>
<td>1 or ON</td>
<td><code>mysql_old_password</code></td>
</tr>
</tbody>
</table>

If `old_passwords=1`, `PASSWORD(str)` returns the same value as `OLD_PASSWORD(str)`. The latter function is not affected by the value of `old_passwords`.

```sql
mysql> SET old_passwords = 0;
mysql> SELECT PASSWORD('mypass'), OLD_PASSWORD('mypass');
+-------------------------------------------+---------------------+
| PASSWORD('mypass')                        | OLD_PASSWORD('mypass') |
| *6C8989366EAP75BB670AD8EA7A7FC1176A95CEF4 | 6f8c114b58f2ce9e       |
```
Encryption performed by `PASSWORD()` is one-way (not reversible). It is not the same type of encryption as used for Unix passwords; for that, use `ENCRYPT()`.

**Note**

`PASSWORD()` is used by the authentication system in MySQL Server; you should not use it in your own applications. For that purpose, consider a more secure function such as `AES_ENCRYPT()` or `SHA2()` instead. Also see RFC 2195, section 2 (Challenge-Response Authentication Mechanism (CRAM)), for more information about handling passwords and authentication securely in your applications.

**Note**

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

**Caution**

Statements that invoke `PASSWORD()` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Client Logging”.

• **SHA1**(str), **SHA**(str)

Calculates an SHA-1 160-bit checksum for the string, as described in RFC 3174 (Secure Hash Algorithm). The value is returned as a string of 40 hexadecimal digits, or `NULL` if the argument was `NULL`. One of the possible uses for this function is as a hash key. See the notes at the beginning of this section about storing hash values efficiently. `SHA()` is synonymous with `SHA1()`.

The return value is a string in the connection character set.

```sql
mysql> SELECT SHA1('abc');
-> 'a9993e364706816aba3e25717850c26c9cd0d89d'
```

`SHA1()` can be considered a cryptographically more secure equivalent of `MD5()`. However, see the note regarding the MD5 and SHA-1 algorithms at the beginning this section.

• **SHA2**(str, hash_length)

Calculates the SHA-2 family of hash functions (SHA-224, SHA-256, SHA-384, and SHA-512). The first argument is the plaintext string to be hashed. The second argument indicates the desired bit length of the result, which must have a value of 224, 256, 384, 512, or 0 (which is equivalent to 256). If either argument is `NULL` or the hash length is not one of the permitted values, the return value is `NULL`.

1335
Otherwise, the function result is a hash value containing the desired number of bits. See the notes at the beginning of this section about storing hash values efficiently.

The return value is a string in the connection character set.

```sql
mysql> SELECT SHA2('abc', 224);
-> '23097d223405d8228642a477bda255b32aadbe4bda0b3f7e36c9da7'
```

This function works only if MySQL has been configured with SSL support. See Section 6.3, “Using Encrypted Connections”.

SHA2() can be considered cryptographically more secure than MD5() or SHA1().

- **UNCOMPRESS**(string_to_uncompress)

Uncompresses a string compressed by the COMPRESS() function. If the argument is not a compressed value, the result is NULL. This function requires MySQL to have been compiled with a compression library such as zlib. Otherwise, the return value is always NULL.

```sql
mysql> SELECT UNCOMPRESS(COMPRESS('any string'));
-> 'any string'
mymysql> SELECT UNCOMPRESS('any string');
-> NULL
```

- **UNCOMPRESSED_LENGTH**(compressed_string)

Returns the length that the compressed string had before being compressed.

```sql
mysql> SELECT UNCOMPRESSED_LENGTH(COMPRESS(REPEAT('a',30)));
-> 30
```

### 12.14 Locking Functions

This section describes functions used to manipulate user-level locks.

**Table 12.18 Locking Functions**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET_LOCK()</td>
<td>Get a named lock</td>
</tr>
<tr>
<td>IS_FREE_LOCK()</td>
<td>Whether the named lock is free</td>
</tr>
<tr>
<td>IS_USED_LOCK()</td>
<td>Whether the named lock is in use; return connection identifier if true</td>
</tr>
<tr>
<td>RELEASE_LOCK()</td>
<td>Release the named lock</td>
</tr>
</tbody>
</table>

**GET_LOCK(str, timeout)**

Tries to obtain a lock with a name given by the string `str`, using a timeout of `timeout` seconds. A negative `timeout` value means infinite timeout.

Returns 1 if the lock was obtained successfully, 0 if the attempt timed out (for example, because another client has previously locked the name), or NULL if an error occurred (such as running out of memory or the thread was killed with `mysqladmin kill`).

A lock obtained with GET_LOCK() is released explicitly by executing RELEASE_LOCK() or implicitly when your session terminates (either normally or abnormally). Locks obtained with GET_LOCK() are not released when transactions commit or roll back.
Important

The behavior of `GET_LOCK()` changes in MySQL 5.7. In consideration of future upgrades, limit the `str` value to 64 characters or less and do not rely on subsequent calls to `GET_LOCK()` releasing previous locks.

`GET_LOCK()` can be used to implement application locks or to simulate record locks. Names are locked on a server-wide basis. If a name has been locked within one session, `GET_LOCK()` blocks any request by another session for a lock with the same name. This enables clients that agree on a given lock name to use the name to perform cooperative advisory locking. But be aware that it also enables a client that is not among the set of cooperating clients to lock a name, either inadvertently or deliberately, and thus prevent any of the cooperating clients from locking that name. One way to reduce the likelihood of this is to use lock names that are database-specific or application-specific. For example, use lock names of the form `db_name.str` or `app_name.str`.

```sql
mysql> SELECT GET_LOCK('lock1',10);
  -> 1

mysql> SELECT IS_FREE_LOCK('lock2');
  -> 1

mysql> SELECT GET_LOCK('lock2',10);
  -> 1

mysql> SELECT RELEASE_LOCK('lock2');
  -> 1

mysql> SELECT RELEASE_LOCK('lock1');
  -> NULL
```

The second `RELEASE_LOCK()` call returns `NULL` because the lock `lock1` was automatically released by the second `GET_LOCK()` call.

If multiple clients are waiting for a lock, the order in which they will acquire it is undefined. Applications should not assume that clients will acquire the lock in the same order that they issued the lock requests.

`GET_LOCK()` is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

- **IS_FREE_LOCK(str)**

  Checks whether the lock named `str` is free to use (that is, not locked). Returns `1` if the lock is free (no one is using the lock), `0` if the lock is in use, and `NULL` if an error occurs (such as an incorrect argument).

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

- **IS_USED_LOCK(str)**

  Checks whether the lock named `str` is in use (that is, locked). If so, it returns the connection identifier of the client session that holds the lock. Otherwise, it returns `NULL`.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

- **RELEASE_LOCK(str)**

  Releases the lock named by the string `str` that was obtained with `GET_LOCK()`. Returns `1` if the lock was released, `0` if the lock was not established by this thread (in which case the lock is not released),
and NULL if the named lock did not exist. The lock does not exist if it was never obtained by a call to GET_LOCK() or if it has previously been released.

The do statement is convenient to use with RELEASE_LOCK(). See Section 13.2.3, “DO Statement”.

This function is unsafe for statement-based replication. A warning is logged if you use this function when binlog_format is set to STATEMENT.

12.15 Information Functions

Table 12.19 Information Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BENCHMARK()</td>
<td>Repeatedly execute an expression</td>
</tr>
<tr>
<td>CHARSET()</td>
<td>Return the character set of the argument</td>
</tr>
<tr>
<td>COERCIBILITY()</td>
<td>Return the collation coercibility value of the string argument</td>
</tr>
<tr>
<td>COLLATION()</td>
<td>Return the collation of the string argument</td>
</tr>
<tr>
<td>CONNECTION_ID()</td>
<td>Return the connection ID (thread ID) for the connection</td>
</tr>
<tr>
<td>CURRENT_USER(), CURRENT_USER</td>
<td>The authenticated user name and host name</td>
</tr>
<tr>
<td>DATABASE()</td>
<td>Return the default (current) database name</td>
</tr>
<tr>
<td>FOUND_ROWS()</td>
<td>For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause</td>
</tr>
<tr>
<td>LAST_INSERT_ID()</td>
<td>Value of the AUTOINCREMENT column for the last INSERT</td>
</tr>
<tr>
<td>ROW_COUNT()</td>
<td>The number of rows updated</td>
</tr>
<tr>
<td>SCHEMA()</td>
<td>Synonym for DATABASE()</td>
</tr>
<tr>
<td>SESSION_USER()</td>
<td>Synonym for USER()</td>
</tr>
<tr>
<td>SYSTEM_USER()</td>
<td>Synonym for USER()</td>
</tr>
<tr>
<td>USER()</td>
<td>The user name and host name provided by the client</td>
</tr>
<tr>
<td>VERSION()</td>
<td>Return a string that indicates the MySQL server version</td>
</tr>
</tbody>
</table>

- **BENCHMARK**(count, expr)

The BENCHMARK() function executes the expression expr repeatedly count times. It may be used to time how quickly MySQL processes the expression. The result value is 0, or NULL for inappropriate arguments such as a NULL or negative repeat count.

The intended use is from within the mysql client, which reports query execution times:

```
mysql> SELECT BENCHMARK(1000000,AES_ENCRYPT('hello','goodbye'));
+---------------------------------------------------+
| BENCHMARK(1000000,AES_ENCRYPT('hello','goodbye')) |
+---------------------------------------------------+
|                                                 0 |
+---------------------------------------------------+
1 row in set (4.74 sec)
```

The time reported is elapsed time on the client end, not CPU time on the server end. It is advisable to execute BENCHMARK() several times, and to interpret the result with regard to how heavily loaded the server machine is.
Information Functions

**BENCHMARK()** is intended for measuring the runtime performance of scalar expressions, which has some significant implications for the way that you use it and interpret the results:

- Only scalar expressions can be used. Although the expression can be a subquery, it must return a single column and at most a single row. For example, `BENCHMARK(10, (SELECT * FROM t))` will fail if the table `t` has more than one column or more than one row.

- Executing a `SELECT expr` statement `N` times differs from executing `SELECT BENCHMARK(N, expr)` in terms of the amount of overhead involved. The two have very different execution profiles and you should not expect them to take the same amount of time. The former involves the parser, optimizer, table locking, and runtime evaluation `N` times each. The latter involves only runtime evaluation `N` times, and all the other components just once. Memory structures already allocated are reused, and runtime optimizations such as local caching of results already evaluated for aggregate functions can alter the results. Use of `BENCHMARK()` thus measures performance of the runtime component by giving more weight to that component and removing the "noise" introduced by the network, parser, optimizer, and so forth.

- **CHARSET(str)**

  Returns the character set of the string argument.

  mysql> SELECT CHARSET('abc');
  -> 'latin1'
  mysql> SELECT CHARSET(CONVERT('abc' USING utf8));
  -> 'utf8'
  mysql> SELECT CHARSET(USER());
  -> 'utf8'

- **COERCIBILITY(str)**

  Returns the collation coercibility value of the string argument.

  mysql> SELECT COERCIBILITY('abc' COLLATE latin1_swedish_ci);
  -> 0
  mysql> SELECT COERCIBILITY(USER());
  -> 3
  mysql> SELECT COERCIBILITY('abc');
  -> 4
  mysql> SELECT COERCIBILITY(1000);
  -> 5

  The return values have the meanings shown in the following table. Lower values have higher precedence.

<table>
<thead>
<tr>
<th>Coercibility</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Explicit collation</td>
<td>Value with COLLATE clause</td>
</tr>
<tr>
<td>1</td>
<td>No collation</td>
<td>Concatenation of strings with different collations</td>
</tr>
<tr>
<td>2</td>
<td>Implicit collation</td>
<td>Column value, stored routine parameter or local variable</td>
</tr>
<tr>
<td>3</td>
<td>System constant</td>
<td>USER() return value</td>
</tr>
<tr>
<td>4</td>
<td>Coercible</td>
<td>Literal string</td>
</tr>
<tr>
<td>5</td>
<td>Numeric</td>
<td>Numeric or temporal value</td>
</tr>
</tbody>
</table>
Information Functions

<table>
<thead>
<tr>
<th>Coercibility</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Ignorable</td>
<td>NULL or an expression derived from NULL</td>
</tr>
</tbody>
</table>

For more information, see Section 10.8.4, “Collation Coercibility in Expressions”.

- **COLLATION(str)**

Returns the collation of the string argument.

```sql
mysql> SELECT COLLATION('abc');
-> 'latin1_swedish_ci'
mysql> SELECT COLLATION(_utf8'abc');
-> 'utf8_general_ci'
```

- **CONNECTION_ID()**

Returns the connection ID (thread ID) for the connection. Every connection has an ID that is unique among the set of currently connected clients.

The value returned by `CONNECTION_ID()` is the same type of value as displayed in the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table, the `Id` column of `SHOW PROCESSLIST` output, and the `PROCESSLIST_ID` column of the Performance Schema `threads` table.

```sql
mysql> SELECT CONNECTION_ID();
-> 23786
```

- **CURRENT_USER, CURRENT_USER()**

Returns the user name and host name combination for the MySQL account that the server used to authenticate the current client. This account determines your access privileges. The return value is a string in the `utf8` character set.

The value of `CURRENT_USER()` can differ from the value of `USER()`.

```sql
mysql> SELECT USER();
-> 'davida@localhost'
mysql> SELECT * FROM mysql.user;
ERROR 1044: Access denied for user ''@'localhost' to database 'mysql'
mysql> SELECT CURRENT_USER();
-> '@localhost'
```

The example illustrates that although the client specified a user name of `davida` (as indicated by the value of the `USER()` function), the server authenticated the client using an anonymous user account (as
Information Functions

seen by the empty user name part of the CURRENT_USER() value). One way this might occur is that there is no account listed in the grant tables for davida.

Within a stored program or view, CURRENT_USER() returns the account for the user who defined the object (as given by its DEFINER value) unless defined with the SQL SECURITY INVOKER characteristic. In the latter case, CURRENT_USER() returns the object's invoker.

Triggers and events have no option to define the SQL SECURITY characteristic, so for these objects, CURRENT_USER() returns the account for the user who defined the object. To return the invoker, use USER() or SESSION_USER().

The following statements support use of the CURRENT_USER() function to take the place of the name of (and, possibly, a host for) an affected user or a definer; in such cases, CURRENT_USER() is expanded where and as needed:

- DROP USER
- RENAME USER
- GRANT
- REVOKE
- CREATE FUNCTION
- CREATE PROCEDURE
- CREATE TRIGGER
- CREATE EVENT
- CREATE VIEW
- ALTER EVENT
- ALTER VIEW
- SET PASSWORD

For information about the implications that this expansion of CURRENT_USER() has for replication, see Section 17.4.1.8, “Replication of CURRENT_USER()”.

- DATABASE()

Returns the default (current) database name as a string in the utf8 character set. If there is no default database, DATABASE() returns NULL. Within a stored routine, the default database is the database that the routine is associated with, which is not necessarily the same as the database that is the default in the calling context.

```sql
mysql> SELECT DATABASE();
+------------------+
| DATABASE()       |
+------------------+
| 'test'           |
+------------------+
```

If there is no default database, DATABASE() returns NULL.

- FOUND_ROWS()

A SELECT statement may include a LIMIT clause to restrict the number of rows the server returns to the client. In some cases, it is desirable to know how many rows the statement would have returned
without the LIMIT, but without running the statement again. To obtain this row count, include an SQL_CALC_FOUND_ROWS option in the SELECT statement, and then invoke FOUND_ROWS() afterward:

```sql
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM tbl_name
    -> WHERE id > 100 LIMIT 10;
mysql> SELECT FOUND_ROWS();
```

The second SELECT returns a number indicating how many rows the first SELECT would have returned had it been written without the LIMIT clause.

In the absence of the SQL_CALC_FOUND_ROWS option in the most recent successful SELECT statement, FOUND_ROWS() returns the number of rows in the result set returned by that statement. If the statement includes a LIMIT clause, FOUND_ROWS() returns the number of rows up to the limit. For example, FOUND_ROWS() returns 10 or 60, respectively, if the statement includes LIMIT 10 or LIMIT 50, 10.

The row count available through FOUND_ROWS() is transient and not intended to be available past the statement following the SELECT SQL_CALC_FOUND_ROWS statement. If you need to refer to the value later, save it:

```sql
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM ...;
mysql> SET @rows = FOUND_ROWS();
```

If you are using SELECT SQL_CALC_FOUND_ROWS, MySQL must calculate how many rows are in the full result set. However, this is faster than running the query again without LIMIT, because the result set need not be sent to the client.

SQL_CALC_FOUND_ROWS and FOUND_ROWS() can be useful in situations when you want to restrict the number of rows that a query returns, but also determine the number of rows in the full result set without running the query again. An example is a Web script that presents a paged display containing links to the pages that show other sections of a search result. Using FOUND_ROWS() enables you to determine how many other pages are needed for the rest of the result.

The use of SQL_CALC_FOUND_ROWS and FOUND_ROWS() is more complex for UNION statements than for simple SELECT statements, because LIMIT may occur at multiple places in a UNION. It may be applied to individual SELECT statements in the UNION, or global to the UNION result as a whole.

The intent of SQL_CALC_FOUND_ROWS for UNION is that it should return the row count that would be returned without a global LIMIT. The conditions for use of SQL_CALC_FOUND_ROWS with UNION are:

- The SQL_CALC_FOUND_ROWS keyword must appear in the first SELECT of the UNION.

- The value of FOUND_ROWS() is exact only if UNION ALL is used. If UNION without ALL is used, duplicate removal occurs and the value of FOUND_ROWS() is only approximate.

- If no LIMIT is present in the UNION, SQL_CALC_FOUND_ROWS is ignored and returns the number of rows in the temporary table that is created to process the UNION.

Beyond the cases described here, the behavior of FOUND_ROWS() is undefined (for example, its value following a SELECT statement that fails with an error).

**Important**

FOUND_ROWS() is not replicated reliably using statement-based replication. This function is automatically replicated using row-based replication.
• `LAST_INSERT_ID()`, `LAST_INSERT_ID(expr)`

With no argument, `LAST_INSERT_ID()` returns a 64-bit value representing the first automatically generated value successfully inserted for an `AUTO_INCREMENT` column as a result of the most recently executed `INSERT` statement. The value has a type of `BIGINT UNSIGNED` as of MySQL 5.5.29, `BIGINT` (signed) before that. The value of `LAST_INSERT_ID()` remains unchanged if no rows are successfully inserted.

With an argument, `LAST_INSERT_ID()` returns an unsigned integer as of MySQL 5.5.29, a signed integer before that.

For example, after inserting a row that generates an `AUTO_INCREMENT` value, you can get the value like this:

```sql
mysql> SELECT LAST_INSERT_ID();
-> 195
```

The currently executing statement does not affect the value of `LAST_INSERT_ID()`. Suppose that you generate an `AUTO_INCREMENT` value with one statement, and then refer to `LAST_INSERT_ID()` in a multiple-row `INSERT` statement that inserts rows into a table with its own `AUTO_INCREMENT` column. The value of `LAST_INSERT_ID()` will remain stable in the second statement; its value for the second and later rows is not affected by the earlier row insertions. (However, if you mix references to `LAST_INSERT_ID()` and `LAST_INSERT_ID(expr)`, the effect is undefined.)

If the previous statement returned an error, the value of `LAST_INSERT_ID()` is undefined. For transactional tables, if the statement is rolled back due to an error, the value of `LAST_INSERT_ID()` is left undefined. For manual `ROLLBACK`, the value of `LAST_INSERT_ID()` is not restored to that before the transaction; it remains as it was at the point of the `ROLLBACK`.

Prior to MySQL 5.5.35, this function was not replicated correctly if replication filtering rules were in use. (Bug #17234370, Bug #69861)

Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects. The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

- If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.
- For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements will not see a changed value.

The ID that was generated is maintained in the server on a `per-connection basis`. This means that the value returned by the function to a given client is the first `AUTO_INCREMENT` value generated for most recent statement affecting an `AUTO_INCREMENT` column by that client. This value cannot be affected by other clients, even if they generate `AUTO_INCREMENT` values of their own. This behavior ensures that
each client can retrieve its own ID without concern for the activity of other clients, and without the need for locks or transactions.

The value of `LAST_INSERT_ID()` is not changed if you set the `AUTO_INCREMENT` column of a row to a non-“magic” value (that is, a value that is not `NULL` and not `0`).

**Important**

If you insert multiple rows using a single `INSERT` statement, `LAST_INSERT_ID()` returns the value generated for the *first* inserted row *only*. The reason for this is to make it possible to reproduce easily the same `INSERT` statement against some other server.

For example:

```sql
mysql> USE test;

mysql> CREATE TABLE t (  
    | id INT AUTO_INCREMENT NOT NULL PRIMARY KEY,  
    | name VARCHAR(10) NOT NULL  
);  

mysql> INSERT INTO t VALUES (NULL, 'Bob');

mysql> SELECT * FROM t;
+----+------+
<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bob</td>
</tr>
</tbody>
</table>
+----+------+

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |

mysql> INSERT INTO t VALUES (NULL, 'Mary'), (NULL, 'Jane'), (NULL, 'Lisa');

mysql> SELECT * FROM t;
+----+------+
<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bob</td>
</tr>
<tr>
<td>2</td>
<td>Mary</td>
</tr>
<tr>
<td>3</td>
<td>Jane</td>
</tr>
<tr>
<td>4</td>
<td>Lisa</td>
</tr>
</tbody>
</table>
+----+------+

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                2 |
```
Although the second `INSERT` statement inserted three new rows into `t`, the ID generated for the first of these rows was 2, and it is this value that is returned by `LAST_INSERT_ID()` for the following `SELECT` statement.

If you use `INSERT IGNORE` and the row is ignored, the `LAST_INSERT_ID()` remains unchanged from the current value (or 0 is returned if the connection has not yet performed a successful `INSERT`) and, for non-transactional tables, the `AUTO_INCREMENT` counter is not incremented. For InnoDB tables, the `AUTO_INCREMENT` counter is incremented if `innodb_autoinc_lock_mode` is set to 1 or 2, as demonstrated in the following example:
**Table: t**

Create Table: CREATE TABLE `t` (  
`id` int(11) NOT NULL AUTO_INCREMENT,  
`val` int(11) DEFAULT NULL,  
PRIMARY KEY (`id`),  
UNIQUE KEY `i1` (`val`)  
) ENGINE=InnoDB AUTO_INCREMENT=5 DEFAULT CHARSET=latin1  

# The LAST_INSERT_ID is unchanged because the previous insert was unsuccessful

**For more information, see Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”.**

If `expr` is given as an argument to LAST_INSERT_ID(), the value of the argument is returned by the function and is remembered as the next value to be returned by LAST_INSERT_ID(). This can be used to simulate sequences:

1. Create a table to hold the sequence counter and initialize it:

   ```
   mysql> CREATE TABLE sequence (id INT NOT NULL);
   mysql> INSERT INTO sequence VALUES (0);
   ```

2. Use the table to generate sequence numbers like this:

   ```
   mysql> UPDATE sequence SET id=LAST_INSERT_ID(id+1);
   mysql> SELECT LAST_INSERT_ID();
   ```

   The UPDATE statement increments the sequence counter and causes the next call to LAST_INSERT_ID() to return the updated value. The SELECT statement retrieves that value. The mysql_insert_id() C API function can also be used to get the value. See Section 23.7.6.37, “mysql_insert_id()”.

You can generate sequences without calling LAST_INSERT_ID(), but the utility of using the function this way is that the ID value is maintained in the server as the last automatically generated value. It is multi-user safe because multiple clients can issue the UPDATE statement and get their own sequence value with the SELECT statement (or mysql_insert_id()), without affecting or being affected by other clients that generate their own sequence values.

Note that mysql_insert_id() is only updated after INSERT and UPDATE statements, so you cannot use the C API function to retrieve the value for LAST_INSERT_ID(expr) after executing other SQL statements like SELECT or SET.
Information Functions

• **ROW_COUNT()**

**ROW_COUNT()** returns a value as follows:

- **DDL statements**: 0. This applies to statements such as `CREATE TABLE` or `DROP TABLE`.

- **DML statements other than SELECT**: The number of affected rows. This applies to statements such as `UPDATE`, `INSERT`, or `DELETE` (as before), but now also to statements such as `ALTER TABLE` and `LOAD DATA`.

- **SELECT**: -1 if the statement returns a result set, or the number of rows “affected” if it does not. For example, for `SELECT * FROM t1`, **ROW_COUNT()** returns -1. For `SELECT * FROM t1 INTO OUTFILE 'file_name'`, **ROW_COUNT()** returns the number of rows written to the file.

- **SIGNAL statements**: 0.

For `UPDATE` statements, the affected-rows value by default is the number of rows actually changed. If you specify the `CLIENT_FOUND_ROWS` flag to `mysql_real_connect()` when connecting to `mysqld`, the affected-rows value is the number of rows “found”; that is, matched by the `WHERE` clause.

For `REPLACE` statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

For `INSERT ... ON DUPLICATE KEY UPDATE` statements, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the `CLIENT_FOUND_ROWS` flag, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

The **ROW_COUNT()** value is similar to the value from the `mysql_affected_rows()` C API function and the row count that the `mysql` client displays following statement execution.

```
mysql> INSERT INTO t VALUES(1),(2),(3);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
| 3           |
+-------------+
1 row in set (0.00 sec)

mysql> DELETE FROM t WHERE i IN(1,2);
Query OK, 2 rows affected (0.00 sec)

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
| 2           |
+-------------+
1 row in set (0.00 sec)
```

**Important**

**ROW_COUNT()** is not replicated reliably using statement-based replication. This function is automatically replicated using row-based replication.
• **SCHEMA()**
  This function is a synonym for `DATABASE()`.

• **SESSION_USER()**
  `SESSION_USER()` is a synonym for `USER()`.

• **SYSTEM_USER()**
  `SYSTEM_USER()` is a synonym for `USER()`.

• **USER()**
  Returns the current MySQL user name and host name as a string in the `utf8` character set.

  ```sql
  mysql> SELECT USER();
  -> 'davida@localhost'
  ```

  The value indicates the user name you specified when connecting to the server, and the client host from which you connected. The value can be different from that of `CURRENT_USER()`.

• **VERSION()**
  Returns a string that indicates the MySQL server version. The string uses the `utf8` character set. The value might have a suffix in addition to the version number. See the description of the `version` system variable in Section 5.1.7, “Server System Variables”.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

  ```sql
  mysql> SELECT VERSION();
  -> '5.5.62-standard'
  ```

### 12.16 Spatial Analysis Functions

MySQL provides functions to perform various operations on spatial data. These functions can be grouped into several major categories according to the type of operation they perform:

- Functions that create geometries in various formats (WKT, WKB, internal)
- Functions that convert geometries between formats
- Functions that access qualitative or quantitative properties of a geometry
- Functions that describe relations between two geometries
- Functions that create new geometries from existing ones

For general background about MySQL support for using spatial data, see Section 11.4, “Spatial Data Types”.

#### 12.16.1 Spatial Function Reference

The following table lists each spatial function and provides a short description of each one.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area()</td>
<td>Return Polygon or MultiPolygon area</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>AsBinary(), AsWKB()</td>
<td>Convert from internal geometry format to WKB</td>
</tr>
<tr>
<td>AsText(), AsWKT()</td>
<td>Convert from internal geometry format to WKT</td>
</tr>
<tr>
<td>Centroid()</td>
<td>Return centroid as a point</td>
</tr>
<tr>
<td>Contains()</td>
<td>Whether MBR of one geometry contains MBR of another</td>
</tr>
<tr>
<td>Crosses()</td>
<td>Whether one geometry crosses another</td>
</tr>
<tr>
<td>Dimension()</td>
<td>Dimension of geometry</td>
</tr>
<tr>
<td>Disjoint()</td>
<td>Whether MBRs of two geometries are disjoint</td>
</tr>
<tr>
<td>EndPoint()</td>
<td>End Point of LineString</td>
</tr>
<tr>
<td>Envelope()</td>
<td>Return MBR of geometry</td>
</tr>
<tr>
<td>Equals()</td>
<td>Whether MBRs of two geometries are equal</td>
</tr>
<tr>
<td>ExteriorRing()</td>
<td>Return exterior ring of Polygon</td>
</tr>
<tr>
<td>GeomCollFromText(),</td>
<td>Return geometry collection from WKT</td>
</tr>
<tr>
<td>GeometryCollectionFromText()</td>
<td></td>
</tr>
<tr>
<td>GeomCollFromWKB(),</td>
<td>Return geometry collection from WKB</td>
</tr>
<tr>
<td>GeometryCollectionFromWKB()</td>
<td></td>
</tr>
<tr>
<td>GeometryCollection()</td>
<td>Construct geometry collection from geometries</td>
</tr>
<tr>
<td>GeometryN()</td>
<td>Return N-th geometry from geometry collection</td>
</tr>
<tr>
<td>GeometryType()</td>
<td>Return name of geometry type</td>
</tr>
<tr>
<td>GeomFromText(), GeometryFromText()</td>
<td>Return geometry from WKT</td>
</tr>
<tr>
<td>GeomFromWKB(), GeometryFromWKB()</td>
<td>Return geometry from WKB</td>
</tr>
<tr>
<td>GLength()</td>
<td>Return length of LineString</td>
</tr>
<tr>
<td>InteriorRingN()</td>
<td>Return N-th interior ring of Polygon</td>
</tr>
<tr>
<td>Intersects()</td>
<td>Whether MBRs of two geometries intersect</td>
</tr>
<tr>
<td>IsClosed()</td>
<td>Whether a geometry is closed and simple</td>
</tr>
<tr>
<td>IsEmpty()</td>
<td>Placeholder function</td>
</tr>
<tr>
<td>IsSimple()</td>
<td>Whether a geometry is simple</td>
</tr>
<tr>
<td>LineFromText(),</td>
<td>Construct LineString from WKT</td>
</tr>
<tr>
<td>LineStringFromText()</td>
<td></td>
</tr>
<tr>
<td>LineFromWKB(),</td>
<td>Construct LineString from WKB</td>
</tr>
<tr>
<td>LineStringFromWKB()</td>
<td></td>
</tr>
<tr>
<td>LineString()</td>
<td>Construct LineString from Point values</td>
</tr>
<tr>
<td>MBRContains()</td>
<td>Whether MBR of one geometry contains MBR of another</td>
</tr>
<tr>
<td>MBRDisjoint()</td>
<td>Whether MBRs of two geometries are disjoint</td>
</tr>
<tr>
<td>MBREqual()</td>
<td>Whether MBRs of two geometries are equal</td>
</tr>
<tr>
<td>MBRIntersects()</td>
<td>Whether MBRs of two geometries intersect</td>
</tr>
<tr>
<td>MBROverlaps()</td>
<td>Whether MBRs of two geometries overlap</td>
</tr>
<tr>
<td>MBRTouches()</td>
<td>Whether MBRs of two geometries touch</td>
</tr>
</tbody>
</table>
### Name | Description
---|---
MBRWithin() | Whether MBR of one geometry is within MBR of another
MLineFromText(), MultiLineStringFromText() | Construct MultiLineString from WKT
MLineFromWKB(), MultiLineStringFromWKB() | Construct MultiLineString from WKB
MPointFromText(), MultiPointFromText() | Construct MultiPoint from WKT
MPointFromWKB(), MultiPointFromWKB() | Construct MultiPoint from WKB
MPolyFromText(), MultiPolygonFromText() | Construct MultiPolygon from WKT
MPolyFromWKB(), MultiPolygonFromWKB() | Construct MultiPolygon from WKB
MultiLineString() | Construct MultiLineString from LineString values
MultiPoint() | Construct MultiPoint from Point values
MultiPolygon() | Construct MultiPolygon from Polygon values
NumGeometries() | Return number of geometries in geometry collection
NumInteriorRings() | Return number of interior rings in Polygon
NumPoints() | Return number of points in LineString
Overlaps() | Whether MBRs of two geometries overlap
Point() | Construct Point from coordinates
PointFromText() | Construct Point from WKT
PointFromWKB() | Construct Point from WKB
PointN() | Return N-th point from LineString
PolyFromText(), PolygonFromText() | Construct Polygon from WKT
PolyFromWKB(), PolygonFromWKB() | Construct Polygon from WKB
Polygon() | Construct Polygon from LineString arguments
SRID() | Return spatial reference system ID for geometry
StartPoint() | Start Point of LineString
Touches() | Whether one geometry touches another
Within() | Whether MBR of one geometry is within MBR of another
X() | Return X coordinate of Point
Y() | Return Y coordinate of Point

### 12.16.2 Argument Handling by Spatial Functions

Spatial values, or geometries, have the properties described at Section 11.4.2.2, “Geometry Class”. The following discussion lists general spatial function argument-handling characteristics. Specific functions or groups of functions may have additional argument-handling characteristics, as discussed in the sections where those function descriptions occur.
Spatial functions are defined only for valid geometry values. If an invalid geometry is passed to a spatial function, the result is undefined.

The spatial reference identifier (SRID) of a geometry identifies the coordinate space in which the geometry is defined. In MySQL, the SRID value is an integer associated with the geometry value. The maximum usable SRID value is $2^{32} - 1$. If a larger value is given, only the lower 32 bits are used.

Geometry values produced by any spatial function inherit the SRID of the geometry arguments.

12.16.3 Functions That Create Geometry Values from WKT Values

These functions take as arguments a Well-Known Text (WKT) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

**GeomFromText()** accepts a WKT value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.

For a description of WKT format, see [Well-Known Text (WKT) Format](#).

- **GeomCollFromText(wkt[, srid]), GeometryCollectionFromText(wkt[, srid])**
  Constructs a **GeometryCollection** value using its WKT representation and SRID.

- **GeomFromText(wkt[, srid]), GeometryFromText(wkt[, srid])**
  Constructs a geometry value of any type using its WKT representation and SRID.

- **LineFromText(wkt[, srid]), LineStringFromText(wkt[, srid])**
  Constructs a **LineString** value using its WKT representation and SRID.

- **MLineFromText(wkt[, srid]), MultiLineStringFromText(wkt[, srid])**
  Constructs a **MultiLineString** value using its WKT representation and SRID.

- **MPointFromText(wkt[, srid]), MultiPointFromText(wkt[, srid])**
  Constructs a **MultiPoint** value using its WKT representation and SRID.

- **MPolyFromText(wkt[, srid]), MultiPolygonFromText(wkt[, srid])**
  Constructs a **MultiPolygon** value using its WKT representation and SRID.

- **PointFromText(wkt[, srid])**
  Constructs a **Point** value using its WKT representation and SRID.

- **PolyFromText(wkt[, srid]), PolygonFromText(wkt[, srid])**
  Constructs a **Polygon** value using its WKT representation and SRID.

12.16.4 Functions That Create Geometry Values from WKB Values

These functions take as arguments a **BLOB** containing a Well-Known Binary (WKB) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

**GeomFromWKB()** accepts a WKB value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.
MySQL-Specific Functions That Create Geometry Values

These functions also accept geometry objects as returned by the functions in Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”. Thus, those functions may be used to provide the first argument to the functions in this section.

For a description of WKB format, see Well-Known Binary (WKB) Format.

- `GeomCollFromWKB(wkb[, srid])`, `GeometryCollectionFromWKB(wkb[, srid])`
  Constructs a `GeometryCollection` value using its WKB representation and SRID.

- `GeomFromWKB(wkb[, srid])`, `GeometryFromWKB(wkb[, srid])`
  Constructs a geometry value of any type using its WKB representation and SRID.

- `LineFromWKB(wkb[, srid])`, `LineStringFromWKB(wkb[, srid])`
  Constructs a `LineString` value using its WKB representation and SRID.

- `MLineFromWKB(wkb[, srid])`, `MultiLineStringFromWKB(wkb[, srid])`
  Constructs a `MultiLineString` value using its WKB representation and SRID.

- `MPointFromWKB(wkb[, srid])`, `MultiPointFromWKB(wkb[, srid])`
  Constructs a `MultiPoint` value using its WKB representation and SRID.

- `MPolyFromWKB(wkb[, srid])`, `MultiPolygonFromWKB(wkb[, srid])`
  Constructs a `MultiPolygon` value using its WKB representation and SRID.

- `PointFromWKB(wkb[, srid])`
  Constructs a `Point` value using its WKB representation and SRID.

- `PolyFromWKB(wkb[, srid])`, `PolygonFromWKB(wkb[, srid])`
  Constructs a `Polygon` value using its WKB representation and SRID.

12.16.5 MySQL-Specific Functions That Create Geometry Values

MySQL provides a set of useful nonstandard functions for creating geometry values. The functions described in this section are MySQL extensions to the OpenGIS specification.

These functions produce geometry objects from either WKB values or geometry objects as arguments. If any argument is not a proper WKB or geometry representation of the proper object type, the return value is `NULL`.

For example, you can insert the geometry return value from `Point()` directly into a `POINT` column:

```
INSERT INTO t1 (pt_col) VALUES(Point(1,2));
```

- `GeometryCollection(g [, g] ...)`
  Constructs a `GeometryCollection` value from the geometry arguments.
  If an argument contains a nonsupported geometry, the return value is `NULL`.

- `LineString(pt [, pt] ...)`
Constructs a LineString value from a number of Point or WKB Point arguments. If the number of arguments is less than two, the return value is NULL.

- MultiLineString(ls [, ls] ...)
  Constructs a MultiLineString value using LineString or WKB LineString arguments.

- MultiPoint(pt [, pt2] ...)
  Constructs a MultiPoint value using Point or WKB Point arguments.

- MultiPolygon(poly [, poly] ...)
  Constructs a MultiPolygon value from a set of Polygon or WKB Polygon arguments.

- Point(x, y)
  Constructs a Point using its coordinates.

- Polygon(ls [, ls] ...)
  Constructs a Polygon value from a number of LineString or WKB LineString arguments. If any argument does not represent a LinearRing (that is, not a closed and simple LineString), the return value is NULL.

### 12.16.6 Geometry Format Conversion Functions

MySQL supports the functions listed in this section for converting geometry values from internal geometry format to WKT or WKB format.

There are also functions to convert a string from WKT or WKB format to internal geometry format. See Section 12.16.3, “Functions That Create Geometry Values from WKT Values”, and Section 12.16.4, “Functions That Create Geometry Values from WKB Values”.

- AsBinary(g), AsWKB(g)
  Converts a value in internal geometry format to its WKB representation and returns the binary result.

  The result is NULL if the geometry argument is NULL or not a syntactically well-formed geometry.

  ```sql
  SELECT AsBinary(g) FROM geom;
  ```

- AsText(g), AsWKT(g)
  Converts a value in internal geometry format to its WKT representation and returns the string result.

  The result is NULL if the geometry argument is NULL or not a syntactically well-formed geometry.

  ```sql
  mysql> SET @g = 'LineString(1 1,2,3 3)';
  mysql> SELECT AsText(GeomFromText(@g));
  +--------------------------+
  | AsText(GeomFromText(@g)) |
  | LINESTRING(1 1,2,3 3)   |
  +--------------------------+
  ```
12.16.7 Geometry Property Functions

Each function that belongs to this group takes a geometry value as its argument and returns some quantitative or qualitative property of the geometry. Some functions restrict their argument type. Such functions return NULL if the argument is of an incorrect geometry type. For example, the Area() polygon function returns NULL if the object type is neither Polygon nor MultiPolygon.

12.16.7.1 General Geometry Property Functions

The functions listed in this section do not restrict their argument and accept a geometry value of any type.

• **Dimension(\textit{g})**

  Returns the inherent dimension of the geometry value \textit{g}. The result can be −1, 0, 1, or 2. The meaning of these values is given in Section 11.4.2.2, “Geometry Class”.

  ```sql
  mysql> SELECT Dimension(GeomFromText('LineString(1 1,2 2)'));
  +------------------------------------------------+
  | Dimension(GeomFromText('LineString(1 1,2 2)')) |
  +------------------------------------------------+
  |                                              1 |
  +------------------------------------------------+
  ```

• **Envelope(\textit{g})**

  Returns the minimum bounding rectangle (MBR) for the geometry value \textit{g}. The result is returned as a Polygon value that is defined by the corner points of the bounding box:

  ```
  POLYGON((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
  ```

  ```sql
  mysql> SELECT AsText(Envelope(GeomFromText('LineString(1 1,2 2)')));
  +-------------------------------------------------------+
  | AsText(Envelope(GeomFromText('LineString(1 1,2 2)'))) |
  +-------------------------------------------------------+
  | POLYGON((1 1,2 1,2 2,1 2,1 1))                        |
  +-------------------------------------------------------+
  ```

• **GeometryType(\textit{g})**

  Returns a binary string indicating the name of the geometry type of which the geometry instance \textit{g} is a member. The name corresponds to one of the instantiable Geometry subclasses.

  ```sql
  mysql> SELECT GeometryType(GeomFromText('POINT(1 1)'));
  +------------------------------------------+
  | GeometryType(GeomFromText('POINT(1 1)')) |
  +------------------------------------------+
  | POINT                                    |
  +------------------------------------------+
  ```

• **IsEmpty(\textit{g})**

  This function is a placeholder that returns 0 for any valid geometry value, 1 for any invalid geometry value or NULL.

  MySQL does not support GIS EMPTY values such as POINT EMPTY.

• **IsSimple(\textit{g})**

  In MySQL 5.5, this function is a placeholder that always returns 0.
The descriptions of the instantiable geometric classes given under Section 11.4.2, “The OpenGIS Geometry Model” includes the specific conditions that cause class instances to be classified as not simple.

- **SRID** \((g)\)

Returns an integer indicating the spatial reference system ID associated with the geometry value \(g\).

```sql
mysql> SELECT SRID(GeomFromText('LineString(1 1,2 2)',101));
+-----------------------------------------------+
| SRID(GeomFromText('LineString(1 1,2 2)',101)) |
+-----------------------------------------------+
|                                           101 |
```

### 12.16.7.2 Point Property Functions

A **Point** consists of X and Y coordinates, which may be obtained using the following functions:

- **X** \((p)\)

Returns the X-coordinate value for the **Point** object \(p\) as a double-precision number.

```sql
mysql> SELECT X(Point(56.7, 53.34));
+-----------------------+
| X(Point(56.7, 53.34)) |
+-----------------------+
|                  56.7 |
```

- **Y** \((p)\)

Returns the Y-coordinate value for the **Point** object \(p\) as a double-precision number.

```sql
mysql> SELECT Y(Point(56.7, 53.34));
+-----------------------+
| Y(Point(56.7, 53.34)) |
+-----------------------+
|                 53.34 |
```

### 12.16.7.3 LineString and MultiLineString Property Functions

A **LineString** consists of **Point** values. You can extract particular points of a **LineString**, count the number of points that it contains, or obtain its length.

Some functions in this section also work for **MultiLineString** values.

- **EndPoint** \((ls)\)

Returns the **Point** that is the endpoint of the **LineString** value \(ls\). If the argument is NULL or an empty geometry, the return value is NULL.

```sql
mysql> SET @ls = 'LineString(1 1,2,3,3)';
mysql> SELECT AsText(EndPoint(GeomFromText(@ls)));
+-------------------------------------+
| AsText(EndPoint(GeomFromText(@ls))) |
+-------------------------------------+
| POINT(3 3)                          |
```

- **GLength** \((ls)\)
Returns a double-precision number indicating the length of the `LineString` or `MultiLineString` value `ls` in its associated spatial reference. The length of a `MultiLineString` value is equal to the sum of the lengths of its elements. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2,3)';
mysql> SELECT GLength(GeomFromText(@ls));
+----------------------------+
| GLength(GeomFromText(@ls)) |
+----------------------------+
| 2.8284271247461903         |
+----------------------------+
```

`GLength()` is a nonstandard name. It corresponds to the OpenGIS `Length()` function. (There is an existing SQL function `Length()` that calculates the length of string values.)

- **IsClosed(ls)**

  For a `LineString` value `ls`, `IsClosed()` returns 1 if `ls` is closed (that is, its `StartPoint()` and `EndPoint()` values are the same). If the argument is `NULL` or an empty geometry, the return value is `NULL`.

  For a `MultiLineString` value `ls`, `IsClosed()` returns 1 if `ls` is closed (that is, the `StartPoint()` and `EndPoint()` values are the same for each `LineString` in `ls`).

  `IsClosed()` returns 0 if `ls` is not closed.

```
mysql> SET @ls1 = 'LineString(1 1,2,3,2)';
mysql> SET @ls2 = 'LineString(1 1,2,3,3,1)';

mysql> SELECT IsClosed(GeomFromText(@ls1));
+-----------------------------+
| IsClosed(GeomFromText(@ls1)) |
| 0                           |
+-----------------------------+

mysql> SELECT IsClosed(GeomFromText(@ls2));
+-----------------------------+
| IsClosed(GeomFromText(@ls2)) |
| 1                           |
+-----------------------------+
```

```
mysql> SET @ls3 = 'MultiLineString((1 1,2,3),(4 4,5 5))';

mysql> SELECT IsClosed(GeomFromText(@ls3));
+-----------------------------+
| IsClosed(GeomFromText(@ls3)) |
| 0                           |
+-----------------------------+
```
Geometry Property Functions

• **NumPoints(ls)**

  Returns the number of Point objects in the LineString value `ls`. If the argument is NULL or an empty geometry, the return value is NULL.

```sql
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT NumPoints(GeomFromText(@ls));
+---------------------------------------------+
<table>
<thead>
<tr>
<th>NumPoints(GeomFromText(@ls))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>
+---------------------------------------------+
```

• **PointN(ls, N)**

  Returns the `N`-th Point in the Linestring value `ls`. Points are numbered beginning with 1. If any argument is NULL or the geometry argument is an empty geometry, the return value is NULL.

```sql
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(PointN(GeomFromText(@ls),2));
+------------------------------------------+
<table>
<thead>
<tr>
<th>AsText(PointN(GeomFromText(@ls),2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>POINT(2 2)</td>
</tr>
</tbody>
</table>
+------------------------------------------+
```

• **StartPoint(ls)**

  Returns the Point that is the start point of the LineString value `ls`. If the argument is NULL or an empty geometry, the return value is NULL.

```sql
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(StartPoint(GeomFromText(@ls)));:
+------------------------------------------+
<table>
<thead>
<tr>
<th>AsText(StartPoint(GeomFromText(@ls)))</th>
</tr>
</thead>
<tbody>
<tr>
<td>POINT(1 1)</td>
</tr>
</tbody>
</table>
+------------------------------------------+
```

12.16.7.4 Polygon and MultiPolygon Property Functions

Functions in this section return properties of Polygon or MultiPolygon values.

• **Area({poly|mpoly})**

  Returns a double-precision number indicating the area of the Polygon or MultiPolygon argument, as measured in its spatial reference system. For arguments of dimension 0 or 1, the result is 0. If the argument is an empty geometry the return value is 0. If the argument is NULL the return value is NULL.

```sql
mysql> SET @poly = 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 1,1 1))';
mysql> SELECT Area(GeomFromText(@poly));
+-------------------+
<table>
<thead>
<tr>
<th>Area(GeomFromText(@poly))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
</tbody>
</table>
+-------------------+

mysql> SET @mpoly = 'MultiPolygon(((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 1,1 1))';
mysql> SELECT Area(GeomFromText(@mpoly));
+-------------------+
<table>
<thead>
<tr>
<th>Area(GeomFromText(@mpoly))</th>
</tr>
</thead>
</table>
+-------------------+
```
Geometry Property Functions

<table>
<thead>
<tr>
<th>8</th>
</tr>
</thead>
</table>

• **Centroid**(poly|mpoly)

Returns the mathematical centroid for the **Polygon** or **MultiPolygon** argument as a **Point**. The result is not guaranteed to be on the argument. If the argument is **NULL** or an empty geometry, the return value is **NULL**.

```sql
mysql> SET @poly = 
    | GeomFromText('POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 7,5 7,5 5))');
mysql> SELECT GeometryType(@poly), AsText(Centroid(@poly));
+---------------------+--------------------------------------------+
<table>
<thead>
<tr>
<th>GeometryType(@poly)</th>
<th>AsText(Centroid(@poly))</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLYGON</td>
<td>POINT(4.958333333333333 4.958333333333333)</td>
</tr>
</tbody>
</table>
+---------------------+--------------------------------------------+
```

• **ExteriorRing**(poly)

Returns the exterior ring of the **Polygon** value **poly** as a **LineString**. If the argument is **NULL** or an empty geometry, the return value is **NULL**.

```sql
mysql> SET @poly = 
    | 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,1 1))';
mysql> SELECT AsText(ExteriorRing(GeomFromText(@poly)));
+-------------------------------------------|
| AsText(ExteriorRing(GeomFromText(@poly))) |
| LINESTRING(0 0,0 3,3 3,3 0,0)             |
+-------------------------------------------|
```

• **InteriorRingN**(poly, N)

Returns the N-th interior ring for the **Polygon** value **poly** as a **LineString**. Rings are numbered beginning with 1. If the argument is **NULL** or an empty geometry, the return value is **NULL**.

```sql
mysql> SET @poly = 
    | 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,1 1))';
mysql> SELECT AsText(InteriorRingN(GeomFromText(@poly), 1));
+----------------------------------------------|
| AsText(InteriorRingN(GeomFromText(@poly), 1)) |
| LINESTRING(1 1,1 2,2 2,1 1)                  |
+----------------------------------------------|
```

• **NumInteriorRings**(poly)

Returns the number of interior rings in the **Polygon** value **poly**. If the argument is **NULL** or an empty geometry, the return value is **NULL**.

```sql
mysql> SET @poly = 
    | 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,1 1))';
mysql> SELECT NumInteriorRings(GeomFromText(@poly));
+---------------------------------------|
| NumInteriorRings(GeomFromText(@poly))  |
|                                    1   |
+---------------------------------------|
```

12.16.7.5 GeometryCollection Property Functions

These functions return properties of **GeometryCollection** values.
Spatial Operator Functions

- **GeometryN(gc, N)**

  Returns the \(N\)-th geometry in the \textbf{GeometryCollection} value \(gc\). Geometries are numbered beginning with 1. If any argument is \textbf{NULL} or the geometry argument is an empty geometry, the return value is \textbf{NULL}.

  
  mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
  mysql> SELECT AsText(GeometryN(GeomFromText(@gc),1));

  +----------------------------------------+
  | AsText(GeometryN(GeomFromText(@gc),1)) |
  | POINT(1 1)                             |
  +----------------------------------------+

- **NumGeometries(gc)**

  Returns the number of geometries in the \textbf{GeometryCollection} value \(gc\). If the argument is \textbf{NULL} or an empty geometry, the return value is \textbf{NULL}.

  mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
  mysql> SELECT NumGeometries(GeomFromText(@gc));

  +----------------------------------+
  | NumGeometries(GeomFromText(@gc)) |
  |                                2 |
  +----------------------------------+

12.16.8 Spatial Operator Functions

Section 12.16.7, “Geometry Property Functions”, discusses several functions that construct new geometries from existing ones. See that section for descriptions of these functions:

- **Envelope(g)**
- **StartPoint(ls)**
- **EndPoint(ls)**
- **PointN(ls, N)**
- **ExteriorRing(poly)**
- **InteriorRingN(poly, N)**
- **GeometryN(gc, N)**

12.16.9 Functions That Test Spatial Relations Between Geometry Objects

The functions described in this section take two geometries as arguments and return a qualitative or quantitative relation between them.

MySQL implements two sets of functions using function names defined by the OpenGIS specification. One set tests the relationship between two geometry values using precise object shapes, the other set uses object minimum bounding rectangles (MBRs).

There is also a MySQL-specific set of MBR-based functions available to test the relationship between two geometry values.
12.16.9.1 Spatial Relation Functions That Use Object Shapes

The OpenGIS specification defines the following functions to test the relationship between two geometry values \( g_1 \) and \( g_2 \), using precise object shapes. The return values 1 and 0 indicate true and false, respectively.

- \( \text{Crosses}(g_1, g_2) \)
  
  The term \textit{spatially crosses} denotes a spatial relation between two given geometries that has the following properties:
  
  - The two geometries intersect.
  - Their intersection results in a geometry that has a dimension that is one less than the maximum dimension of the two given geometries.
  - Their intersection is not equal to either of the two given geometries.

  This function returns 1 or 0 to indicate whether \( g_1 \) spatially crosses \( g_2 \). If \( g_1 \) is a \text{Polygon} or a \text{MultiPolygon}, or if \( g_2 \) is a \text{Point} or a \text{MultiPoint}, the return value is \text{NULL}.

- \( \text{Touches}(g_1, g_2) \)
  
  Two geometries \textit{spatially touch} if their interiors do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

  This function returns 1 or 0 to indicate whether \( g_1 \) spatially touches \( g_2 \).

12.16.9.2 Spatial Relation Functions That Use Minimum Bounding Rectangles

MySQL provides several MySQL-specific functions that test the relationship between minimum bounding rectangles (MBRs) of two geometries \( g_1 \) and \( g_2 \). The return values 1 and 0 indicate true and false, respectively.

A corresponding set of MBR functions defined according to the OpenGIS specification is described later in this section.

- \( \text{MBRContains}(g_1, g_2) \)
  
  Returns 1 or 0 to indicate whether the minimum bounding rectangle of \( g_1 \) contains the minimum bounding rectangle of \( g_2 \). This tests the opposite relationship as \( \text{MBRWithin()} \).

  ```sql
  mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
  mysql> SET @g2 = GeomFromText('Point(1 1)');
  mysql> SELECT MBRContains(@g1,@g2), MBRWithin(@g2,@g1);
  +----------------------+--------------------+
  | MBRContains(@g1,@g2) | MBRWithin(@g2,@g1) |
  +----------------------+--------------------+
  |                    1 |                  1 |
  +----------------------+--------------------+
  ```

- \( \text{MBRDisjoint}(g_1, g_2) \)
  
  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries \( g_1 \) and \( g_2 \) are disjoint (do not intersect).

- \( \text{MBREqual}(g_1, g_2) \)
  
  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries \( g_1 \) and \( g_2 \) are the same.
Functions That Test Spatial Relations Between Geometry Objects

- **MBRIntersects**(g1, g2)

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries g1 and g2 intersect.

- **MBROverlaps**(g1, g2)

  Two geometries spatially overlap if they intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

  This function returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries g1 and g2 overlap.

- **MBRTouches**(g1, g2)

  Two geometries spatially touch if their interiors do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

  This function returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries g1 and g2 touch.

- **MBRWithin**(g1, g2)

  Returns 1 or 0 to indicate whether the minimum bounding rectangle of g1 is within the minimum bounding rectangle of g2. This tests the opposite relationship as MBRContains().

```
mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
mysql> SET @g2 = GeomFromText('Polygon((0 0,0 5,5 5,5 0,0 0))');
mysql> SELECT MBRWithin(@g1,@g2), MBRWithin(@g2,@g1);
+--------------------+--------------------+
| MBRWithin(@g1,@g2) | MBRWithin(@g2,@g1) |
+--------------------+--------------------+
|                  1 |                  0 |
+--------------------+--------------------+
```

The OpenGIS specification defines the following functions that test the relationship between two geometry values g1 and g2. The MySQL implementation uses minimum bounding rectangles, so these functions return the same result as the corresponding MBR-based functions described earlier in this section. The return values 1 and 0 indicate true and false, respectively.

- **Contains**(g1, g2)

  Returns 1 or 0 to indicate whether g1 completely contains g2. This tests the opposite relationship as Within().

- **Disjoint**(g1, g2)

  Returns 1 or 0 to indicate whether g1 is spatially disjoint from (does not intersect) g2.

- **Equals**(g1, g2)

  Returns 1 or 0 to indicate whether g1 is spatially equal to g2.

- **Intersects**(g1, g2)

  Returns 1 or 0 to indicate whether g1 spatially intersects g2.

- **Overlaps**(g1, g2)
Two geometries *spatially overlap* if they intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

This function returns 1 or 0 to indicate whether $g_1$ spatially overlaps $g_2$.

- **Within($g_1$, $g_2$)**
  - Returns 1 or 0 to indicate whether $g_1$ is spatially within $g_2$. This tests the opposite relationship as `Contains()`.

### 12.17 Aggregate (GROUP BY) Functions

#### 12.17.1 Aggregate (GROUP BY) Function Descriptions

This section describes group (aggregate) functions that operate on sets of values.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG()</td>
<td>Return the average value of the argument</td>
</tr>
<tr>
<td>BIT_AND()</td>
<td>Return bitwise AND</td>
</tr>
<tr>
<td>BIT_OR()</td>
<td>Return bitwise OR</td>
</tr>
<tr>
<td>BIT_XOR()</td>
<td>Return bitwise XOR</td>
</tr>
<tr>
<td>COUNT()</td>
<td>Return a count of the number of rows returned</td>
</tr>
<tr>
<td>COUNT(DISTINCT)</td>
<td>Return the count of a number of different values</td>
</tr>
<tr>
<td>GROUP_CONCAT()</td>
<td>Return a concatenated string</td>
</tr>
<tr>
<td>MAX()</td>
<td>Return the maximum value</td>
</tr>
<tr>
<td>MIN()</td>
<td>Return the minimum value</td>
</tr>
<tr>
<td>STD()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV_POP()</td>
<td>Return the population standard deviation</td>
</tr>
<tr>
<td>STDDEV_SAMP()</td>
<td>Return the sample standard deviation</td>
</tr>
<tr>
<td>SUM()</td>
<td>Return the sum</td>
</tr>
<tr>
<td>VAR_POP()</td>
<td>Return the population standard variance</td>
</tr>
<tr>
<td>VAR_SAMP()</td>
<td>Return the sample variance</td>
</tr>
<tr>
<td>VARIANCE()</td>
<td>Return the population standard variance</td>
</tr>
</tbody>
</table>

Unless otherwise stated, group functions ignore NULL values.

If you use a group function in a statement containing no `GROUP BY` clause, it is equivalent to grouping on all rows. For more information, see Section 12.17.3, “MySQL Handling of GROUP BY”.

For numeric arguments, the variance and standard deviation functions return a DOUBLE value. The `SUM()` and `AVG()` functions return a DECIMAL value for exact-value arguments (integer or DECIMAL), and a DOUBLE value for approximate-value arguments (FLOAT or DOUBLE).

The `SUM()` and `AVG()` aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:
Functions such as \textbf{SUM()} or \textbf{AVG()} that expect a numeric argument cast the argument to a number if necessary. For \texttt{SET} or \texttt{ENUM} values, the cast operation causes the underlying numeric value to be used.

The \textbf{BIT\_AND()}, \textbf{BIT\_OR()}, and \textbf{BIT\_XOR()} aggregate functions perform bit operations. They require \texttt{BIGINT} (64-bit integer) arguments and return \texttt{BIGINT} values. Arguments of other types are converted to \texttt{BIGINT} and truncation might occur.

- \textbf{AVG([DISTINCT] expr)}
  
  Returns the average value of \textit{expr}. The \texttt{DISTINCT} option can be used to return the average of the distinct values of \textit{expr}.

  If there are no matching rows, \textbf{AVG()} returns \texttt{NULL}.

  ```sql
  mysql> SELECT student_name, AVG(test_score)
       > FROM student
       > GROUP BY student_name;
  ```

- \textbf{BIT\_AND(expr)}
  
  Returns the bitwise \texttt{AND} of all bits in \textit{expr}. The calculation is performed with 64-bit (\texttt{BIGINT}) precision.

  If there are no matching rows, \textbf{BIT\_AND()} returns a neutral value (all bits set to 1).

- \textbf{BIT\_OR(expr)}
  
  Returns the bitwise \texttt{OR} of all bits in \textit{expr}. The calculation is performed with 64-bit (\texttt{BIGINT}) precision.

  If there are no matching rows, \textbf{BIT\_OR()} returns a neutral value (all bits set to 0).

- \textbf{BIT\_XOR(expr)}
  
  Returns the bitwise \texttt{XOR} of all bits in \textit{expr}. The calculation is performed with 64-bit (\texttt{BIGINT}) precision.

  If there are no matching rows, \textbf{BIT\_XOR()} returns a neutral value (all bits set to 0).

- \textbf{COUNT(expr)}
  
  Returns a count of the number of non-\texttt{NULL} values of \textit{expr} in the rows retrieved by a \texttt{SELECT} statement. The result is a \texttt{BIGINT} value.

  If there are no matching rows, \textbf{COUNT()} returns \texttt{0}.

  ```sql
  mysql> SELECT student.student_name, COUNT(*)
       > FROM student, course
       > WHERE student.student_id=course.student_id
       > GROUP BY student_name;
  ```

\textbf{COUNT(*)} is somewhat different in that it returns a count of the number of rows retrieved, whether or not they contain \texttt{NULL} values.

For transactional storage engines such as \texttt{InnoDB}, storing an exact row count is problematic. Multiple transactions may be occurring at the same time, each of which may affect the count.

\texttt{InnoDB} does not keep an internal count of rows in a table because concurrent transactions might “see” different numbers of rows at the same time. Consequently, \texttt{SELECT COUNT(*)} statements only count rows visible to the current transaction.
To process a `SELECT COUNT(*)` statement, InnoDB scans an index of the table, which takes some time if the index is not entirely in the buffer pool. For a faster count, create a counter table and let your application update it according to the inserts and deletes it does. However, this method may not scale well in situations where thousands of concurrent transactions are initiating updates to the same counter table. If an approximate row count is sufficient, use `SHOW TABLE STATUS`.

InnoDB handles `SELECT COUNT(*)` and `SELECT COUNT(1)` operations in the same way. There is no performance difference.

For MyISAM tables, `COUNT(*)` is optimized to return very quickly if the `SELECT` retrieves from one table, no other columns are retrieved, and there is no `WHERE` clause. For example:

```
mysql> SELECT COUNT(*) FROM student;
```

This optimization only applies to MyISAM tables, because an exact row count is stored for this storage engine and can be accessed very quickly. `COUNT(1)` is only subject to the same optimization if the first column is defined as `NOT NULL`.

- `COUNT(DISTINCT expr, [expr...])`

Returns a count of the number of rows with different non-NULL `expr` values.

If there are no matching rows, `COUNT(DISTINCT)` returns 0.

```
mysql> SELECT COUNT(DISTINCT results) FROM student;
```

In MySQL, you can obtain the number of distinct expression combinations that do not contain `NULL` by giving a list of expressions. In standard SQL, you would have to do a concatenation of all expressions inside `COUNT(DISTINCT ...)`.

- `GROUP_CONCAT(expr)`

This function returns a string result with the concatenated non-NULL values from a group. It returns NULL if there are no non-NULL values. The full syntax is as follows:

```
GROUP_CONCAT([DISTINCT] expr [, expr ...]
  [ORDER BY {unsigned_integer | col_name | expr}
   [ASC | DESC] [, col_name ...]]
  [SEPARATOR str_val])
```

```
mysql> SELECT student_name,
            GROUP_CONCAT(test_score)
    FROM student
    GROUP BY student_name;
```

Or:

```
mysql> SELECT student_name,
            GROUP_CONCAT(DISTINCT test_score
              ORDER BY test_score DESC SEPARATOR ' ')
    FROM student
    GROUP BY student_name;
```

In MySQL, you can get the concatenated values of expression combinations. To eliminate duplicate values, use the `DISTINCT` clause. To sort values in the result, use the `ORDER BY` clause. To sort in reverse order, add the `DESC` (descending) keyword to the name of the column you are sorting by in the `ORDER BY` clause. The default is ascending order; this may be specified explicitly using the `ASC` keyword. The default separator between values in a group is comma (,). To specify a separator
explicitly, use `SEPARATOR` followed by the string literal value that should be inserted between group values. To eliminate the separator altogether, specify `SEPARATOR ''`.

The result is truncated to the maximum length that is given by the `group_concat_max_len` system variable, which has a default value of 1024. The value can be set higher, although the effective maximum length of the return value is constrained by the value of `max_allowed_packet`. The syntax to change the value of `group_concat_max_len` at runtime is as follows, where `val` is an unsigned integer:

```
SET [GLOBAL | SESSION] group_concat_max_len = val;
```

The return value is a nonbinary or binary string, depending on whether the arguments are nonbinary or binary strings. The result type is `TEXT` or `BLOB` unless `group_concat_max_len` is less than or equal to 512, in which case the result type is `VARCHAR` or `VARBINARY`.

See also `CONCAT()` and `CONCAT_WS()`: Section 12.7, “String Functions and Operators”.

- **`MAX([DISTINCT] expr)`**

Returns the maximum value of `expr`. `MAX()` may take a string argument; in such cases, it returns the maximum string value. See Section 8.3.1, “How MySQL Uses Indexes”. The `DISTINCT` keyword can be used to find the maximum of the distinct values of `expr`, however, this produces the same result as omitting `DISTINCT`.

If there are no matching rows, `MAX()` returns `NULL`.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
    FROM student
    GROUP BY student_name;
```

For `MAX()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them.

- **`MIN([DISTINCT] expr)`**

Returns the minimum value of `expr`. `MIN()` may take a string argument; in such cases, it returns the minimum string value. See Section 8.3.1, “How MySQL Uses Indexes”. The `DISTINCT` keyword can be used to find the minimum of the distinct values of `expr`, however, this produces the same result as omitting `DISTINCT`.

If there are no matching rows, `MIN()` returns `NULL`.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
    FROM student
    GROUP BY student_name;
```

For `MIN()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them.

- **`STD(expr)`**

Returns the population standard deviation of `expr`. `STD()` is a synonym for the standard SQL function `STDDEV_POP()`, provided as a MySQL extension.

If there are no matching rows, `STD()` returns `NULL`.  

---

1365
• `STDDEV(expr)`
  Returns the population standard deviation of `expr`. `STDDEV()` is a synonym for the standard SQL function `STDDEV_POP()`, provided for compatibility with Oracle.
  If there are no matching rows, `STDDEV()` returns NULL.

• `STDDEV_POP(expr)`
  Returns the population standard deviation of `expr` (the square root of `VAR_POP()`). You can also use `STD()` or `STDDEV()`, which are equivalent but not standard SQL.
  If there are no matching rows, `STDDEV_POP()` returns NULL.

• `STDDEV_SAMP(expr)`
  Returns the sample standard deviation of `expr` (the square root of `VAR_SAMP()`).
  If there are no matching rows, `STDDEV_SAMP()` returns NULL.

• `SUM([DISTINCT] expr)`
  Returns the sum of `expr`. If the return set has no rows, `SUM()` returns NULL. The `DISTINCT` keyword can be used to sum only the distinct values of `expr`.
  If there are no matching rows, `SUM()` returns NULL.

• `VAR_POP(expr)`
  Returns the population standard variance of `expr`. It considers rows as the whole population, not as a sample, so it has the number of rows as the denominator. You can also use `VARIANCE()`, which is equivalent but is not standard SQL.
  If there are no matching rows, `VAR_POP()` returns NULL.

• `VAR_SAMP(expr)`
  Returns the sample variance of `expr`. That is, the denominator is the number of rows minus one.
  If there are no matching rows, `VAR_SAMP()` returns NULL.

• `VARIANCE(expr)`
  Returns the population standard variance of `expr`. `VARIANCE()` is a synonym for the standard SQL function `VAR_POP()`, provided as a MySQL extension.
  If there are no matching rows, `VARIANCE()` returns NULL.

### 12.17.2 GROUP BY Modifiers

The `GROUP BY` clause permits a `WITH ROLLUP` modifier that causes summary output to include extra rows that represent higher-level (that is, super-aggregate) summary operations. `ROLLUP` thus enables you to answer questions at multiple levels of analysis with a single query. For example, `ROLLUP` can be used to provide support for OLAP (Online Analytical Processing) operations.

Suppose that a `sales` table has `year`, `country`, `product`, and `profit` columns for recording sales profitability:

```sql
CREATE TABLE sales
```
GROUP BY Modifiers

```sql
(  
    year INT,
    country VARCHAR(20),
    product VARCHAR(32),
    profit INT
  );
```

To summarize table contents per year, use a simple `GROUP BY` like this:

```sql
mysql> SELECT year, SUM(profit) AS profit 
    FROM sales 
    GROUP BY year;
```

```
+------+--------+
<table>
<thead>
<tr>
<th>year</th>
<th>profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>4525</td>
</tr>
<tr>
<td>2001</td>
<td>3010</td>
</tr>
</tbody>
</table>
+------+--------+
```

The output shows the total (aggregate) profit for each year. To also determine the total profit summed over all years, you must add up the individual values yourself or run an additional query. Or you can use `ROLLUP`, which provides both levels of analysis with a single query. Adding a `WITH ROLLUP` modifier to the `GROUP BY` clause causes the query to produce another (super-aggregate) row that shows the grand total over all year values:

```sql
mysql> SELECT year, SUM(profit) AS profit 
    FROM sales 
    GROUP BY year WITH ROLLUP;
```

```
+------+--------+
<table>
<thead>
<tr>
<th>year</th>
<th>profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>4525</td>
</tr>
<tr>
<td>2001</td>
<td>3010</td>
</tr>
<tr>
<td>NULL</td>
<td>7535</td>
</tr>
</tbody>
</table>
+------+--------+
```

The `NULL` value in the `year` column identifies the grand total super-aggregate line.

`ROLLUP` has a more complex effect when there are multiple `GROUP BY` columns. In this case, each time there is a change in value in any but the last grouping column, the query produces an extra super-aggregate summary row.

For example, without `ROLLUP`, a summary of the `sales` table based on `year, country, and product` might look like this, where the output indicates summary values only at the year/country/product level of analysis:

```sql
mysql> SELECT year, country, product, SUM(profit) AS profit 
    FROM sales 
    GROUP BY year, country, product;
```

```
+------+---------+------------+--------+
<table>
<thead>
<tr>
<th>year</th>
<th>country</th>
<th>product</th>
<th>profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Finland</td>
<td>Computer</td>
<td>1500</td>
</tr>
<tr>
<td>2000</td>
<td>Finland</td>
<td>Phone</td>
<td>100</td>
</tr>
<tr>
<td>2000</td>
<td>India</td>
<td>Calculator</td>
<td>150</td>
</tr>
<tr>
<td>2000</td>
<td>India</td>
<td>Computer</td>
<td>1200</td>
</tr>
<tr>
<td>2000</td>
<td>USA</td>
<td>Calculator</td>
<td>75</td>
</tr>
<tr>
<td>2000</td>
<td>USA</td>
<td>Computer</td>
<td>1500</td>
</tr>
<tr>
<td>2001</td>
<td>Finland</td>
<td>Phone</td>
<td>10</td>
</tr>
<tr>
<td>2001</td>
<td>USA</td>
<td>Calculator</td>
<td>50</td>
</tr>
<tr>
<td>2001</td>
<td>USA</td>
<td>Computer</td>
<td>2700</td>
</tr>
<tr>
<td>2001</td>
<td>USA</td>
<td>TV</td>
<td>250</td>
</tr>
</tbody>
</table>
+------+---------+------------+--------+
```

With `ROLLUP` added, the query produces several extra rows:
GROUP BY Modifiers

Now the output includes summary information at four levels of analysis, not just one:

- Following each set of product rows for a given year and country, an extra super-aggregate summary row appears showing the total for all products. These rows have the `product` column set to `NULL`.

- Following each set of rows for a given year, an extra super-aggregate summary row appears showing the total for all countries and products. These rows have the `country` and `products` columns set to `NULL`.

- Finally, following all other rows, an extra super-aggregate summary row appears showing the grand total for all years, countries, and products. This row has the `year`, `country`, and `products` columns set to `NULL`.

The `NULL` indicators in each super-aggregate row are produced when the row is sent to the client. The server looks at the columns named in the `GROUP BY` clause following the leftmost one that has changed value. For any column in the result set with a name that matches any of those names, its value is set to `NULL`. (If you specify grouping columns by column position, the server identifies which columns to set to `NULL` by position.)

Because the `NULL` values in the super-aggregate rows are placed into the result set at such a late stage in query processing, you can test them as `NULL` values only in the select list or `HAVING` clause. You cannot test them as `NULL` values in join conditions or the `WHERE` clause to determine which rows to select. For example, you cannot add `WHERE product IS NULL` to the query to eliminate from the output all but the super-aggregate rows.

The `NULL` values do appear as `NULL` on the client side and can be tested as such using any MySQL client programming interface. However, at this point, you cannot distinguish whether a `NULL` represents a regular grouped value or a super-aggregate value.

Other Considerations When using ROLLUP

The following discussion lists some behaviors specific to the MySQL implementation of `ROLLUP`.

When you use `ROLLUP`, you cannot also use an `ORDER BY` clause to sort the results. In other words, `ROLLUP` and `ORDER BY` are mutually exclusive in MySQL. However, you still have some control over sort
order. `GROUP BY` in MySQL implicitly sorts results by default (in the absence of `ASC` or `DESC` designators). However, implicit `GROUP BY` sorting in MySQL is deprecated. To achieve a specific sort order of grouped results:

- Use explicit `ASC` and `DESC` keywords with columns named in the `GROUP BY` list to specify sort order for individual columns. In this case, the super-aggregate summary rows added by `ROLLUP` still appear after the rows from which they are calculated, regardless of the sort order.

- To work around the restriction that prevents using `ROLLUP` with `ORDER BY`, generate the grouped result set as a derived table and apply `ORDER BY` to it. For example:

  ```sql
  SELECT * FROM
  (SELECT year, SUM(profit) AS profit
   FROM sales GROUP BY year WITH ROLLUP) AS dt
  ORDER BY year DESC;
  ```

  In this case, the super-aggregate summary rows sort with the rows from which they are calculated, and their placement depends on sort order (at the beginning for ascending sort, at the end for descending sort).

  `LIMIT` can be used to restrict the number of rows returned to the client. `LIMIT` is applied after `ROLLUP`, so the limit applies against the extra rows added by `ROLLUP`. For example:

  ```sql
  SELECT year, country, product, SUM(profit) AS profit
  FROM sales
  GROUP BY year, country, product WITH ROLLUP
  LIMIT 5;
  ```

  Using `LIMIT` with `ROLLUP` may produce results that are more difficult to interpret, because there is less context for understanding the super-aggregate rows.

  A MySQL extension permits a column that does not appear in the `GROUP BY` list to be named in the `select` list. (For information about nonaggregated columns and `GROUP BY`, see Section 12.17.3, "MySQL Handling of GROUP BY".) In this case, the server is free to choose any value from this nonaggregated column in summary rows, and this includes the extra rows added by `WITH ROLLUP`. For example, in the following query, `country` is a nonaggregated column that does not appear in the `GROUP BY` list and values chosen for this column are nondeterministic:

  ```sql
  SELECT year, country, SUM(profit) AS profit
  FROM sales
  GROUP BY year WITH ROLLUP;
  ```
This behavior is permitted when the `ONLY_FULL_GROUP_BY` SQL mode is not enabled. If that mode is enabled, the server rejects the query as illegal because `country` is not listed in the `GROUP BY` clause.

### 12.17.3 MySQL Handling of GROUP BY

In standard SQL, a query that includes a `GROUP BY` clause cannot refer to nonaggregated columns in the select list that are not named in the `GROUP BY` clause. For example, this query is illegal in standard SQL because the nonaggregated `name` column in the select list does not appear in the `GROUP BY`:

```sql
SELECT o.custid, c.name, MAX(o.payment)
FROM orders AS o, customers AS c
WHERE o.custid = c.custid
GROUP BY o.custid;
```

For the query to be legal, the `name` column must be omitted from the select list or named in the `GROUP BY` clause.

MySQL extends the standard SQL use of `GROUP BY` so that the select list can refer to nonaggregated columns not named in the `GROUP BY` clause. This means that the preceding query is legal in MySQL. You can use this feature to get better performance by avoiding unnecessary column sorting and grouping. However, this is useful primarily when all values in each nonaggregated column not named in the `GROUP BY` are the same for each group. The server is free to choose any value from each group, so unless they are the same, the values chosen are nondeterministic. Furthermore, the selection of values from each group cannot be influenced by adding an `ORDER BY` clause. Result set sorting occurs after values have been chosen, and `ORDER BY` does not affect which values within each group the server chooses.

A similar MySQL extension applies to the `HAVING` clause. In standard SQL, a query cannot refer to nonaggregated columns in the `HAVING` clause that are not named in the `GROUP BY` clause. To simplify calculations, a MySQL extension permits references to such columns. This extension assumes that the nongrouped columns have the same group-wise values. Otherwise, the result is nondeterministic.

To disable the MySQL `GROUP BY` extension and enable standard SQL behavior, enable the `ONLY_FULL_GROUP_BY` SQL mode. In this case, columns not named in the `GROUP BY` clause cannot be used in the select list or `HAVING` clause unless enclosed in an aggregate function.

The select list extension also applies to `ORDER BY`. That is, you can refer to nonaggregated columns in the `ORDER BY` clause that do not appear in the `GROUP BY` clause. (However, as mentioned previously, `ORDER BY` does not affect which values are chosen from nonaggregated columns; it only sorts them after they have been chosen.) This extension does not apply if the `ONLY_FULL_GROUP_BY` SQL mode is enabled.

If a query has aggregate functions and no `GROUP BY` clause, it cannot have nonaggregated columns in the select list, `HAVING` condition, or `ORDER BY` list with `ONLY_FULL_GROUP_BY` enabled:

```sql
mysql> SELECT name, MAX(age) FROM t;
ERROR 1140 (42000): Mixing of GROUP columns (MIN(),MAX(),COUNT(),...)
with no GROUP BY clause is illegal if there is no GROUP BY clause
```

Without `GROUP BY`, there is a single group and it is nondeterministic which `name` value to choose for the group.

Another MySQL extension to standard SQL permits references in the `HAVING` clause to aliased expressions in the select list. Enabling `ONLY_FULL_GROUP_BY` prevents this. For example, the following query returns `name` values that occur only once in table `orders`; the query is accepted regardless of whether `ONLY_FULL_GROUP_BY` is enabled:
SELECT name, COUNT(name) FROM orders 
    GROUP BY name 
    HAVING COUNT(name) = 1;

The following query is accepted only if `ONLY_FULL_GROUP_BY` is disabled.

SELECT name, COUNT(name) AS c FROM orders 
    GROUP BY name 
    HAVING c = 1;

If you are trying to follow standard SQL, you can use only column expressions in `GROUP BY` clauses. As a workaround, use an alias for the expression:

```
SELECT id, FLOOR(value/100) AS val 
FROM tbl_name 
GROUP BY id, val;
```

MySQL permits noncolumn expressions in `GROUP BY` clauses, so the alias is unnecessary:

```
SELECT id, FLOOR(value/100) 
FROM tbl_name 
GROUP BY id, FLOOR(value/100);
```

### 12.18 Miscellaneous Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFAULT()</td>
<td>Return the default value for a table column</td>
</tr>
<tr>
<td>INET_ATON()</td>
<td>Return the numeric value of an IP address</td>
</tr>
<tr>
<td>INET_NTOA()</td>
<td>Return the IP address from a numeric value</td>
</tr>
<tr>
<td>MASTER_POS_WAIT()</td>
<td>Block until the slave has read and applied all updates up to the specified position</td>
</tr>
<tr>
<td>NAME_CONST()</td>
<td>Cause the column to have the given name</td>
</tr>
<tr>
<td>SLEEP()</td>
<td>Sleep for a number of seconds</td>
</tr>
<tr>
<td>UUID()</td>
<td>Return a Universal Unique Identifier (UUID)</td>
</tr>
<tr>
<td>UUID_SHORT()</td>
<td>Return an integer-valued universal identifier</td>
</tr>
<tr>
<td>VALUES()</td>
<td>Define the values to be used during an INSERT</td>
</tr>
</tbody>
</table>

- **DEFAULT(col_name)**
  Returns the default value for a table column. An error results if the column has no default value.

```
mysql> UPDATE t SET i = DEFAULT(i)+1 WHERE id < 100;
```

- **FORMAT(X, D)**
  Formats the number $X$ to a format like `'#,###,##.##'`, rounded to $D$ decimal places, and returns the result as a string. For details, see Section 12.7, “String Functions and Operators”.

- **INET_ATON(expr)**
  Given the dotted-quad representation of an IPv4 network address as a string, returns an integer that represents the numeric value of the address in network byte order (big endian). `INET_ATON()` returns `NULL` if it does not understand its argument.
For this example, the return value is calculated as $10 \times 256^3 + 0 \times 256^2 + 5 \times 256 + 9$.

**INET_ATON()** may or may not return a non-NULL result for short-form IP addresses (such as `'127.1'` as a representation of `'127.0.0.1'`). Because of this, **INET_ATON()** a should not be used for such addresses.

### Note
To store values generated by **INET_ATON()**, use an **INT UNSIGNED** column rather than **INT**, which is signed. If you use a signed column, values corresponding to IP addresses for which the first octet is greater than 127 cannot be stored correctly. See Section 11.1.7, "Out-of-Range and Overflow Handling".

**INET_NTOA(expr)**

Given a numeric IPv4 network address in network byte order, returns the dotted-quad representation of the address as a string. **INET_NTOA()** returns **NULL** if it does not understand its argument.

The return value is a string in the connection character set.

```
mysql> SELECT INET_NTOA(167773449);
-> '10.0.5.9'
```

**MASTER_POS_WAIT(log_name, log_pos[, timeout])**

This function is useful for control of master/slave synchronization. It blocks until the slave has read and applied all updates up to the specified position in the master log. The return value is the number of log events the slave had to wait for to advance to the specified position. The function returns **NULL** if the slave SQL thread is not started, the slave’s master information is not initialized, the arguments are incorrect, or an error occurs. It returns **-1** if the timeout has been exceeded. If the slave SQL thread stops while **MASTER_POS_WAIT()** is waiting, the function returns **NULL**. If the slave is past the specified position, the function returns immediately.

If a **timeout** value is specified, **MASTER_POS_WAIT()** stops waiting when **timeout** seconds have elapsed. **timeout** must be greater than 0; a zero or negative **timeout** means no timeout. The lock is exclusive. While held by one session, other sessions cannot obtain a lock of the same name.

This function is unsafe for statement-based replication. A warning is logged if you use this function when **binlog_format** is set to **STATEMENT**.

**NAME_CONST(name, value)**

Returns the given value. When used to produce a result set column, **NAME_CONST()** causes the column to have the given name. The arguments should be constants.

```
mysql> SELECT NAME_CONST('myname', 14);
+--------+
| myname |
| 14     |
+--------+
```

This function is for internal use only. The server uses it when writing statements from stored programs that contain references to local program variables, as described in Section 20.7, "Stored Program Binary Logging". You might see this function in the output from **mysqlbinlog**.
For your applications, you can obtain exactly the same result as in the example just shown by using simple aliasing, like this:

```
mysql> SELECT 14 AS myname;
+--------+
| myname |
|   14   |
+--------+
1 row in set (0.00 sec)
```

See Section 13.2.9, “SELECT Statement”, for more information about column aliases.

- **SLEEP**(duration)

Sleeps (pauses) for the number of seconds given by the `duration` argument, then returns 0. If `SLEEP()` is interrupted, it returns 1. The duration may have a fractional part.

When `SLEEP()` returns normally (without interruption), it returns 0:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
|           0  |
+-------------+
```

When `SLEEP()` is the only thing invoked by a query that is interrupted, it returns 1 and the query itself returns no error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
|           1  |
+-------------+
```

When `SLEEP()` is only part of a query that is interrupted, the query returns an error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT 1 FROM t1 WHERE SLEEP(1000);
ERROR 1317 (70100): Query execution was interrupted
```

This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. 
• **UUID()**

Returns a Universal Unique Identifier (UUID) generated according to RFC 4122, “A Universally Unique Identifier (UUID) URN Namespace” (http://www.ietf.org/rfc/rfc4122.txt).

A UUID is designed as a number that is globally unique in space and time. Two calls to `UUID()` are expected to generate two different values, even if these calls are performed on two separate devices not connected to each other.

**Warning**

Although `UUID()` values are intended to be unique, they are not necessarily unguessable or unpredictable. If unpredictability is required, UUID values should be generated some other way.

`UUID()` returns a value that conforms to UUID version 1 as described in RFC 4122. The value is a 128-bit number represented as a `utf8` string of five hexadecimal numbers in `aaaaaaaa-bbbb-cccc-dddd-eeeeeeeeeeee` format:

- The first three numbers are generated from the low, middle, and high parts of a timestamp. The high part also includes the UUID version number.
- The fourth number preserves temporal uniqueness in case the timestamp value loses monotonicity (for example, due to daylight saving time).
- The fifth number is an IEEE 802 node number that provides spatial uniqueness. A random number is substituted if the latter is not available (for example, because the host device has no Ethernet card, or it is unknown how to find the hardware address of an interface on the host operating system). In this case, spatial uniqueness cannot be guaranteed. Nevertheless, a collision should have very low probability.

The MAC address of an interface is taken into account only on FreeBSD, Linux, and Windows. On other operating systems, MySQL uses a randomly generated 48-bit number.

```sql
mysql> SELECT UUID();
-> '6ccd780c-baba-1026-9564-5b8c656024db'
```

This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`.

• **UUID_SHORT()**

Returns a “short” universal identifier as a 64-bit unsigned integer. Values returned by `UUID_SHORT()` differ from the string-format 128-bit identifiers returned by the `UUID()` function and have different
Precision Math

uniqueness properties. The value of `UUID_SHORT()` is guaranteed to be unique if the following conditions hold:

- The `server_id` value of the current server is between 0 and 255 and is unique among your set of master and slave servers
- You do not set back the system time for your server host between `mysqld` restarts
- You invoke `UUID_SHORT()` on average fewer than 16 million times per second between `mysqld` restarts

The `UUID_SHORT()` return value is constructed this way:

```
(server_id & 255) << 56
+ (server_startup_time_in_seconds << 24)
+ incremented_variable++;
```

```
mysql> SELECT UUID_SHORT();
    -> 92395783831158784
```

Note

`UUID_SHORT()` does not work with statement-based replication.

- `VALUES(col_name)`

In an `INSERT ... ON DUPLICATE KEY UPDATE` statement, you can use the `VALUES(col_name)` function in the `UPDATE` clause to refer to column values from the `INSERT` portion of the statement. In other words, `VALUES(col_name)` in the `UPDATE` clause refers to the value of `col_name` that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is meaningful only in the `ON DUPLICATE KEY UPDATE` clause of `INSERT` statements and returns `NULL` otherwise. See Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”.

```
mysql> INSERT INTO table (a,b,c) VALUES (1,2,3),(4,5,6)
    -> ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
```

12.19 Precision Math

MySQL provides support for precision math: numeric value handling that results in extremely accurate results and a high degree control over invalid values. Precision math is based on these two features:

- SQL modes that control how strict the server is about accepting or rejecting invalid data.
- The MySQL library for fixed-point arithmetic.

These features have several implications for numeric operations and provide a high degree of compliance with standard SQL:

- **Precise calculations**: For exact-value numbers, calculations do not introduce floating-point errors. Instead, exact precision is used. For example, MySQL treats a number such as `.0001` as an exact value rather than as an approximation, and summing it 10,000 times produces a result of exactly 1, not a value that is merely “close” to 1.

- **Well-defined rounding behavior**: For exact-value numbers, the result of `ROUND()` depends on its argument, not on environmental factors such as how the underlying C library works.
Types of Numeric Values

- **Platform independence**: Operations on exact numeric values are the same across different platforms such as Windows and Unix.

- **Control over handling of invalid values**: Overflow and division by zero are detectable and can be treated as errors. For example, you can treat a value that is too large for a column as an error rather than having the value truncated to lie within the range of the column’s data type. Similarly, you can treat division by zero as an error rather than as an operation that produces a result of NULL. The choice of which approach to take is determined by the setting of the server SQL mode.

The following discussion covers several aspects of how precision math works, including possible incompatibilities with older applications. At the end, some examples are given that demonstrate how MySQL handles numeric operations precisely. For information about controlling the SQL mode, see Section 5.1.10, “Server SQL Modes”.

### 12.19.1 Types of Numeric Values

The scope of precision math for exact-value operations includes the exact-value data types (integer and `DECIMAL` types) and exact-value numeric literals. Approximate-value data types and numeric literals are handled as floating-point numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: `1`, `.2`, `3.4`, `−5`, `−6.78`, `+9.10`.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: `1.2E3`, `1.2E−3`, `−1.2E3`, `−1.2E−3`.

Two numbers that look similar may be treated differently. For example, `2.34` is an exact-value (fixed-point) number, whereas `2.34E0` is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types.

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

### 12.19.2 DECIMAL Data Type Characteristics

This section discusses the characteristics of the `DECIMAL` data type (and its synonyms), with particular regard to the following topics:

- Maximum number of digits
- Storage format
- Storage requirements
- The nonstandard MySQL extension to the upper range of `DECIMAL` columns

Possible incompatibilities with applications that are written for older versions of MySQL (prior to 5.0.3) are noted throughout this section.

The declaration syntax for a `DECIMAL` column is `DECIMAL (M, D)`. The ranges of values for the arguments are as follows:

- `M` is the maximum number of digits (the precision). It has a range of 1 to 65. (Older versions of MySQL permitted a range of 1 to 254.)
• $D$ is the number of digits to the right of the decimal point (the scale). It has a range of 0 to 30 and must be no larger than $M$.

If $D$ is omitted, the default is 0. If $M$ is omitted, the default is 10.

The maximum value of 65 for $M$ means that calculations on \texttt{DECIMAL} values are accurate up to 65 digits. This limit of 65 digits of precision also applies to exact-value numeric literals, so the maximum range of such literals differs from before. (In older versions of MySQL, decimal values could have up to 254 digits. However, calculations were done using floating-point and thus were approximate, not exact.)

Values for \texttt{DECIMAL} columns are stored using a binary format that packs nine decimal digits into 4 bytes. The storage requirements for the integer and fractional parts of each value are determined separately. Each multiple of nine digits requires 4 bytes, and any remaining digits left over require some fraction of 4 bytes. The storage required for remaining digits is given by the following table.

<table>
<thead>
<tr>
<th>Leftover Digits</th>
<th>Number of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1–2</td>
<td>1</td>
</tr>
<tr>
<td>3–4</td>
<td>2</td>
</tr>
<tr>
<td>5–6</td>
<td>3</td>
</tr>
<tr>
<td>7–9</td>
<td>4</td>
</tr>
</tbody>
</table>

For example, a \texttt{DECIMAL(18, 9)} column has nine digits on either side of the decimal point, so the integer part and the fractional part each require 4 bytes. A \texttt{DECIMAL(20, 6)} column has fourteen integer digits and six fractional digits. The integer digits require four bytes for nine of the digits and 3 bytes for the remaining five digits. The six fractional digits require 3 bytes.

Unlike some older versions of MySQL, \texttt{DECIMAL} columns in MySQL 5.5 do not store a leading + character or – character or leading 0 digits. If you insert +0003.1 into a \texttt{DECIMAL(5, 1)} column, it is stored as 3.1. For negative numbers, a literal – character is not stored. Applications that rely on the older behavior must be modified to account for this change.

\texttt{DECIMAL} columns do not permit values larger than the range implied by the column definition. For example, a \texttt{DECIMAL(3, 0)} column supports a range of $-999$ to $999$. A \texttt{DECIMAL(M, D)} column permits up to $M - D$ digits to the left of the decimal point. This is not compatible with applications relying on older versions of MySQL that permitted storing an extra digit in lieu of a + sign.

The SQL standard requires that the precision of \texttt{NUMERIC(M, D)} be exactly $M$ digits. For \texttt{DECIMAL(M, D)}, the standard requires a precision of at least $M$ digits but permits more. In MySQL, \texttt{DECIMAL(M, D)} and \texttt{NUMERIC(M, D)} are the same, and both have a precision of exactly $M$ digits.

For a full explanation of the internal format of \texttt{DECIMAL} values, see the file \texttt{strings/decimal.c} in a MySQL source distribution. The format is explained (with an example) in the \texttt{decimal2bin()} function.

For more detailed information about porting applications that rely on the old treatment of the \texttt{DECIMAL} data type, see the \texttt{MySQL 5.0 Reference Manual}.

12.19.3 Expression Handling

With precision math, exact-value numbers are used as given whenever possible. For example, numbers in comparisons are used exactly as given without a change in value. In strict SQL mode, for \texttt{INSERT} into a column with an exact data type (\texttt{DECIMAL} or integer), a number is inserted with its exact value if it is within the column range. When retrieved, the value should be the same as what was inserted. (If strict SQL mode is not enabled, truncation for \texttt{INSERT} is permissible.)
Handling of a numeric expression depends on what kind of values the expression contains:

- If any approximate values are present, the expression is approximate and is evaluated using floating-point arithmetic.

- If no approximate values are present, the expression contains only exact values. If any exact value contains a fractional part (a value following the decimal point), the expression is evaluated using DECIMAL exact arithmetic and has a precision of 65 digits. The term “exact” is subject to the limits of what can be represented in binary. For example, \( \frac{1.0}{3.0} \) can be approximated in decimal notation as \( .333... \), but not written as an exact number, so \( (1.0/3.0)*3.0 \) does not evaluate to exactly 1.0.

- Otherwise, the expression contains only integer values. The expression is exact and is evaluated using integer arithmetic and has a precision the same as BIGINT (64 bits).

If a numeric expression contains any strings, they are converted to double-precision floating-point values and the expression is approximate.

Inserts into numeric columns are affected by the SQL mode, which is controlled by the sql_mode system variable. (See Section 5.1.10, “Server SQL Modes”.) The following discussion mentions strict mode (selected by the STRICT_ALL_TABLES or STRICT_TRANS_TABLES mode values) and ERROR_FOR_DIVISION_BY_ZERO. To turn on all restrictions, you can simply use TRADITIONAL mode, which includes both strict mode values and ERROR_FOR_DIVISION_BY_ZERO:

```
SET sql_mode='TRADITIONAL';
```

If a number is inserted into an exact type column (DECIMAL or integer), it is inserted with its exact value if it is within the column range and precision.

If the value has too many digits in the fractional part, rounding occurs and a note is generated. Rounding is done as described in Section 12.19.4, “Rounding Behavior”. Truncation due to rounding of the fractional part is not an error, even in strict mode.

If the value has too many digits in the integer part, it is too large (out of range) and is handled as follows:

- If strict mode is not enabled, the value is truncated to the nearest legal value and a warning is generated.

- If strict mode is enabled, an overflow error occurs.

Underflow is not detected, so underflow handling is undefined.

For inserts of strings into numeric columns, conversion from string to number is handled as follows if the string has nonnumeric contents:

- A string that does not begin with a number cannot be used as a number and produces an error in strict mode, or a warning otherwise. This includes the empty string.

- A string that begins with a number can be converted, but the trailing nonnumeric portion is truncated. If the truncated portion contains anything other than spaces, this produces an error in strict mode, or a warning otherwise.

By default, division by zero produces a result of NULL and no warning. By setting the SQL mode appropriately, division by zero can be restricted.

With the ERROR_FOR_DIVISION_BY_ZERO SQL mode enabled, MySQL handles division by zero differently:

- If strict mode is not enabled, a warning occurs.
Rounding Behavior

• If strict mode is enabled, inserts and updates involving division by zero are prohibited, and an error occurs.

In other words, inserts and updates involving expressions that perform division by zero can be treated as errors, but this requires `ERROR_FOR_DIVISION_BY_ZERO` in addition to strict mode.

Suppose that we have this statement:

```sql
INSERT INTO t SET i = 1/0;
```

This is what happens for combinations of strict and `ERROR_FOR_DIVISION_BY_ZERO` modes.

<table>
<thead>
<tr>
<th>sql_mode Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>'' (Default)</td>
<td>No warning, no error; i is set to NULL.</td>
</tr>
<tr>
<td>strict</td>
<td>No warning, no error; i is set to NULL.</td>
</tr>
<tr>
<td><code>ERROR_FOR_DIVISION_BY_ZERO</code></td>
<td>Warning, no error; i is set to NULL.</td>
</tr>
<tr>
<td>strict, <code>ERROR_FOR_DIVISION_BY_ZERO</code></td>
<td>Error condition; no row is inserted.</td>
</tr>
</tbody>
</table>

**12.19.4 Rounding Behavior**

This section discusses precision math rounding for the `ROUND()` function and for inserts into columns with exact-value types (`DECIMAL` and integer).

The `ROUND()` function rounds differently depending on whether its argument is exact or approximate:

• For exact-value numbers, `ROUND()` uses the “round half up” rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative. (In other words, it is rounded toward zero.)

• For approximate-value numbers, the result depends on the C library. On many systems, this means that `ROUND()` uses the “round to nearest even” rule: A value with a fractional part exactly half way between two integers is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

```sql
mysql> SELECT ROUND(2.5), ROUND(25E-1);
+------------+--------------+
<table>
<thead>
<tr>
<th>ROUND(2.5)</th>
<th>ROUND(25E-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
```

For inserts into a `DECIMAL` or integer column, the target is an exact data type, so rounding uses “round half away from zero,” regardless of whether the value to be inserted is exact or approximate:

```sql
mysql> CREATE TABLE t (d DECIMAL(10,0));
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t VALUES(2.5),(2.5E0);
Query OK, 2 rows affected, 2 warnings (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 2

mysql> SHOW WARNINGS;
+-------+------+----------------------------------------+
<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note</td>
<td>1265</td>
<td>Data truncated for column 'd' at row 1</td>
</tr>
<tr>
<td>Note</td>
<td>1265</td>
<td>Data truncated for column 'd' at row 2</td>
</tr>
</tbody>
</table>
```
12.19.5 Precision Math Examples

This section provides some examples that show precision math query results in MySQL. These examples demonstrate the principles described in Section 12.19.3, “Expression Handling”, and Section 12.19.4, “Rounding Behavior”.

Example 1. Numbers are used with their exact value as given when possible:

```
mysql> SELECT (.1 + .2) = .3;
+----------------+
| (.1 + .2) = .3 |
+----------------+
|             1   |
+----------------+
```

For floating-point values, results are inexact:

```
mysql> SELECT (.1E0 + .2E0) = .3E0;
+----------------------+
| (.1E0 + .2E0) = .3E0 |
+----------------------+
|                   0   |
+----------------------+
```

Another way to see the difference in exact and approximate value handling is to add a small number to a sum many times. Consider the following stored procedure, which adds .0001 to a variable 1,000 times.

```
CREATE PROCEDURE p ()
BEGIN
    DECLARE i INT DEFAULT 0;
    DECLARE d DECIMAL(10,4) DEFAULT 0;
    DECLARE f FLOAT DEFAULT 0;
    WHILE i < 10000 DO
        SET d = d + .0001;
        SET f = f + .0001E0;
        SET i = i + 1;
    END WHILE;
    SELECT d, f;
END;
```

The sum for both \( d \) and \( f \) logically should be 1, but that is true only for the decimal calculation. The floating-point calculation introduces small errors:

```
<table>
<thead>
<tr>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.99999999999991</td>
</tr>
</tbody>
</table>
```
Example 2. Multiplication is performed with the scale required by standard SQL. That is, for two numbers $X_1$ and $X_2$ that have scale $S_1$ and $S_2$, the scale of the result is $S_1 + S_2$:

```sql
mysql> SELECT .01 * .01;
+-----------+
| .01 * .01  |
+-----------+
| 0.0001    |
+-----------+
```

Example 3. Rounding behavior for exact-value numbers is well-defined:

Rounding behavior (for example, with the `ROUND()` function) is independent of the implementation of the underlying C library, which means that results are consistent from platform to platform.

- Rounding for exact-value columns (`DECIMAL` and integer) and exact-valued numbers uses the “round half away from zero” rule. A value with a fractional part of .5 or greater is rounded away from zero to the nearest integer, as shown here:

```sql
mysql> SELECT ROUND(2.5), ROUND(-2.5);
+------------+-------------+
| ROUND(2.5) | ROUND(-2.5) |
+------------+-------------+
| 3          | -3          |
+------------+-------------+
```

- Rounding for floating-point values uses the C library, which on many systems uses the “round to nearest even” rule. A value with a fractional part exactly half way between two integers is rounded to the nearest even integer:

```sql
mysql> SELECT ROUND(2.5E0), ROUND(-2.5E0);
+--------------+---------------+
| ROUND(2.5E0) | ROUND(-2.5E0) |
+--------------+---------------+
| 2            | -2            |
+--------------+---------------+
```

Example 4. In strict mode, inserting a value that is out of range for a column causes an error, rather than truncation to a legal value.

When MySQL is not running in strict mode, truncation to a legal value occurs:

```sql
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)
mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.01 sec)
mysql> INSERT INTO t SET i = 128;
Query OK, 1 row affected, 1 warning (0.00 sec)
mysql> SELECT i FROM t;
+------+
| i    |
+------+
| 127  |
+------+
1 row in set (0.00 sec)
```

However, an error occurs if strict mode is in effect:

```sql
mysql> SET sql_mode='STRICT_ALL_TABLES';
Query OK, 0 rows affected (0.00 sec)
```
Example 5: In strict mode and with ERROR_FOR_DIVISION_BY_ZERO set, division by zero causes an error, not a result of NULL.

In nonstrict mode, division by zero has a result of NULL:

However, division by zero is an error if the proper SQL modes are in effect:

Example 6. Exact-value literals are evaluated as exact values.

Prior to MySQL 5.0.3, exact-value and approximate-value literals both are evaluated as double-precision floating-point values:
As of MySQL 5.0.3, the approximate-value literal is evaluated using floating point, but the exact-value literal is handled as DECIMAL:

mysql> SELECT VERSION();
+-----------------+
| VERSION()       |
+-----------------+
| 5.1.6-alpha-log |
+-----------------+
1 row in set (0.11 sec)

mysql> CREATE TABLE t SELECT 2.5 AS a, 25E-1 AS b;
Query OK, 1 row affected (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> DESCRIBE t;
+-------+-----------------------+------+-----+---------+-------+
| Field | Type                  | Null | Key | Default | Extra |
+-------+-----------------------+------+-----+---------+-------+
| a     | decimal(2,1) unsigned | NO   |     | 0.0     |       |
| b     | double                | NO   |     | 0       |       |
+-------+-----------------------+------+-----+---------+-------+
2 rows in set (0.01 sec)

**Example 7.** If the argument to an aggregate function is an exact numeric type, the result is also an exact numeric type, with a scale at least that of the argument.

Consider these statements:

mysql> CREATE TABLE t (i INT, d DECIMAL, f FLOAT);
mysql> INSERT INTO t VALUES(1,1,1);
mysql> CREATE TABLE y SELECT AVG(i), AVG(d), AVG(f) FROM t;

Before MySQL 5.0.3, the result is a double no matter the argument type:

mysql> DESCRIBE y;
+--------+--------------+------+-----+---------+-------+
| Field  | Type         | Null | Key | Default | Extra |
+--------+--------------+------+-----+---------+-------+
| AVG(i) | double(17,4) | YES  |     | NULL    |       |
| AVG(d) | double(17,4) | YES  |     | NULL    |       |
| AVG(f) | double       | YES  |     | NULL    |       |
+--------+--------------+------+-----+---------+-------+
3 rows in set (0.01 sec)

As of MySQL 5.0.3, the result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type:

mysql> DESCRIBE y;
+--------+---------------+------+-----+---------+-------+
| Field  | Type          | Null | Key | Default | Extra |
+--------+---------------+------+-----+---------+-------+
| AVG(i) | decimal(14,4)| YES  |     | NULL    |       |
| AVG(d) | decimal(14,4)| YES  |     | NULL    |       |
| AVG(f) | double        | YES  |     | NULL    |       |
+--------+---------------+------+-----+---------+-------+
3 rows in set (0.01 sec)

The result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type.
## Table of Contents

### 13.1 Data Definition Statements
- 13.1.1 ALTER DATABASE Statement .................................................. 1386
- 13.1.2 ALTER EVENT Statement ....................................................... 1387
- 13.1.3 ALTER FUNCTION Statement .................................................. 1389
- 13.1.4 ALTER LOGFILE GROUP Statement .......................................... 1389
- 13.1.5 ALTER PROCEDURE Statement ................................................. 1390
- 13.1.6 ALTER SERVER Statement ..................................................... 1391
- 13.1.7 ALTER TABLE Statement ....................................................... 1391
- 13.1.8 ALTER TABLESPACE Statement .............................................. 1410
- 13.1.9 ALTER VIEW Statement ......................................................... 1411
- 13.1.10 CREATE DATABASE Statement .............................................. 1411
- 13.1.11 CREATE EVENT Statement .................................................. 1412
- 13.1.12 CREATE FUNCTION Statement ............................................. 1416
- 13.1.13 CREATE INDEX Statement ................................................... 1417
- 13.1.14 CREATE LOGFILE GROUP Statement ...................................... 1422
- 13.1.15 CREATE PROCEDURE and CREATE FUNCTION Statements .......... 1423
- 13.1.16 CREATE SERVER Statement .................................................. 1429
- 13.1.17 CREATE TABLE Statement .................................................... 1430
- 13.1.18 CREATE TABLESPACE Statement ........................................... 1464
- 13.1.19 CREATE TRIGGER Statement ............................................... 1465
- 13.1.20 CREATE VIEW Statement .................................................... 1467
- 13.1.21 DROP DATABASE Statement ................................................. 1471
- 13.1.22 DROP EVENT Statement ..................................................... 1473
- 13.1.23 DROP FUNCTION Statement ................................................ 1473
- 13.1.24 DROP INDEX Statement ....................................................... 1473
- 13.1.25 DROP LOGFILE GROUP Statement ....................................... 1473
- 13.1.26 DROP PROCEDURE and DROP FUNCTION Statements ............. 1474
- 13.1.27 DROP SERVER Statement .................................................... 1474
- 13.1.28 DROP TABLE Statement ....................................................... 1474
- 13.1.29 DROP TABLESPACE Statement ............................................ 1475
- 13.1.30 DROP TRIGGER Statement .................................................. 1476
- 13.1.31 DROP VIEW Statement ....................................................... 1476
- 13.1.32 RENAME TABLE Statement ................................................ 1476
- 13.1.33 TRUNCATE TABLE Statement ............................................... 1477

### 13.2 Data Manipulation Statements
- 13.2.1 CALL Statement ............................................................... 1478
- 13.2.2 DELETE Statement ............................................................. 1480
- 13.2.3 DO Statement ................................................................. 1483
- 13.2.4 HANDLER Statement ........................................................ 1484
- 13.2.5 INSERT Statement ............................................................ 1485
- 13.2.6 LOAD DATA Statement ........................................................ 1494
- 13.2.7 LOAD XML Statement .......................................................... 1504
- 13.2.8 REPLACE Statement ............................................................ 1512
- 13.2.9 SELECT Statement ............................................................. 1514
- 13.2.10 Subqueries ................................................................. 1529
- 13.2.11 UPDATE Statement ............................................................ 1543

### 13.3 Transactional and Locking Statements
- 13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Statements .... 1545
13.1 Data Definition Statements

13.1.1 ALTER DATABASE Statement

```
ALTER [DATABASE | SCHEMA] [db_name]
    alter_specification ...
```

```
ALTER [DATABASE | SCHEMA] db_name
    UPGRADE DATA DIRECTORY NAME
```

```
alter_specification:
    [DEFAULT] CHARACTER SET [=] charset_name
    | [DEFAULT] COLLATE [=] collation_name
```

ALTER DATABASE enables you to change the overall characteristics of a database. These characteristics are stored in the `db.opt` file in the database directory. To use ALTER DATABASE, you need the ALTER privilege on the database. ALTER SCHEMA is a synonym for ALTER DATABASE.

The database name can be omitted from the first syntax, in which case the statement applies to the default database.
National Language Characteristics

The CHARACTER SET clause changes the default database character set. The COLLATE clause changes the default database collation. Chapter 10, Character Sets, Collations, Unicode, discusses character set and collation names.

You can see what character sets and collations are available using, respectively, the SHOW CHARACTER SET and SHOW COLLATION statements. See Section 13.7.5.4, “SHOW CHARACTER SET Statement”, and Section 13.7.5.5, “SHOW COLLATION Statement”, for more information.

If you change the default character set or collation for a database, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”.)

Upgrading from Versions Older than MySQL 5.1

The syntax that includes the UPGRADE DATA DIRECTORY NAME clause updates the name of the directory associated with the database to use the encoding implemented in MySQL 5.1 for mapping database names to database directory names (see Section 9.2.4, “Mapping of Identifiers to File Names”). This clause is for use under these conditions:

• It is intended when upgrading MySQL to 5.1 or later from older versions.
• It is intended to update a database directory name to the current encoding format if the name contains special characters that need encoding.
• The statement is used by mysqlcheck (as invoked by mysql_upgrade).

For example, if a database in MySQL 5.0 has the name a-b-c, the name contains instances of the – (dash) character. In MySQL 5.0, the database directory is also named a-b-c, which is not necessarily safe for all file systems. In MySQL 5.1 and later, the same database name is encoded as a@002db@002dc to produce a file system-neutral directory name.

When a MySQL installation is upgraded to MySQL 5.1 or later from an older version, the server displays a name such as a-b-c (which is in the old format) as #mysql50#a-b-c, and you must refer to the name using the #mysql50# prefix. Use UPGRADE DATA DIRECTORY NAME in this case to explicitly tell the server to re-encode the database directory name to the current encoding format:

```sql
ALTER DATABASE `#mysql50#a-b-c` UPGRADE DATA DIRECTORY NAME;
```

After executing this statement, you can refer to the database as a-b-c without the special #mysql50# prefix.

13.1.2 ALTER EVENT Statement

The ALTER EVENT statement changes one or more of the characteristics of an existing event without the need to drop and recreate it. The syntax for each of the DEFINER, ON SCHEDULE, ON COMPLETION, COMMENT, ENABLE / DISABLE, and DO clauses is exactly the same as when used with CREATE EVENT. (See Section 13.1.11, “CREATE EVENT Statement”.)
Any user can alter an event defined on a database for which that user has the `EVENT` privilege. When a user executes a successful `ALTER EVENT` statement, that user becomes the definer for the affected event.

`ALTER EVENT` works only with an existing event:

```
mysql> ALTER EVENT no_such_event
    > ON SCHEDULE
    > EVERY '2:3' DAY_HOUR;
ERROR 1517 (HY000): Unknown event 'no_such_event'
```

In each of the following examples, assume that the event named `myevent` is defined as shown here:

```
CREATE EVENT myevent
    ON SCHEDULE
        EVERY 6 HOUR
    COMMENT 'A sample comment.'
    DO
        UPDATE myschema.mytable SET mycol = mycol + 1;
```

The following statement changes the schedule for `myevent` from once every six hours starting immediately to once every twelve hours, starting four hours from the time the statement is run:

```
ALTER EVENT myevent
    ON SCHEDULE
        EVERY 12 HOUR
    STARTS CURRENT_TIMESTAMP + INTERVAL 4 HOUR;
```

It is possible to change multiple characteristics of an event in a single statement. This example changes the SQL statement executed by `myevent` to one that deletes all records from `mytable`; it also changes the schedule for the event such that it executes once, one day after this `ALTER EVENT` statement is run.

```
ALTER EVENT myevent
    ON SCHEDULE
        AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
    DO
        TRUNCATE TABLE myschema.mytable;
```

Specify the options in an `ALTER EVENT` statement only for those characteristics that you want to change; omitted options keep their existing values. This includes any default values for `CREATE EVENT` such as `ENABLE`.

To disable `myevent`, use this `ALTER EVENT` statement:

```
ALTER EVENT myevent
    DISABLE;
```

The `ON SCHEDULE` clause may use expressions involving built-in MySQL functions and user variables to obtain any of the `timestamp` or `interval` values which it contains. You cannot use stored routines or user-defined functions in such expressions, and you cannot use any table references; however, you can use `SELECT FROM DUAL`. This is true for both `ALTER EVENT` and `CREATE EVENT` statements. References to stored routines, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Although an `ALTER EVENT` statement that contains another `ALTER EVENT` statement in its `DO` clause appears to succeed, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

To rename an event, use the `ALTER EVENT` statement's `RENAME TO` clause. This statement renames the event `myevent` to `yourevent`:

```
ALTER EVENT myevent
    RENAME TO yourevent;
```
You can also move an event to a different database using `ALTER EVENT ... RENAME TO ...` and `db_name.event_name` notation, as shown here:

```
ALTER EVENT olddb.myevent
    RENAME TO newdb.myevent;
```

To execute the previous statement, the user executing it must have the `EVENT` privilege on both the `olddb` and `newdb` databases.

**Note**

There is no `RENAME EVENT` statement.

The value `DISABLE ON SLAVE` is used on a replication slave instead of `ENABLE` or `DISABLE` to indicate an event that was created on the master and replicated to the slave, but that is not executed on the slave. Normally, `DISABLE ON SLAVE` is set automatically as required; however, there are some circumstances under which you may want or need to change it manually. See Section 17.4.1.15, "Replication of Invoked Features", for more information.

### 13.1.3 ALTER FUNCTION Statement

```
ALTER FUNCTION func_name [characteristic ...]
```

This statement can be used to change the characteristics of a stored function. More than one change may be specified in an `ALTER FUNCTION` statement. However, you cannot change the parameters or body of a stored function using this statement; to make such changes, you must drop and re-create the function using `DROP FUNCTION` and `CREATE FUNCTION`.

You must have the `ALTER ROUTINE` privilege for the function. (That privilege is granted automatically to the function creator.) If binary logging is enabled, the `ALTER FUNCTION` statement might also require the `SUPER` privilege, as described in Section 20.7, “Stored Program Binary Logging”.

### 13.1.4 ALTER LOGFILE GROUP Statement

```
ALTER LOGFILE GROUP logfile_group
    ADD UNDOFILE 'file_name'
    [INITIAL_SIZE [=] size]
    [WAIT]
    ENGINE [=] engine_name
```

This statement adds an UNDO file named `file_name` to an existing log file group `logfile_group`. An `ALTER LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. No `DROP UNDOFILE` clause is currently supported.

**Note**

All NDB Cluster Disk Data objects share the same namespace. This means that each Disk Data object must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and an undo log file with the same name, or an undo log file and a data file with the same name.

The optional `INITIAL_SIZE` parameter sets the UNDO file’s initial size in bytes; if not specified, the initial size defaults to `134217728` (128 MB). Prior to MySQL NDB Cluster 7.2.14, this value was required to be
ALTER PROCEDURE Statement

specified using digits (Bug #13116514, Bug #16104705, Bug #62858); in MySQL NDB Cluster 7.2.14 and later, you may optionally follow size with a one-letter abbreviation for an order of magnitude, similar to those used in my.cnf. Generally, this is one of the letters M (megabytes) or G (gigabytes).

On 32-bit systems, the maximum supported value for INITIAL_SIZE is 4294967296 (4 GB). (Bug #29186)

The minimum allowed value for INITIAL_SIZE is 1048576 (1 MB). (Bug #29574)

Note
WAIT is parsed but otherwise ignored. This keyword currently has no effect, and is intended for future expansion.

The ENGINE parameter (required) determines the storage engine which is used by this log file group, with engine_name being the name of the storage engine. Currently, the only accepted values for engine_name are "NDBCLUSTER" and "NDB". The two values are equivalent.

Here is an example, which assumes that the log file group lg_3 has already been created using CREATE LOGFILE GROUP (see Section 13.1.14, “CREATE LOGFILE GROUP Statement”):

```
ALTER LOGFILE GROUP lg_3
  ADD UNDOFILE 'undo_10.dat'
  INITIAL_SIZE=32M
  ENGINE=NDBCLUSTER;
```

When ALTER LOGFILE GROUP is used with ENGINE = NDBCLUSTER (alternatively, ENGINE = NDB), an UNDO log file is created on each NDB Cluster data node. You can verify that the UNDO files were created and obtain information about them by querying the INFORMATION_SCHEMA.FILES table. For example:

```
mysql> SELECT FILE_NAME, LOGFILE_GROUP_NUMBER, EXTRA -> FROM INFORMATION_SCHEMA.FILES -> WHERE LOGFILE_GROUP_NAME = 'lg_3';
+-------------+----------------------+----------------+
| FILE_NAME   | LOGFILE_GROUP_NUMBER | EXTRA          |
|-------------+----------------------|----------------|
| newdata.dat |                    0 | CLUSTER_NODE=3 |
| newdata.dat |                    0 | CLUSTER_NODE=4 |
| undo_10.dat |                   11 | CLUSTER_NODE=3 |
| undo_10.dat |                   11 | CLUSTER_NODE=4 |
+-------------+----------------------+----------------+
4 rows in set (0.01 sec)
```

(See Section 21.30.1, “The INFORMATION_SCHEMA.FILES Table”.)

Memory used for UNDO_BUFFER_SIZE comes from the global pool whose size is determined by the value of the SharedGlobalMemory data node configuration parameter. This includes any default value implied for this option by the setting of the InitialLogFileGroup data node configuration parameter.

ALTER LOGFILE GROUP is useful only with Disk Data storage for NDB Cluster. For more information, see Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.5 ALTER PROCEDURE Statement

```
ALTER PROCEDURE proc_name [characteristic ...]

characteristic:
  COMMENT 'string'
  LANGUAGE SQL
  { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  SQL SECURITY { DEFINER | INVOKER }
```
ALTER SERVER Statement

This statement can be used to change the characteristics of a stored procedure. More than one change may be specified in an ALTER PROCEDURE statement. However, you cannot change the parameters or body of a stored procedure using this statement; to make such changes, you must drop and re-create the procedure using DROP PROCEDURE and CREATE PROCEDURE.

You must have the ALTER ROUTINE privilege for the procedure. By default, that privilege is granted automatically to the procedure creator. This behavior can be changed by disabling the automatic_sp_privileges system variable. See Section 20.2.2, “Stored Routines and MySQL Privileges”.

13.1.6 ALTER SERVER Statement

```
ALTER SERVER  server_name
   OPTIONS (option [, option] ...)
```

Alters the server information for server_name, adjusting any of the options permitted in the CREATE SERVER statement. The corresponding fields in the mysql.servers table are updated accordingly. This statement requires the SUPER privilege.

For example, to update the USER option:

```
ALTER SERVER  s OPTIONS (USER 'sally');
```

**ALTER SERVER causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

**ALTER SERVER is not written to the binary log, regardless of the logging format that is in use.

13.1.7 ALTER TABLE Statement

```
ALTER [ONLINE|OFFLINE] [IGNORE] TABLE  tbl_name
   [alter_specification [, alter_specification] ...]
   [partition_options]
```

```
alter_specification:
   table_options
   | ADD [COLUMN]  col_name  column_definition
   |               [FIRST | AFTER col_name]
   | ADD [COLUMN]  (col_name column_definition,...)
   | ADD [INDEX|KEY]  [index_name]
   |               [index_type]  (key_part,...)  [index_option] ...
   | ADD [INDEX|KEY]  (key_part,...)  [index_option] ...
   | ADD [CONSTRAINT [symbol]] PRIMARY KEY
   |               [index_type]  (key_part,...)
   |               [index_option] ...
   | ADD [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
   |               [index_name]  [index_type]  (key_part,...)
   |               [index_option] ...
   | ADD [CONSTRAINT [symbol]] FOREIGN KEY
   |               [index_name]  (col_name,...)
   | reference_definition
   | ADD CHECK (expr)
   | ALTER [COLUMN]  col_name  (SET DEFAULT literal | DROP DEFAULT)
   | CHANGE [COLUMN]  old_col_name new_col_name column_definition
   |               [FIRST|AFTER col_name]
   | [DEFAULT] CHARACTER SET [-]  charset_name  [COLLATE [-]  collation_name]
   | CONVERT TO CHARACTER SET  charset_name  [COLLATE collation_name]
   | [DISABLE | ENABLE] KEYS
   | [DISCARD | IMPORT] TABLESPACE
   | DROP [COLUMN]  col_name
   | DROP [INDEX|KEY]  index_name
   | DROP PRIMARY KEY
```
ALTER TABLE Statement

ALTER TABLE Statement

DROP FOREIGN KEY *fk_symbol*
FORCE
MODIFY [COLUMN] *col_name* column_definition
[FIRST | AFTER *col_name*]
ORDER BY *col_name* [, *col_name*] ...
RENAME [TO|AS] *new_tbl_name*

**partition_options:**

*partition_option* [partition_option] ...

**partition_option:**

ADD PARTITION (*partition_definition*)
DROP PARTITION *partition_names*
TRUNCATE PARTITION {partition_names | ALL}
COALESCE PARTITION *number*
REORGANIZE PARTITION [partition_names INTO (partition_definitions)]
ANALYZE PARTITION {partition_names | ALL}
CHECK PARTITION {partition_names | ALL}
OPTIMIZE PARTITION {partition_names | ALL}
REBUILD PARTITION {partition_names | ALL}
PARTITION BY *partitioning_expression*
RENAME PARTITION *

**key_part:**

*col_name* [(length)] [ASC | DESC]

**index_type:**

USING {BTREE | HASH}

**index_option:**

KEY_BLOCK_SIZE [=] value
INDEX
WITH PARSER *parser_name*
COMMENT 'string'

**table_options:**

[table_option] ...

**table_option:**

AUTO_INCREMENT [=] value
AVG_ROW_LENGTH [=] value
[DEFAULT] CHARACTER SET [=] *charset_name*
CHECKSUM [=] {0 | 1}
[DEFAULT] COLLATE [=] *collation_name*
COMMENT [=] 'string'
CONNECTION [=] 'connect_string'
{DATA|INDEX} DIRECTORY [=] 'absolute path to directory'
DELAY_KEY_WRITE [=] {0 | 1}
ENGINE [=] *engine_name*
INSERT_METHOD [=] {NO | FIRST | LAST}
KEY_BLOCK_SIZE [=] value
MAX_ROWS [=] value
MIN_ROWS [=] value
PACK_KEYS [=] {0 | 1 | DEFAULT}
PASSWORD [=] 'string'
ROW_FORMAT [=] {DEFAULT|DYNAMIC|FIXED|COMPRESSED|REDUNDANT|COMPACT}
TABLESPACE *tablespace_name* [STORAGE {DISK|M]
UNION [=] {tbl_name|tbl_name}...)

**ALTER TABLE** changes the structure of a table. For example, you can add or delete columns, create or destroy indexes, change the type of existing columns, or rename columns or the table itself. You can also change characteristics such as the storage engine used for the table or the table comment.

- To use **ALTER TABLE**, you need **ALTER**, **CREATE**, and **INSERT** privileges for the table. Renaming a table requires **ALTER** and **DROP** on the old table, **ALTER**, **CREATE**, and **INSERT** on the new table.
ALTER TABLE Statement

• Following the table name, specify the alterations to be made. If none are given, ALTER TABLE does nothing.

• The syntax for many of the permissible alterations is similar to clauses of the CREATE TABLE statement. column_definition clauses use the same syntax for ADD and CHANGE as for CREATE TABLE. For more information, see Section 13.1.17, “CREATE TABLE Statement”.

• The word COLUMN is optional and can be omitted.

• Multiple ADD, ALTER, DROP, and CHANGE clauses are permitted in a single ALTER TABLE statement, separated by commas. This is a MySQL extension to standard SQL, which permits only one of each clause per ALTER TABLE statement. For example, to drop multiple columns in a single statement, do this:

```
ALTER TABLE t2 DROP COLUMN c, DROP COLUMN d;
```

• If a storage engine does not support an attempted ALTER TABLE operation, a warning may result. Such warnings can be displayed with SHOW WARNINGS. See Section 13.7.5.41, “SHOW WARNINGS Statement”. For information on troubleshooting ALTER TABLE, see Section B.4.6.1, “Problems with ALTER TABLE”.

• For usage examples, see Section 13.1.7.2, “ALTER TABLE Examples”.

• With the mysql_info() C API function, you can find out how many rows were copied by ALTER TABLE, and (when IGNORE is used) how many rows were deleted due to duplication of unique key values. See Section 23.7.6.35, “mysql_info()”.

There are several additional aspects to the ALTER TABLE statement, described under the following topics in this section:

• Table Options
• Performance and Space Requirements
• Adding and Dropping Columns
• Renaming, Redefining, and Reordering Columns
• Primary Keys and Indexes
• Foreign Keys and Other Constraints
• Changing the Character Set
• Discarding and Importing InnoDB Tablespaces
• Row Order for MyISAM Tables
• Partitioning Options

Table Options

table_options signifies table options of the kind that can be used in the CREATE TABLE statement, such as ENGINE, AUTO_INCREMENT, AVG_ROW_LENGTH, MAX_ROWS, or ROW_FORMAT.

For descriptions of all table options, see Section 13.1.17, “CREATE TABLE Statement”. However, ALTER TABLE ignores DATA DIRECTORY and INDEX DIRECTORY when given as table options. ALTER TABLE permits them only as partitioning options, and, as of MySQL 5.5.54, requires that you have the FILE privilege.
Use of table options with `ALTER TABLE` provides a convenient way of altering single table characteristics. For example:

- If `t1` is currently not an InnoDB table, this statement changes its storage engine to InnoDB:
  ```sql
  ALTER TABLE t1 ENGINE = InnoDB;
  ```
- See Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB” for considerations when switching tables to the InnoDB storage engine.
- When you specify an `ENGINE` clause, `ALTER TABLE` rebuilds the table. This is true even if the table already has the specified storage engine.
- You can also use `ALTER TABLE tbl_name FORCE` to perform a “null” alter operation that rebuilds the table.
- The outcome of attempting to change the storage engine of a table is affected by whether the desired storage engine is available and the setting of the `NO_ENGINE_SUBSTITUTION` SQL mode, as described in Section 5.1.10, “Server SQL Modes”.
- To prevent inadvertent loss of data, `ALTER TABLE` cannot be used to change the storage engine of a table to MERGE or BLACKHOLE.
- To change the InnoDB table to use compressed row-storage format:
  ```sql
  ALTER TABLE t1 ROW_FORMAT = COMPRESSED;
  ```
- To reset the current auto-increment value:
  ```sql
  ALTER TABLE t1 AUTO_INCREMENT = 13;
  ```
  You cannot reset the counter to a value less than or equal to any that have already been used. For MyISAM, if the value is less than or equal to the maximum value currently in the `AUTO_INCREMENT` column, the value is reset to the current maximum plus one. For InnoDB, if the value is less than the current maximum value in the column, no error occurs and the current sequence value is not changed.
- To change the default table character set:
  ```sql
  ALTER TABLE t1 CHARACTER SET = utf8;
  ```
  See also Changing the Character Set.
- To add (or change) a table comment:
  ```sql
  ALTER TABLE t1 COMMENT = 'New table comment';
  ```
  To verify that the table options were changed as intended, use `SHOW CREATE TABLE`, or query the `INFORMATION_SCHEMA.TABLES` table.

**Performance and Space Requirements**

`ALTER TABLE` operations are processed using either the `table-copy` method or `in-place` method. Operations that use the table-copy method are performed on a temporary copy of the original table, which can require more time, particularly for large tables. Operations that use the in place method do not create temporary copy of the table and tend to be faster.

`ALTER TABLE` operations that are performed on a temporary copy of the original table wait for other operations that are modifying the table to complete. After alterations are applied to the table copy, data
is copied over, the original table is deleted, and the table copy is renamed to the name of the original table. While the `ALTER TABLE` operation executes, the original table is readable by other sessions (with the exception noted shortly). Updates and writes to the table started after the `ALTER TABLE` operation begins are stalled until the new table is ready, then are automatically redirected to the new table. The temporary copy of the table is created in the database directory of the original table unless it is a `RENAME TO` operation that moves the table to a database that resides in a different directory.

The exception referred to earlier is that `ALTER TABLE` blocks reads (not just writes) at the point where it is ready to install a new version of the table `.frm` file, discard the old file, and clear outdated table structures from the table and table definition caches. At this point, it must acquire an exclusive lock. To do so, it waits for current readers to finish, and blocks new reads and writes.

To force use of the table-copy method for an `ALTER TABLE` operation that would otherwise not use it, enable the `old_alter_table` system variable.

For InnoDB tables, a table-copying `ALTER TABLE` operation on a table that resides in a shared tablespace such as the `system tablespace` can increase the amount of space used by the tablespace. Such operations require as much additional space as the data in the table plus indexes. For a table residing in a shared tablespace, the additional space used during the operation is not released back to the operating system as it is for a table that resides in a `file-per-table` tablespace.

`ALTER TABLE` operations that use the in-place method include:

- `ALTER TABLE tbl_name RENAME TO new_tbl_name` operations executed without any other options. MySQL renames files that correspond to the table `tbl_name` without making a copy. (You can also use the `RENAME TABLE` statement to rename tables. See Section 13.1.32, “RENAME TABLE Statement”.) Privileges granted specifically for the renamed table are not migrated to the new name. They must be changed manually.

- Operations that only modify table metadata. These operations are immediate because the server only alters the table `.frm` file, not touch table contents. Metadata-only operations include:
  - Renaming a column (except for InnoDB tables).
  - Changing the default value of a column (except for NDB tables; see Limitations of NDB online operations).
  - Changing the definition of an `ENUM` or `SET` column by adding new enumeration or set members to the `end` of the list of valid member values, as long as the storage size of the data type does not change. For example, adding a member to a `SET` column that has 8 members changes the required storage per value from 1 byte to 2 bytes; this requires a table copy. Adding members in the middle of the list causes renumbering of existing members, which requires a table copy.
  - Adding or dropping a secondary index, for InnoDB and NDBCLUSTER tables. See Section 14.16, “InnoDB Fast Index Creation”.
  - For NDBCLUSTER tables, operations that add and drop indexes on variable-width columns. These operations occur online, without table copying and without blocking concurrent DML actions for most of their duration. See Section 18.5.13, “Online Operations with ALTER TABLE in NDB Cluster”.

For MyISAM tables, you can speed up index re-creation (the slowest part of the alteration process) by setting the `myisam_sort_buffer_size` system variable to a high value.

`ALTER TABLE` with `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REBUILD PARTITION`, or `REORGANIZE PARTITION` does not create temporary tables (except when used with NDB tables); however, these operations can and do create temporary partition files.
ADD or DROP operations for RANGE or LIST partitions are immediate operations or nearly so. ADD or
COALESCE operations for HASH or KEY partitions copy data between all partitions, unless LINEAR HASH
or LINEAR KEY was used; this is effectively the same as creating a new table, although the ADD or
COALESCE operation is performed partition by partition. REORGANIZE operations copy only changed
partitions and do not touch unchanged ones.

Note
Pending INSERT DELAYED statements are lost if a table is write locked and ALTER
TABLE is used to modify the table structure.

Adding and Dropping Columns

Use ADD to add new columns to a table, and DROP to remove existing columns. DROP col_name is a
MySQL extension to standard SQL.

To add a column at a specific position within a table row, use FIRST or AFTER col_name. The default is
to add the column last.

If a table contains only one column, the column cannot be dropped. If what you intend is to remove the
table, use the DROP TABLE statement instead.

If columns are dropped from a table, the columns are also removed from any index of which they are a
part. If all columns that make up an index are dropped, the index is dropped as well.

Renaming, Redefining, and Reordering Columns

The CHANGE, MODIFY, and ALTER clauses enable the names and definitions of existing columns to be
altered. They have these comparative characteristics:

• CHANGE:
  • Can rename a column and change its definition, or both.
  • Has more capability than MODIFY, but at the expense of convenience for some operations. CHANGE
    requires naming the column twice if not renaming it.
  • With FIRST or AFTER, can reorder columns.

• MODIFY:
  • Can change a column definition but not its name.
  • More convenient than CHANGE to change a column definition without renaming it.
  • With FIRST or AFTER, can reorder columns.

• ALTER: Used only to change a column default value.

CHANGE is a MySQL extension to standard SQL. MODIFY is a MySQL extension for Oracle compatibility.

To alter a column to change both its name and definition, use CHANGE, specifying the old and new names
and the new definition. For example, to rename an INT NOT NULL column from a to b and change its
definition to use the BIGINT data type while retaining the NOT NULL attribute, do this:

```sql
ALTER TABLE t1 CHANGE a b BIGINT NOT NULL;
```
To change a column definition but not its name, use `CHANGE` or `MODIFY`. With `CHANGE`, the syntax requires two column names, so you must specify the same name twice to leave the name unchanged. For example, to change the definition of column `b`, do this:

```sql
ALTER TABLE t1 CHANGE b b INT NOT NULL;
```

`MODIFY` is more convenient to change the definition without changing the name because it requires the column name only once:

```sql
ALTER TABLE t1 MODIFY b INT NOT NULL;
```

To change a column name but not its definition, use `CHANGE`. The syntax requires a column definition, so to leave the definition unchanged, you must respecify the definition the column currently has. For example, to rename an `INT NOT NULL` column from `b` to `a`, do this:

```sql
ALTER TABLE t1 CHANGE b a INT NOT NULL;
```

For column definition changes using `CHANGE` or `MODIFY`, the definition must include the data type and all attributes that should apply to the new column, other than index attributes such as `PRIMARY KEY` or `UNIQUE`. Attributes present in the original definition but not specified for the new definition are not carried forward. Suppose that a column `col1` is defined as `INT UNSIGNED DEFAULT 1 COMMENT 'my column'` and you modify the column as follows, intending to change only `INT` to `BIGINT`:

```sql
ALTER TABLE t1 MODIFY col1 BIGINT;
```

That statement changes the data type from `INT` to `BIGINT`, but it also drops the `UNSIGNED`, `DEFAULT`, and `COMMENT` attributes. To retain them, the statement must include them explicitly:

```sql
ALTER TABLE t1 MODIFY col1 BIGINT UNSIGNED DEFAULT 1 COMMENT 'my column';
```

For data type changes using `CHANGE` or `MODIFY`, MySQL tries to convert existing column values to the new type as well as possible.

**Warning**

This conversion may result in alteration of data. For example, if you shorten a string column, values may be truncated. To prevent the operation from succeeding if conversions to the new data type would result in loss of data, enable strict SQL mode before using `ALTER TABLE` (see Section 5.1.10, “Server SQL Modes”).

If you use `CHANGE` or `MODIFY` to shorten a column for which an index exists on the column, and the resulting column length is less than the index length, MySQL shortens the index automatically.

For columns renamed by `CHANGE`, MySQL automatically renames these references to the renamed column:

- Indexes that refer to the old column, including indexes and disabled `MyISAM` indexes.

For columns renamed by `CHANGE`, MySQL does not automatically rename these references to the renamed column:

- Foreign keys that refer to the old column.
- Partition expressions that refer to the renamed column. You must use `CHANGE` to redefine such expressions in the same `ALTER TABLE` statement as the one that renames the column.
- Views and stored programs that refer to the renamed column. You must manually alter the definition of these objects to refer to the new column name.

To reorder columns within a table, use `FIRST` and `AFTER` in `CHANGE` or `MODIFY` operations.
ALTER ... SET DEFAULT or ALTER ... DROP DEFAULT specify a new default value for a column or remove the old default value, respectively. If the old default is removed and the column can be NULL, the new default is NULL. If the column cannot be NULL, MySQL assigns a default value as described in Section 11.5, “Data Type Default Values”.

Primary Keys and Indexes

DROP PRIMARY KEY drops the primary key. If there is no primary key, an error occurs. For information about the performance characteristics of primary keys, especially for InnoDB tables, see Section 8.3.2, “Primary Key Optimization”.

If you add a UNIQUE INDEX or PRIMARY KEY to a table, MySQL stores it before any nonunique index to permit detection of duplicate keys as early as possible.

IGNORE is a MySQL extension to standard SQL. It controls how ALTER TABLE works if there are duplicates on unique keys in the new table or if warnings occur when strict mode is enabled. If IGNORE is not specified, the copy is aborted and rolled back if duplicate-key errors occur. If IGNORE is specified, only one row is used of rows with duplicates on a unique key. The other conflicting rows are deleted. Incorrect values are truncated to the closest matching acceptable value.

Note
Due to a bug related to Fast Index Creation (Bug #40344), ALTER IGNORE TABLE ... ADD UNIQUE INDEX does not delete duplicate rows. The IGNORE keyword is ignored. If any duplicate rows exist, the operation fails with a Duplicate entry error. A workaround is to set old_alter_table=1 prior to running an ALTER IGNORE TABLE ... ADD UNIQUE INDEX statement.

DROP INDEX removes an index. This is a MySQL extension to standard SQL. See Section 13.1.24, “DROP INDEX Statement”. To determine index names, use SHOW INDEX FROM tbl_name.

Some storage engines permit you to specify an index type when creating an index. The syntax for the index_type specifier is USING type_name. For details about USING, see Section 13.1.13, “CREATE INDEX Statement”. The preferred position is after the column list. Support for use of the option before the column list will be removed in a future MySQL release.

index_option values specify additional options for an index. For details about permissible index_option values, see Section 13.1.13, “CREATE INDEX Statement”.

If you use ALTER TABLE on a MyISAM table, all nonunique indexes are created in a separate batch (as for REPAIR TABLE). This should make ALTER TABLE much faster when you have many indexes.

For MyISAM tables, key updating can be controlled explicitly. Use ALTER TABLE ... DISABLE KEYS to tell MySQL to stop updating nonunique indexes. Then use ALTER TABLE ... ENABLE KEYS to re-create missing indexes. MyISAM does this with a special algorithm that is much faster than inserting keys one by one, so disabling keys before performing bulk insert operations should give a considerable speedup. Using ALTER TABLE ... DISABLE KEYS requires the INDEX privilege in addition to the privileges mentioned earlier.

While the nonunique indexes are disabled, they are ignored for statements such as SELECT and EXPLAIN that otherwise would use them.

After an ALTER TABLE statement, it may be necessary to run ANALYZE TABLE to update index cardinality information. See Section 13.7.5.23, “SHOW INDEX Statement”.

1398
Foreign Keys and Other Constraints

If `ALTER TABLE` for an InnoDB table results in changes to column values (for example, because a column is truncated), InnoDB's FOREIGN KEY constraint checks do not notice possible violations caused by changing the values.

The FOREIGN KEY and REFERENCES clauses are supported by the InnoDB storage engine, which implements `ADD [CONSTRAINT [symbol]] FOREIGN KEY [index_name] (...) REFERENCES ... (...)`. See Section 13.1.17.6, “FOREIGN KEY Constraints”. For other storage engines, the clauses are parsed but ignored.

The CHECK constraint clause is parsed but ignored by all storage engines. See Section 13.1.17, “CREATE TABLE Statement”. The reason for accepting but ignoring syntax clauses is for compatibility, to make it easier to port code from other SQL servers, and to run applications that create tables with references. See Section 1.7.2, “MySQL Differences from Standard SQL”.

For `ALTER TABLE`, unlike `CREATE TABLE`, `ADD FOREIGN KEY` ignores `index_name` if given and uses an automatically generated foreign key name. As a workaround, include the CONSTRAINT clause to specify the foreign key name:

```
ADD CONSTRAINT name FOREIGN KEY (...) ...
```

Important

MySQL silently ignores inline REFERENCES specifications, where the references are defined as part of the column specification. MySQL accepts only REFERENCES clauses defined as part of a separate FOREIGN KEY specification.

Note

Partitioned InnoDB tables do not support foreign keys. For more information, see Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”.

InnoDB supports the use of `ALTER TABLE` to drop foreign keys:

```
ALTER TABLE tbl_name DROP FOREIGN KEY fk_symbol;
```

Adding and dropping a foreign key in separate clauses of a single `ALTER TABLE` statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.

```
ALTER TABLE tbl_name RENAME new_tbl_name changes internally generated foreign key constraint names and user-defined foreign key constraint names that begin with the string “tbl_name_ibfk_” to reflect the new table name. InnoDB interprets foreign key constraint names that begin with the string “tbl_name_ibfk_” as internally generated names.
```

Changing the Character Set

To change the table default character set and all character columns (CHAR, VARCHAR, TEXT) to a new character set, use a statement like this:

```
ALTER TABLE tbl_name
CONVERT TO CHARACTER SET charset_name [COLLATE collation_name];
```

The statement also changes the collation of all character columns. If you specify no COLLATE clause to indicate which collation to use, the statement uses default collation for the character set. If this collation is inappropriate for the intended table use (for example, if it would change from a case-sensitive collation to a case-insensitive collation), specify a collation explicitly.
For a column that has a data type of \texttt{VARCHAR} or one of the \texttt{TEXT} types, \texttt{CONVERT TO CHARACTER SET} changes the data type as necessary to ensure that the new column is long enough to store as many characters as the original column. For example, a \texttt{TEXT} column has two length bytes, which store the byte-length of values in the column, up to a maximum of 65,535. For a \texttt{latin1 TEXT} column, each character requires a single byte, so the column can store up to 65,535 characters. If the column is converted to \texttt{utf8}, each character might require up to three bytes, for a maximum possible length of $3 \times 65,535 = 196,605$ bytes. That length does not fit in a \texttt{TEXT} column’s length bytes, so MySQL converts the data type to \texttt{MEDIUMTEXT}, which is the smallest string type for which the length bytes can record a value of 196,605. Similarly, a \texttt{VARCHAR} column might be converted to \texttt{MEDIUMTEXT}.

To avoid data type changes of the type just described, do not use \texttt{CONVERT TO CHARACTER SET}. Instead, use \texttt{MODIFY} to change individual columns. For example:

\begin{verbatim}
ALTER TABLE t MODIFY latin1_text_col TEXT CHARACTER SET utf8;
ALTER TABLE t MODIFY latin1_varchar_col VARCHAR(M) CHARACTER SET utf8;
\end{verbatim}

If you specify \texttt{CONVERT TO CHARACTER SET binary}, the \texttt{CHAR}, \texttt{VARCHAR}, and \texttt{TEXT} columns are converted to their corresponding binary string types (\texttt{BINARY}, \texttt{VARBINARY}, \texttt{BLOB}). This means that the columns no longer will have a character set and a subsequent \texttt{CONVERT TO} operation will not apply to them.

If \texttt{charset_name} is \texttt{DEFAULT} in a \texttt{CONVERT TO CHARACTER SET} operation, the character set named by the \texttt{character_set_database} system variable is used.

\begin{warning}
The \texttt{CONVERT TO} operation converts column values between the original and named character sets. This is \textit{not} what you want if you have a column in one character set (like \texttt{latin1}) but the stored values actually use some other, incompatible character set (like \texttt{utf8}). In this case, you have to do the following for each such column:

\begin{verbatim}
ALTER TABLE t1 CHANGE c1 c1 BLOB;
ALTER TABLE t1 CHANGE c1 c1 TEXT CHARACTER SET utf8;
\end{verbatim}

The reason this works is that there is no conversion when you convert to or from \texttt{BLOB} columns.
\end{warning}

To change only the \textit{default} character set for a table, use this statement:

\begin{verbatim}
ALTER TABLE \texttt{tbl_name} DEFAULT CHARACTER SET \texttt{charset_name};
\end{verbatim}

The word \texttt{DEFAULT} is optional. The default character set is the character set that is used if you do not specify the character set for columns that you add to a table later (for example, with \texttt{ALTER TABLE ... ADD column}).

When the \texttt{foreign_key_checks} system variable is enabled, which is the default setting, character set conversion is not permitted on tables that include a character string column used in a foreign key constraint. The workaround is to disable \texttt{foreign_key_checks} before performing the character set conversion. You must perform the conversion on both tables involved in the foreign key constraint before re-enabling \texttt{foreign_key_checks}. If you re-enable \texttt{foreign_key_checks} after converting only one of the tables, an \texttt{ON DELETE CASCADE} or \texttt{ON UPDATE CASCADE} operation could corrupt data in the referencing table due to implicit conversion that occurs during these operations (Bug \#45290, Bug \#74816).

\section*{Discarding and Importing InnoDB Tablespaces}
ALTER TABLE Statement

For an **InnoDB** table that is created with its own tablespace in an `.ibd` file, that file can be discarded and imported. To discard the `.ibd` file, use this statement:

```
ALTER TABLE tbl_name DISCARD TABLESPACE;
```

This deletes the current `.ibd` file, so be sure that you have a backup first. Attempting to access the table while the tablespace file is discarded results in an error.

To import the backup `.ibd` file back into the table, copy it into the database directory, and then issue this statement:

```
ALTER TABLE tbl_name IMPORT TABLESPACE;
```

The tablespace file must have been created on the server into which it is imported later.

**Note**

The `ALTER TABLE ... IMPORT TABLESPACE` feature does not enforce foreign key constraints on imported data.

See *Section 14.9.3.2, “File-Per-Table Tablespaces”.*

**Row Order for MyISAM Tables**

**ORDER BY** enables you to create the new table with the rows in a specific order. This option is useful primarily when you know that you query the rows in a certain order most of the time. By using this option after major changes to the table, you might be able to get higher performance. In some cases, it might make sorting easier for MySQL if the table is in order by the column that you want to order it by later.

**Note**

The table does not remain in the specified order after inserts and deletes.

**ORDER BY** syntax permits one or more column names to be specified for sorting, each of which optionally can be followed by **ASC** or **DESC** to indicate ascending or descending sort order, respectively. The default is ascending order. Only column names are permitted as sort criteria; arbitrary expressions are not permitted. This clause should be given last after any other clauses.

**ORDER BY** does not make sense for **InnoDB** tables because **InnoDB** always orders table rows according to the clustered index.

When used on a partitioned table, `ALTER TABLE ... ORDER BY` orders rows within each partition only.

**Partitioning Options**

`partition_options` signifies options that can be used with partitioned tables for repartitioning, to add, drop, discard, merge, and split partitions, and to perform partitioning maintenance.

It is possible for an `ALTER TABLE` statement to contain a **PARTITION BY** or **REMOVE PARTITIONING** clause in an addition to other alter specifications, but the **PARTITION BY** or **REMOVE PARTITIONING** clause must be specified last after any other specifications. The **ADD PARTITION**, **DROP PARTITION**, **COALESCE PARTITION**, **REORGANIZE PARTITION**, **ANALYZE PARTITION**, **CHECK PARTITION**, and **REPAIR PARTITION** options cannot be combined with other alter specifications in a single **ALTER TABLE**, since the options just listed act on individual partitions.

For a list of partition options and a description of each, see *Section 13.1.17, “CREATE TABLE Statement”*. For additional information, see *Section 13.1.7.1, “ALTER TABLE Partition Operations”*. 
13.1.7.1 ALTER TABLE Partition Operations

Partitioning-related clauses for ALTER TABLE can be used with partitioned tables for repartitioning, to add, drop, discard, merge, and split partitions, and to perform partitioning maintenance.

- Simply using a partition_options clause with ALTER TABLE on a partitioned table repartitions the table according to the partitioning scheme defined by the partition_options. This clause always begins with PARTITION BY, and follows the same syntax and other rules as apply to the partition_options clause for CREATE TABLE (for more detailed information, see Section 13.1.17, “CREATE TABLE Statement”), and can also be used to partition an existing table that is not already partitioned. For example, consider a (nonpartitioned) table defined as shown here:

```sql
CREATE TABLE t1 (
    id INT,
    year_col INT
);```

This table can be partitioned by HASH, using the id column as the partitioning key, into 8 partitions by means of this statement:

```sql
ALTER TABLE t1
    PARTITION BY HASH(id)
    PARTITIONS 8;
```

MySQL 5.5.31 and later supports an ALGORITHM option with [SUB]PARTITION BY [LINEAR] KEY. ALGORITHM=1 causes the server to use the same key-hashing functions as MySQL 5.1 when computing the placement of rows in partitions; ALGORITHM=2 means that the server employs the key-hashing functions implemented and used by default for new KEY partitioned tables in MySQL 5.5 and later. (Partitioned tables created with the key-hashing functions employed in MySQL 5.5 and later cannot be used by a MySQL 5.1 server.) Not specifying the option has the same effect as using ALGORITHM=2. This option is intended for use chiefly when upgrading or downgrading [LINEAR] KEY partitioned tables between MySQL 5.1 and later MySQL versions, or for creating tables partitioned by KEY or LINEAR KEY on a MySQL 5.5 or later server which can be used on a MySQL 5.1 server.

To upgrade a KEY partitioned table that was created in MySQL 5.1, first execute SHOW CREATE TABLE and note the exact columns and number of partitions shown. Now execute an ALTER TABLE statement using exactly the same column list and number of partitions as in the CREATE TABLE statement, while adding ALGORITHM=2 immediately following the PARTITION BY keywords. (You should also include the LINEAR keyword if it was used for the original table definition.) An example from a session in the mysql client is shown here:

```sql
mysql> SHOW CREATE TABLE p\G
*************************** 1. row ***************************
Table: p
Create Table: CREATE TABLE `p` (
    `id` int(11) NOT NULL AUTO_INCREMENT,
    `cd` datetime NOT NULL,
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY LINEAR KEY (id)
PARTITIONS 32 */
1 row in set (0.00 sec)
mysql> ALTER TABLE p PARTITION BY LINEAR KEY ALGORITHM=2 (id) PARTITIONS 32;
Query OK, 0 rows affected (5.34 sec)
Records: 0  Duplicates: 0  Warnings: 0
mysql> SHOW CREATE TABLE p\G
*************************** 1. row ***************************
Table: p
```

1402
ALTER TABLE Statement

Create Table: CREATE TABLE `p` (
   `id` int(11) NOT NULL AUTO_INCREMENT,
   `cd` datetime NOT NULL,
   PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY LINEAR KEY (id)
PARTITIONS 32 */
1 row in set (0.00 sec)

Downgrading a table created using the default key-hashing used in MySQL 5.5 and later to enable its use by a MySQL 5.1 server is similar, except in this case you should use ALGORITHM=1 to force the table’s partitions to be rebuilt using the MySQL 5.1 key-hashing functions. It is recommended that you not do this except when necessary for compatibility with a MySQL 5.1 server, as the improved KEY hashing functions used by default in MySQL 5.5 and later provide fixes for a number of issues found in the older implementation.

**Note**

A table upgraded by means of ALTER TABLE ... PARTITION BY ALGORITHM=2 [LINEAR] KEY ... can no longer be used by a MySQL 5.1 server. (Such a table would need to be downgraded with ALTER TABLE ... PARTITION BY ALGORITHM=1 [LINEAR] KEY ... before it could be used again by a MySQL 5.1 server.)

The table that results from using an ALTER TABLE ... PARTITION BY statement must follow the same rules as one created using CREATE TABLE ... PARTITION BY. This includes the rules governing the relationship between any unique keys (including any primary key) that the table might have, and the column or columns used in the partitioning expression, as discussed in Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”. The CREATE TABLE ... PARTITION BY rules for specifying the number of partitions also apply to ALTER TABLE ... PARTITION BY.

The partition_definition clause for ALTER TABLE ADD PARTITION supports the same options as the clause of the same name for the CREATE TABLE statement. (See Section 13.1.17, “CREATE TABLE Statement”, for the syntax and description.) Suppose that you have the partitioned table created as shown here:

```sql
CREATE TABLE t1 (  
id INT,
year_col INT
)  
PARTITION BY RANGE (year_col) (  
PARTITION p0 VALUES LESS THAN (1991),  
PARTITION p1 VALUES LESS THAN (1995),  
PARTITION p2 VALUES LESS THAN (1999)
);
```

You can add a new partition p3 to this table for storing values less than 2002 as follows:

```sql
ALTER TABLE t1 ADD PARTITION (PARTITION p3 VALUES LESS THAN (2002));
```

DROP PARTITION can be used to drop one or more RANGE or LIST partitions. This statement cannot be used with HASH or KEY partitions; instead, use COALESCE PARTITION (see below). Any data that
ALTER TABLE Statement

was stored in the dropped partitions named in the `partition_names` list is discarded. For example, given the table `t1` defined previously, you can drop the partitions named `p0` and `p1` as shown here:

```
ALTER TABLE t1 DROP PARTITION p0, p1;
```

**Note**

`DROP PARTITION` does not work with tables that use the `NDBCLUSTER` storage engine. See Section 19.3.1, “Management of RANGE and LIST Partitions”, and Section 18.1.7, “Known Limitations of NDB Cluster”.

**ADD PARTITION** and **DROP PARTITION** do not currently support `IF [NOT] EXISTS`.

Renames of partitioned tables are supported. You can rename individual partitions indirectly using `ALTER TABLE ... REORGANIZE PARTITION`; however, this operation copies the partition's data.

To delete rows from selected partitions, use the **TRUNCATE PARTITION** option. This option takes a list of one or more comma-separated partition names. For example, consider the table `t1` as defined here:

```
CREATE TABLE t1 (  
id INT,  
year_col INT  
)  
PARTITION BY RANGE (year_col) {  
  PARTITION p0 VALUES LESS THAN (1991),  
  PARTITION p1 VALUES LESS THAN (1995),  
  PARTITION p2 VALUES LESS THAN (1999),  
  PARTITION p3 VALUES LESS THAN (2003),  
  PARTITION p4 VALUES LESS THAN (2007)  
};
```

To delete all rows from partition `p0`, use the following statement:

```
ALTER TABLE t1 TRUNCATE PARTITION p0;
```

The statement just shown has the same effect as the following **DELETE** statement:

```
DELETE FROM t1 WHERE year_col < 1991;
```

When truncating multiple partitions, the partitions do not have to be contiguous: This can greatly simplify delete operations on partitioned tables that would otherwise require very complex `WHERE` conditions if done with **DELETE** statements. For example, this statement deletes all rows from partitions `p1` and `p3`:

```
ALTER TABLE t1 TRUNCATE PARTITION p1, p3;
```

An equivalent **DELETE** statement is shown here:

```
DELETE FROM t1 WHERE  
  (year_col >= 1991 AND year_col < 1995)  
OR
```

1404
ALTER TABLE Statement

(year_col >= 2003 AND year_col < 2007);

If you use the ALL keyword in place of the list of partition names, the statement acts on all table partitions.

TRUNCATE PARTITION merely deletes rows; it does not alter the definition of the table itself, or of any of its partitions.

Note

TRUNCATE PARTITION does not work with subpartitions.

To verify that the rows were dropped, check the INFORMATION_SCHEMA.PARTITIONS table, using a query such as this one:

SELECT PARTITION_NAME, TABLE_ROWS
FROM INFORMATION_SCHEMA.PARTITIONS
WHERE TABLE_NAME = 't1';

TRUNCATE PARTITION is supported only for partitioned tables that use the MyISAM, InnoDB, or MEMORY storage engine. It also works on BLACKHOLE tables (but has no effect). It is not supported for ARCHIVE tables.

COALESCE PARTITION can be used with a table that is partitioned by HASH or KEY to reduce the number of partitions by number. Suppose that you have created table t2 as follows:

CREATE TABLE t2 (  
    name VARCHAR (30),  
    started DATE  
)  
PARTITION BY HASH( YEAR(started) )  
PARTITIONS 6;

To reduce the number of partitions used by t2 from 6 to 4, use the following statement:

ALTER TABLE t2 COALESCE PARTITION 2;

The data contained in the last number partitions will be merged into the remaining partitions. In this case, partitions 4 and 5 will be merged into the first 4 partitions (the partitions numbered 0, 1, 2, and 3).

To change some but not all the partitions used by a partitioned table, you can use REORGANIZE PARTITION. This statement can be used in several ways:

• To merge a set of partitions into a single partition. This is done by naming several partitions in the partition_names list and supplying a single definition for partition_definition.

• To split an existing partition into several partitions. Accomplish this by naming a single partition for partition_names and providing multiple partition_definitions.

• To change the ranges for a subset of partitions defined using VALUES LESS THAN or the value lists for a subset of partitions defined using VALUES IN.

• This statement may also be used without the partition_names INTO (partition_definitions) option on tables that are automatically partitioned using HASH partitioning to force redistribution of data. (Currently, only NDB tables are automatically partitioned in this way.) This is useful in NDB Cluster where, after you have added new NDB Cluster data nodes online to an existing NDB Cluster, you wish to redistribute existing NDB Cluster table data to the new...
data nodes. In such cases, you should invoke the statement with the \texttt{ONLINE} option; in other words, as shown here:

\begin{verbatim}
ALTER ONLINE TABLE \textit{table} REORGANIZE PARTITION;
\end{verbatim}

You cannot perform other DDL concurrently with online table reorganization—that is, no other DDL statements can be issued while an \texttt{ALTER ONLINE TABLE \ldots REORGANIZE PARTITION} statement is executing. For more information about adding NDB Cluster data nodes online, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

\texttt{ALTER ONLINE TABLE \ldots REORGANIZE PARTITION} does not work with tables which were created using the \texttt{MAX_ROWS} option, because it uses the constant \texttt{MAX_ROWS} value specified in the original \texttt{CREATE TABLE} statement to determine the number of partitions required, so no new partitions are created. Beginning with MySQL NDB Cluster 7.2.6, you can use \texttt{ALTER ONLINE TABLE \ldots MAX_ROWS=rows} to increase the maximum number of rows for such a table; in this case, \texttt{ALTER ONLINE TABLE \ldots REORGANIZE PARTITION} is not needed (and causes an error if executed). The value of \texttt{rows} must be greater than the value specified for \texttt{MAX_ROWS} in the original \texttt{CREATE TABLE} statement for this to work.

Attempting to use \texttt{REORGANIZE PARTITION} without the \texttt{partition_names INTO (partitionDefinitions)} option on explicitly partitioned tables results in the error \texttt{REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH partitioning}.

\textbf{Note}

For partitions that have not been explicitly named, MySQL automatically provides the default names \texttt{p0, p1, p2}, and so on. The same is true with regard to subpartitions.

For more detailed information about and examples of \texttt{ALTER TABLE \ldots REORGANIZE PARTITION} statements, see Section 19.3.1, “Management of RANGE and LIST Partitions”.

\begin{itemize}
\item Several options provide partition maintenance and repair functionality analogous to that implemented for nonpartitioned tables by statements such as \texttt{CHECK TABLE} and \texttt{REPAIR TABLE} (which are also supported for partitioned tables; for more information, see Section 13.7.2, “Table Maintenance Statements”). These include \texttt{ANALYZE PARTITION}, \texttt{CHECK PARTITION}, \texttt{OPTIMIZE PARTITION}, \texttt{REBUILD PARTITION}, and \texttt{REPAIR PARTITION}. Each of these options takes a \texttt{partition_names} clause consisting of one or more names of partitions, separated by commas. The partitions must already exist in the table to be altered. You can also use the \texttt{ALL} keyword in place of \texttt{partition_names}, in which case the statement acts on all table partitions. For more information and examples, see Section 19.3.3, “Maintenance of Partitions”.
\end{itemize}

Prior to MySQL 5.5.30, it was not safe to execute multiple concurrent \texttt{REBUILD TABLE} operations on partitioned tables, whether on the same or different tables. (Bug #14589559, Bug #66645)

Some MySQL storage engines, such as \texttt{InnoDB}, do not support per-partition optimization. For a partitioned table using such a storage engine, \texttt{ALTER TABLE \ldots OPTIMIZE PARTITION} rebuilds the entire table. This is a known issue. Beginning with MySQL 5.5.30, running this statement on such
ALTER TABLE Statement

a table causes the entire table to be rebuilt and analyzed, and an appropriate warning to be issued. (Bug #11751825, Bug #42822)

To work around this problem, use the statements ALTER TABLE ... REBUILD PARTITION and ALTER TABLE ... ANALYZE PARTITION instead.

The ANALYZE PARTITION, CHECK PARTITION, OPTIMIZE PARTITION, and REPAIR PARTITION options are not permitted for tables which are not partitioned.

• REMOVE PARTITIONING enables you to remove a table’s partitioning without otherwise affecting the table or its data. This option can be combined with other ALTER TABLE options such as those used to add, drop, or rename columns or indexes.

• Using the ENGINE option with ALTER TABLE changes the storage engine used by the table without affecting the partitioning.

It is possible for an ALTER TABLE statement to contain a PARTITION BY or REMOVE PARTITIONING clause in an addition to other alter specifications, but the PARTITION BY or REMOVE PARTITIONING clause must be specified last after any other specifications.

The ADD PARTITION, DROP PARTITION, COALESCE PARTITION, REORGANIZE PARTITION, ANALYZE PARTITION, CHECK PARTITION, and REPAIR PARTITION options cannot be combined with other alter specifications in a single ALTER TABLE, since the options just listed act on individual partitions. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

Only a single instance of any one of the following options can be used in a given ALTER TABLE statement: PARTITION BY, ADD PARTITION, DROP PARTITION, TRUNCATE PARTITION, REORGANIZE PARTITION, or COALESCE PARTITION, ANALYZE PARTITION, CHECK PARTITION, OPTIMIZE PARTITION, REBUILD PARTITION, REMOVE PARTITIONING.

For example, the following two statements are invalid:

ALTER TABLE t1 ANALYZE PARTITION p1, ANALYZE PARTITION p2;
ALTER TABLE t1 ANALYZE PARTITION p1, CHECK PARTITION p2;

In the first case, you can analyze partitions p1 and p2 of table t1 concurrently using a single statement with a single ANALYZE PARTITION option that lists both of the partitions to be analyzed, like this:

ALTER TABLE t1 ANALYZE PARTITION p1, p2;

In the second case, it is not possible to perform ANALYZE and CHECK operations on different partitions of the same table concurrently. Instead, you must issue two separate statements, like this:

ALTER TABLE t1 ANALYZE PARTITION p1;
ALTER TABLE t1 CHECK PARTITION p2;

ANALYZE, CHECK, OPTIMIZE, REBUILD, REPAIR, and TRUNCATE operations are not supported for subpartitions.

13.1.7.2 ALTER TABLE Examples

Begin with a table t1 created as shown here:

CREATE TABLE t1 (a INTEGER, b CHAR(10));

To rename the table from t1 to t2:

ALTER TABLE t1 RENAME t2;
To change column \texttt{a} from \texttt{INTEGER} to \texttt{TINYINT NOT NULL} (leaving the name the same), and to change column \texttt{b} from \texttt{CHAR(10)} to \texttt{CHAR(20)} as well as renaming it from \texttt{b} to \texttt{c}:

\begin{verbatim}
ALTER TABLE t2 MODIFY a TINYINT NOT NULL, CHANGE b c CHAR(20);
\end{verbatim}

To add a new \texttt{TIMESTAMP} column named \texttt{d}:

\begin{verbatim}
ALTER TABLE t2 ADD d TIMESTAMP;
\end{verbatim}

To add an index on column \texttt{d} and a \texttt{UNIQUE} index on column \texttt{a}:

\begin{verbatim}
ALTER TABLE t2 ADD INDEX (d), ADD UNIQUE (a);
\end{verbatim}

To remove column \texttt{c}:

\begin{verbatim}
ALTER TABLE t2 DROP COLUMN c;
\end{verbatim}

To add a new \texttt{AUTO_INCREMENT} integer column named \texttt{c}:

\begin{verbatim}
ALTER TABLE t2 ADD c INT UNSIGNED NOT NULL AUTO_INCREMENT,
ADD PRIMARY KEY (c);
\end{verbatim}

We indexed \texttt{c} (as a \texttt{PRIMARY KEY}) because \texttt{AUTO_INCREMENT} columns must be indexed, and we declare \texttt{c} as \texttt{NOT NULL} because primary key columns cannot be \texttt{NULL}.

For \texttt{NDB} tables, it is also possible to change the storage type used for a table or column. For example, consider an \texttt{NDB} table created as shown here:

\begin{verbatim}
mysql> CREATE TABLE t1 (c1 INT) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.27 sec)
\end{verbatim}

To convert this table to disk-based storage, you can use the following \texttt{ALTER TABLE} statement:

\begin{verbatim}
mysql> ALTER TABLE t1 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (2.99 sec)
Records: 0  Duplicates: 0  Warnings: 0
\end{verbatim}

\begin{verbatim}
mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.01 sec)
\end{verbatim}

It is not necessary that the tablespace was referenced when the table was originally created; however, the tablespace must be referenced by the \texttt{ALTER TABLE}:

\begin{verbatim}
mysql> CREATE TABLE t2 (c1 INT) ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.00 sec)
\end{verbatim}

\begin{verbatim}
mysql> ALTER TABLE t2 STORAGE DISK;
ERROR 1005 (HY000): Can't create table 't2' (errno: 140)
\end{verbatim}

\begin{verbatim}
mysql> ALTER TABLE t2 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (3.42 sec)
Records: 0  Duplicates: 0  Warnings: 0
\end{verbatim}

\begin{verbatim}
mysql> SHOW CREATE TABLE t2\G
*************************** 1. row ***************************
Table: t1
Create Table: CREATE TABLE `t2` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
\end{verbatim}
To change the storage type of an individual column, you can use `ALTER TABLE ... MODIFY [COLUMN]`. For example, suppose you create an NDB Cluster Disk Data table with two columns, using this `CREATE TABLE` statement:

```
mysql> CREATE TABLE t3 (c1 INT, c2 INT)
    -> TABLESPACE ts_1 STORAGE DISK ENGINE NDB;
Query OK, 0 rows affected (1.34 sec)
```

To change column `c2` from disk-based to in-memory storage, include a `STORAGE MEMORY` clause in the column definition used by the `ALTER TABLE` statement, as shown here:

```
mysql> ALTER TABLE t3 MODIFY c2 INT STORAGE MEMORY;
Query OK, 0 rows affected (3.14 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

You can make an in-memory column into a disk-based column by using `STORAGE DISK` in a similar fashion.

Column `c1` uses disk-based storage, since this is the default for the table (determined by the table-level `STORAGE DISK` clause in the `CREATE TABLE` statement). However, column `c2` uses in-memory storage, as can be seen here in the output of `SHOW CREATE TABLE`:

```
mysql> SHOW CREATE TABLE t3\G
*************************** 1. row ***************************
Table: t3
Create Table: CREATE TABLE `t3` (  
  `c1` int(11) DEFAULT NULL,  
  `c2` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.02 sec)
```

When you add an `AUTO_INCREMENT` column, column values are filled in with sequence numbers automatically. For `MyISAM` tables, you can set the first sequence number by executing `SET INSERT_ID=value` before `ALTER TABLE` or by using the `AUTO_INCREMENT=value` table option.

With `MyISAM` tables, if you do not change the `AUTO_INCREMENT` column, the sequence number is not affected. If you drop an `AUTO_INCREMENT` column and then add another `AUTO_INCREMENT` column, the numbers are resequenced beginning with 1.

When replication is used, adding an `AUTO_INCREMENT` column to a table might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to the table `t1`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 (id INT AUTO_INCREMENT PRIMARY KEY)
SELECT * FROM t1 ORDER BY col1, col2;
```

This assumes that the table `t1` has columns `col1` and `col2`.

This set of statements will also produce a new table `t2` identical to `t1`, with the addition of an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
```
### 13.1.8 ALTER TABLESPACE Statement

The `ALTER TABLESPACE` statement is used either to add a new data file, or to drop a data file from a tablespace.

#### ADD DATAFILE

The `ADD DATAFILE` variant enables you to specify an initial size using an `INITIAL_SIZE` clause, where `size` is measured in bytes; the default value is 134217728 (128 MB). Prior to MySQL NDB Cluster 7.2.14, this value was required to be specified using digits (Bug #13116514, Bug #16104705, Bug #62858); in MySQL NDB Cluster 7.2.14 and later, you may optionally follow `size` with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (megabytes) or `G` (gigabytes).

#### DROP DATAFILE

Using `DROP DATAFILE` with `ALTER TABLESPACE` drops the data file `file_name` from the tablespace. You cannot drop a data file from a tablespace which is in use by any table; in other words, the data file must be empty (no extents used). See Section 18.5.12.1, “NDB Cluster Disk Data Objects”. In addition, any data file to be dropped must previously have been added to the tablespace with `CREATE TABLESPACE` or `ALTER TABLESPACE`.

### Note

All NDB Cluster Disk Data objects share the same namespace. This means that each Disk Data object must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a data file with the same name, or an undo log file and a tablespace with the same name.

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is 4294967296 (4 GB). (Bug #29186)

`INITIAL_SIZE` is rounded, explicitly, as for `CREATE TABLESPACE`.

Once a data file has been created, its size cannot be changed; however, you can add more data files to the tablespace using additional `ALTER TABLESPACE ... ADD DATAFILE` statements.

Using `DROP DATAFILE` with `ALTER TABLESPACE` drops the data file `file_name` from the tablespace. You cannot drop a data file from a tablespace which is in use by any table; in other words, the data file must be empty (no extents used). See Section 18.5.12.1, “NDB Cluster Disk Data Objects”. In addition, any data file to be dropped must previously have been added to the tablespace with `CREATE TABLESPACE` or `ALTER TABLESPACE`.

Both `ALTER TABLESPACE ... ADD DATAFILE` and `ALTER TABLESPACE ... DROP DATAFILE` require an `ENGINE` clause which specifies the storage engine used by the tablespace. Currently, the only accepted values for `engine_name` are `NDB` and `NDBCLUSTER`.

`WAIT` is parsed but otherwise ignored, and so has no effect in MySQL 5.5. It is intended for future expansion.
When `ALTER TABLESPACE ... ADD DATAFILE` is used with `ENGINE = NDB`, a data file is created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example, the following query shows all data files belonging to the tablespace named `newts`:

```sql
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
```

```
+--------------------+--------------+----------------+
<table>
<thead>
<tr>
<th>LOGFILE_GROUP_NAME</th>
<th>FILE_NAME</th>
<th>EXTRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>lg_3</td>
<td>newdata.dat</td>
<td>CLUSTER_NODE=3</td>
</tr>
<tr>
<td>lg_3</td>
<td>newdata.dat</td>
<td>CLUSTER_NODE=4</td>
</tr>
<tr>
<td>lg_3</td>
<td>newdata2.dat</td>
<td>CLUSTER_NODE=3</td>
</tr>
<tr>
<td>lg_3</td>
<td>newdata2.dat</td>
<td>CLUSTER_NODE=4</td>
</tr>
</tbody>
</table>
+--------------------+--------------+----------------+
2 rows in set (0.03 sec)
```

See Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.

`ALTER TABLESPACE` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

### 13.1.9 ALTER VIEW Statement

```sql
ALTER
    [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}]
    [DEFINER = user]
    [SQL SECURITY { DEFINER | INVOKER }]
VIEW view_name [(column_list)]
AS select_statement
 [WITH [CASCADED | LOCAL] CHECK OPTION]
```

This statement changes the definition of a view, which must exist. The syntax is similar to that for `CREATE VIEW` (see Section 13.1.20, “CREATE VIEW Statement”). This statement requires the `CREATE VIEW` and `DROP` privileges for the view, and some privilege for each column referred to in the `SELECT` statement. `ALTER VIEW` is permitted only to the definer or users with the `SUPER` privilege.

### 13.1.10 CREATE DATABASE Statement

```sql
CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name
    [create_specification] ...
```

`CREATE DATABASE` creates a database with the given name. To use this statement, you need the `CREATE` privilege for the database. `CREATE SCHEMA` is a synonym for `CREATE DATABASE`.

An error occurs if the database exists and you did not specify `IF NOT EXISTS`.

`CREATE DATABASE` is not permitted within a session that has an active `LOCK TABLES` statement.

`create_specification` options specify database characteristics. Database characteristics are stored in the `db.opt` file in the database directory. The `CHARACTER SET` clause specifies the default database character set. The `COLLATE` clause specifies the default database collation. Chapter 10, `Character Sets, Collations, Unicode`, discusses character set and collation names.

A database in MySQL is implemented as a directory containing files that correspond to tables in the database. Because there are no tables in a database when it is initially created, the `CREATE DATABASE`
statement creates only a directory under the MySQL data directory and the \texttt{db.opt} file. Rules for permissible database names are given in Section 9.2, “Schema Object Names”. If a database name contains special characters, the name for the database directory contains encoded versions of those characters as described in Section 9.2.4, “Mapping of Identifiers to File Names”.

If you manually create a directory under the data directory (for example, with \texttt{mkdir}), the server considers it a database directory and it shows up in the output of \texttt{SHOW DATABASES}.

MySQL has no limit on the number of databases. The underlying file system may have a limit on the number of directories.

You can also use the \texttt{mysqladmin} program to create databases. See Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”.

13.1.11 CREATE EVENT Statement

\begin{verbatim}
CREATE [DEFINER = user] EVENT [IF NOT EXISTS] event_name
ON SCHEDULE schedule
[ON COMPLETION [NOT] PRESERVE]
[ENABLE | DISABLE | DISABLE ON SLAVE]
[COMMENT 'string']
DO event_body;
\end{verbatim}

\texttt{schedule:}
\begin{itemize}
  \item \texttt{AT} timestamp [+ INTERVAL interval] ...
  \item \texttt{EVERY} interval
  \item \texttt{STARTS} timestamp [+ INTERVAL interval] ...
  \item \texttt{ENDS} timestamp [+ INTERVAL interval] ...
\end{itemize}

\texttt{interval:}
\begin{itemize}
  \item quantity \{YEAR | QUARTER | MONTH | DAY | HOUR | MINUTE |
  \item WEEK | SECOND | YEAR_MONTH | DAY_HOUR | DAY_MINUTE |
  \item DAY_SECOND | HOUR_MINUTE | HOUR_SECOND | MINUTE_SECOND\}
\end{itemize}

This statement creates and schedules a new event. The event will not run unless the Event Scheduler is enabled. For information about checking Event Scheduler status and enabling it if necessary, see Section 20.4.2, “Event Scheduler Configuration”.

\texttt{CREATE EVENT} requires the \texttt{EVENT} privilege for the schema in which the event is to be created. If the \texttt{DEFINER} clause is present, the privileges required depend on the \texttt{user} value, as discussed in Section 20.6, “Stored Object Access Control”.

The minimum requirements for a valid \texttt{CREATE EVENT} statement are as follows:

\begin{itemize}
  \item The keywords \texttt{CREATE EVENT} plus an event name, which uniquely identifies the event in a database schema.
  \item An \texttt{ON SCHEDULE} clause, which determines when and how often the event executes.
  \item A \texttt{DO} clause, which contains the SQL statement to be executed by an event.
\end{itemize}

This is an example of a minimal \texttt{CREATE EVENT} statement:

\begin{verbatim}
CREATE EVENT myevent
  ON SCHEDULE AT CURRENT_TIMESTAMP + INTERVAL 1 HOUR
  DO
    UPDATE myschema.mytable SET mycol = mycol + 1;
\end{verbatim}
The previous statement creates an event named `myevent`. This event executes once—one hour following its creation—by running an SQL statement that increments the value of the `myschema.mytable` table’s `mycol` column by 1.

The `event_name` must be a valid MySQL identifier with a maximum length of 64 characters. Event names are not case-sensitive, so you cannot have two events named `myevent` and `MyEvent` in the same schema. In general, the rules governing event names are the same as those for names of stored routines. See Section 9.2, “Schema Object Names”.

An event is associated with a schema. If no schema is indicated as part of `event_name`, the default (current) schema is assumed. To create an event in a specific schema, qualify the event name with a schema using `schema_name.event_name` syntax.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at event execution time. If the `DEFINER` clause is present, the `user` value should be a MySQL account specified as `'user_name'@'host_name'`, `CURRENT_USER`, or `CURRENT_USER()`. The permitted `user` values depend on the privileges you hold, as discussed in Section 20.6, “Stored Object Access Control”. Also see that section for additional information about event security.

If the `DEFINER` clause is omitted, the default definer is the user who executes the `CREATE EVENT` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

Within an event body, the `CURRENT_USER` function returns the account used to check privileges at event execution time, which is the `DEFINER` user. For information about user auditing within events, see Section 6.2.14, “SQL-Based Account Activity Auditing”.

`IF NOT EXISTS` has the same meaning for `CREATE EVENT` as for `CREATE TABLE`: If an event named `event_name` already exists in the same schema, no action is taken, and no error results. (However, a warning is generated in such cases.)

The `ON SCHEDULE` clause determines when, how often, and for how long the `event_body` defined for the event repeats. This clause takes one of two forms:

- `AT timestamp` is used for a one-time event. It specifies that the event executes one time only at the date and time given by `timestamp`, which must include both the date and time, or must be an expression that resolves to a datetime value. You may use a value of either the `DATETIME` or `TIMESTAMP` type for this purpose. If the date is in the past, a warning occurs, as shown here:

  ```
  mysql> SELECT NOW();
  +---------------------+
  | NOW()               |
  +---------------------+
  | 2006-02-10 23:59:01 |
  +---------------------+
  1 row in set (0.04 sec)
  mysql> CREATE EVENT e_totals
  --> ON SCHEDULE AT '2006-02-10 23:59:00'
  --> DO INSERT INTO test.totals VALUES (NOW());
  Query OK, 0 rows affected, 1 warning (0.00 sec)
  mysql> SHOW WARNINGS\G
  *************************** 1. row ***************************
  Level: Note
  Code: 1588
  Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.
  ```

- `AT NOW()` is used to schedule events to run continuously, at the current time. It specifies that the event runs once each time it is scheduled to run.

`CREATE EVENT` statements which are themselves invalid—for whatever reason—fail with an error.
You may use `CURRENT_TIMESTAMP` to specify the current date and time. In such a case, the event acts as soon as it is created.

To create an event which occurs at some point in the future relative to the current date and time—such as that expressed by the phrase “three weeks from now”—you can use the optional clause `+ INTERVAL interval`. The `interval` portion consists of two parts, a quantity and a unit of time, and follows the syntax rules described in Temporal Intervals, except that you cannot use any units keywords that involving microseconds when defining an event. With some interval types, complex time units may be used. For example, “two minutes and ten seconds” can be expressed as `+ INTERVAL '2:10' MINUTE_SECOND`.

You can also combine intervals. For example, `AT CURRENT_TIMESTAMP + INTERVAL 3 WEEK + INTERVAL 2 DAY` is equivalent to “three weeks and two days from now”. Each portion of such a clause must begin with `+ INTERVAL`.

- To repeat actions at a regular interval, use an `EVERY` clause. The `EVERY` keyword is followed by an `interval` as described in the previous discussion of the `AT` keyword. (`+ INTERVAL` is not used with `EVERY`.) For example, `EVERY 6 WEEK` means “every six weeks”.

Although `+ INTERVAL` clauses are not permitted in an `EVERY` clause, you can use the same complex time units permitted in a `+ INTERVAL`.

An `EVERY` clause may contain an optional `STARTS` clause. `STARTS` is followed by a `timestamp` value that indicates when the action should begin repeating, and may also use `+ INTERVAL interval` to specify an amount of time “from now”. For example, `EVERY 3 MONTH STARTS CURRENT_TIMESTAMP + INTERVAL 1 WEEK` means “every three months, beginning one week from now”. Similarly, you can express “every two weeks, beginning six hours and fifteen minutes from now” as `EVERY 2 WEEK STARTS CURRENT_TIMESTAMP + INTERVAL '6:15' HOUR_MINUTE`. Not specifying `STARTS` is the same as using `STARTS CURRENT_TIMESTAMP`—that is, the action specified for the event begins repeating immediately upon creation of the event.

An `EVERY` clause may contain an optional `ENDS` clause. The `ENDS` keyword is followed by a `timestamp` value that tells MySQL when the event should stop repeating. You may also use `+ INTERVAL interval` with `ENDS`; for instance, `EVERY 12 HOUR STARTS CURRENT_TIMESTAMP + INTERVAL 30 MINUTE ENDS CURRENT_TIMESTAMP + INTERVAL 4 WEEK` is equivalent to “every twelve hours, beginning thirty minutes from now, and ending four weeks from now”. Not using `ENDS` means that the event continues executing indefinitely.

`ENDS` supports the same syntax for complex time units as `STARTS` does.

You may use `STARTS`, `ENDS`, both, or neither in an `EVERY` clause.

If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the `GET_LOCK()` function, or row or table locking.

The `ON SCHEDULE` clause may use expressions involving built-in MySQL functions and user variables to obtain any of the `timestamp` or `interval` values which it contains. You may not use stored functions or user-defined functions in such expressions, nor may you use any table references; however, you may use `SELECT FROM DUAL`. This is true for both `CREATE EVENT` and `ALTER EVENT` statements. References to stored functions, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Times in the `ON SCHEDULE` clause are interpreted using the current session `time_zone` value. This becomes the event time zone; that is, the time zone that is used for event scheduling and is in effect
within the event as it executes. These times are converted to UTC and stored along with the event time zone in the mysql.event table. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. For additional information about representation of event times, see Section 20.4.4, “Event Metadata”. See also Section 13.7.5.19, “SHOW EVENTS Statement”, and Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”.

Normally, once an event has expired, it is immediately dropped. You can override this behavior by specifying ON COMPLETION PRESERVE. Using ON COMPLETION NOT PRESERVE merely makes the default nonpersistent behavior explicit.

You can create an event but prevent it from being active using the DISABLE keyword. Alternatively, you can use ENABLE to make explicit the default status, which is active. This is most useful in conjunction with ALTER EVENT (see Section 13.1.2, “ALTER EVENT Statement”).

A third value may also appear in place of ENABLE or DISABLE; DISABE ON SLAVE is set for the status of an event on a replication slave to indicate that the event was created on the master and replicated to the slave, but is not executed on the slave. See Section 17.4.1.15, “Replication of Invoked Features”.

You may supply a comment for an event using a COMMENT clause. comment may be any string of up to 64 characters that you wish to use for describing the event. The comment text, being a string literal, must be surrounded by quotation marks.

The DO clause specifies an action carried by the event, and consists of an SQL statement. Nearly any valid MySQL statement that can be used in a stored routine can also be used as the action statement for a scheduled event. (See Section 20.8, “Restrictions on Stored Programs”.) For example, the following event e_hourly deletes all rows from the sessions table once per hour, where this table is part of the site_activity schema:

```sql
CREATE EVENT e_hourly
  ON SCHEDULE
    EVERY 1 HOUR
  COMMENT 'Clears out sessions table each hour.'
  DO
    DELETE FROM site_activity.sessions;
```

MySQL stores the sql_mode system variable setting in effect when an event is created or altered, and always executes the event with this setting in force, regardless of the current server SQL mode when the event begins executing.

A CREATE EVENT statement that contains an ALTER EVENT statement in its DO clause appears to succeed; however, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

Note

Statements such as SELECT or SHOW that merely return a result set have no effect when used in an event; the output from these is not sent to the MySQL Monitor, nor is it stored anywhere. However, you can use statements such as SELECT ... INTO and INSERT INTO ... SELECT that store a result. (See the next example in this section for an instance of the latter.)

The schema to which an event belongs is the default schema for table references in the DO clause. Any references to tables in other schemas must be qualified with the proper schema name.

As with stored routines, you can use compound-statement syntax in the DO clause by using the BEGIN and END keywords, as shown here:

```sql
delimiter |
```
CREATE EVENT `e_daily`
ON SCHEDULE
EVERY 1 DAY
COMMENT 'Saves total number of sessions then clears the table each day'
DO
BEGIN
    INSERT INTO site_activity.totals (time, total)
    SELECT CURRENT_TIMESTAMP, COUNT(*)
    FROM site_activity.sessions;
    DELETE FROM site_activity.sessions;
END |
delimiter ;

This example uses the `delimiter` command to change the statement delimiter. See Section 20.1, "Defining Stored Programs".

More complex compound statements, such as those used in stored routines, are possible in an event. This example uses local variables, an error handler, and a flow control construct:

delimiter |
CREATE EVENT `e`
ON SCHEDULE
EVERY 5 SECOND
DO
BEGIN
    DECLARE v INTEGER;
    DECLARE CONTINUE HANDLER FOR SQLEXCEPTION BEGIN END;
    SET v = 0;
    WHILE v < 5 DO
        INSERT INTO t1 VALUES (0);
        UPDATE t2 SET s1 = s1 + 1;
        SET v = v + 1;
    END WHILE;
END |
delimiter ;

There is no way to pass parameters directly to or from events; however, it is possible to invoke a stored routine with parameters within an event:

CREATE EVENT `e_call_myproc`
ON SCHEDULE
AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
DO CALL myproc(5, 27);

If an event's definer has privileges sufficient to set global system variables (see Section 5.1.8.1, "System Variable Privileges"), the event can read and write global variables. As granting such privileges entails a potential for abuse, extreme care must be taken in doing so.

Generally, any statements that are valid in stored routines may be used for action statements executed by events. For more information about statements permitted within stored routines, see Section 20.2.1, "Stored Routine Syntax". You can create an event as part of a stored routine, but an event cannot be created by another event.

13.1.12 CREATE FUNCTION Statement

The `CREATE FUNCTION` statement is used to create stored functions and user-defined functions (UDFs):
CREATE INDEX Statement

• For information about creating stored functions, see Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”.

• For information about creating user-defined functions, see Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”.

13.1.13 CREATE INDEX Statement

```
CREATE [ONLINE | OFFLINE] [UNIQUE | FULLTEXT | SPATIAL] INDEX index_name
    [index_type]
    ON tbl_name (key_part,...)
    [index_option] ...

key_part:
    col_name [length] [ASC | DESC]

index_option:
    KEY_BLOCK_SIZE [=] value
    | index_type
    | WITH PARSER parser_name
    | COMMENT 'string'

index_type:
    USING {BTREE | HASH}
```

Normally, you create all indexes on a table at the time the table itself is created with CREATE TABLE. See Section 13.1.17, “CREATE TABLE Statement”. This guideline is especially important for InnoDB tables, where the primary key determines the physical layout of rows in the data file. CREATE INDEX enables you to add indexes to existing tables.

CREATE INDEX is mapped to an ALTER TABLE statement to create indexes. See Section 13.1.7, “ALTER TABLE Statement”. CREATE INDEX cannot be used to create a PRIMARY KEY; use ALTER TABLE instead. For more information about indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

An index specification of the form (key_part1, key_part2, ...) creates an index with multiple key parts. Index key values are formed by concatenating the values of the given key parts. For example (col1, col2, col3) specifies a multiple-column index with index keys consisting of values from col1, col2, and col3.

A key_part specification can end with ASC or DESC. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

The following sections describe different aspects of the CREATE INDEX statement:

• Column Prefix Key Parts
• Unique Indexes
• Full-Text Indexes
• Spatial Indexes
• Index Options
• Table Copying and Locking Options

**Column Prefix Key Parts**

For string columns, indexes can be created that use only the leading part of column values, using `col_name(length)` syntax to specify an index prefix length:
CREATE INDEX Statement

- Prefixes can be specified for CHAR, VARCHAR, BINARY, and VARBINARY key parts.
- Prefixes must be specified for BLOB and TEXT key parts. Additionally, BLOB and TEXT columns can be indexed only for InnoDB, MyISAM, and BLACKHOLE tables.
- Prefix limits are measured in bytes. However, prefix lengths for index specifications in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements are interpreted as number of characters for nonbinary string types (CHAR, VARCHAR, TEXT) and number of bytes for binary string types (BINARY, VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.
- Prefix support and lengths of prefixes (where supported) are storage engine dependent. For example, a prefix can be up to 767 bytes long for InnoDB tables or 3072 bytes if the innodb_large_prefix option is enabled. For MyISAM tables, the prefix length limit is 1000 bytes. The NDB storage engine does not support prefixes (see Section 18.1.7.6, “Unsupported or Missing Features in NDB Cluster”).
- The statement shown here creates an index using the first 10 characters of the name column (assuming that name has a nonbinary string type):

```
CREATE INDEX part_of_name ON customer (name(10));
```

If names in the column usually differ in the first 10 characters, lookups performed using this index should not be much slower than using an index created from the entire name column. Also, using column prefixes for indexes can make the index file much smaller, which could save a lot of disk space and might also speed up INSERT operations.

Unique Indexes

A UNIQUE index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. If you specify a prefix value for a column in a UNIQUE index, the column values must be unique within the prefix length. A UNIQUE index permits multiple NULL values for columns that can contain NULL.

If a table has a PRIMARY KEY or UNIQUE NOT NULL index that consists of a single column that has an integer type, you can use _rowid to refer to the indexed column in SELECT statements, as follows:

- _rowid refers to the PRIMARY KEY column if there is a PRIMARY KEY consisting of a single integer column. If there is a PRIMARY KEY but it does not consist of a single integer column, _rowid cannot be used.
- Otherwise, _rowid refers to the column in the first UNIQUE NOT NULL index if that index consists of a single integer column. If the first UNIQUE NOT NULL index does not consist of a single integer column, _rowid cannot be used.

Full-Text Indexes

FULLTEXT indexes are supported only for MyISAM tables and can include only CHAR, VARCHAR, and TEXT columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, “Full-Text Search Functions”, for details of operation.

Spatial Indexes

The MyISAM, InnoDB, NDB, and ARCHIVE storage engines support spatial columns such as POINT and GEOMETRY. (Section 11.4, “Spatial Data Types”, describes the spatial data types.) However, support for spatial column indexing varies among engines. Spatial and nonspatial indexes on spatial columns are available according to the following rules.
CREATE INDEX Statement

Spatial indexes on spatial columns (created using `SPATIAL INDEX`) have these characteristics:

- Available only for `MyISAM` tables. Specifying `SPATIAL INDEX` for other storage engines results in an error.
- Indexed columns must be `NOT NULL`.
- Column prefix lengths are prohibited. The full width of each column is indexed.

Nonspatial indexes on spatial columns (created with `INDEX`, `UNIQUE`, or `PRIMARY KEY`) have these characteristics:

- Permitted for any storage engine that supports spatial columns except `ARCHIVE`.
- Columns can be `NULL` unless the index is a primary key.
- For each spatial column in a non-`SPATIAL` index except `POINT` columns, a column prefix length must be specified. (This is the same requirement as for indexed `BLOB` columns.) The prefix length is given in bytes.
- The index type for a non-`SPATIAL` index depends on the storage engine. Currently, B-tree is used.
- Permitted for a column that can have `NULL` values only for `InnoDB`, `MyISAM`, and `MEMORY` tables.

Index Options

Following the key part list, index options can be given. An `index_option` value can be any of the following:

- `KEY_BLOCK_SIZE [=] value`
  
  For `MyISAM` tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides a table-level `KEY_BLOCK_SIZE` value.

  `KEY_BLOCK_SIZE` is not supported at the index level for `InnoDB` tables. See Section 13.1.17, “CREATE TABLE Statement”.

- `index_type`

  Some storage engines permit you to specify an index type when creating an index. For example:

  ```sql
  CREATE TABLE lookup (id INT) ENGINE = MEMORY;
  CREATE INDEX id_index ON lookup (id) USING BTREE;
  ```

  Table 13.1, “Index Types Per Storage Engine” shows the permissible index type values supported by different storage engines. Where multiple index types are listed, the first one is the default when no index type specifier is given. Storage engines not listed in the table do not support an `index_type` clause in index definitions.

<table>
<thead>
<tr>
<th>Storage Engine</th>
<th>Permissible Index Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>InnoDB</td>
<td>BTREE</td>
</tr>
<tr>
<td>MyISAM</td>
<td>BTREE</td>
</tr>
<tr>
<td>MEMORY/HEAP</td>
<td>HASH, BTREE</td>
</tr>
<tr>
<td>NDB</td>
<td>BTREE, HASH (see note in text)</td>
</tr>
</tbody>
</table>
The `index_type` clause cannot be used for `FULLTEXT INDEX` or `SPATIAL INDEX` specifications. Full-text index implementation is storage engine dependent. Spatial indexes are implemented as R-tree indexes.

**BTREE** indexes are implemented by the `NDB` storage engine as T-tree indexes.

**Note**
For indexes on `NDB` table columns, the `USING` option can be specified only for a unique index or primary key. `USING HASH` prevents the creation of an ordered index; otherwise, creating a unique index or primary key on an `NDB` table automatically results in the creation of both an ordered index and a hash index, each of which indexes the same set of columns.

For unique indexes that include one or more `NULL` columns of an `NDB` table, the hash index can be used only to look up literal values, which means that `IS [NOT] NULL` conditions require a full scan of the table. One workaround is to make sure that a unique index using one or more `NULL` columns on such a table is always created in such a way that it includes the ordered index; that is, avoid employing `USING HASH` when creating the index.

If you specify an index type that is not valid for a given storage engine, but another index type is available that the engine can use without affecting query results, the engine uses the available type. The parser recognizes `RTREE` as a type name, but currently this cannot be specified for any storage engine.

**Note**
Use of the `index_type` option before the `ON tbl_name` clause is deprecated; support for use of the option in this position will be removed in a future MySQL release. If an `index_type` option is given in both the earlier and later positions, the final option applies.

`TYPE type_name` is recognized as a synonym for `USING type_name`. However, `USING` is the preferred form.

The following tables show index characteristics for the storage engines that support the `index_type` option.

**Table 13.2 InnoDB Storage Engine Index Characteristics**

<table>
<thead>
<tr>
<th>Index Class</th>
<th>Index Type</th>
<th>Stores NULL VALUES</th>
<th>Permits Multiple NULL Values</th>
<th>IS NULL Scan Type</th>
<th>IS NOT NULL Scan Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary key</td>
<td>BTREE</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Unique</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Key</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
</tbody>
</table>

**Table 13.3 MyISAM Storage Engine Index Characteristics**

<table>
<thead>
<tr>
<th>Index Class</th>
<th>Index Type</th>
<th>Stores NULL VALUES</th>
<th>Permits Multiple NULL Values</th>
<th>IS NULL Scan Type</th>
<th>IS NOT NULL Scan Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary key</td>
<td>BTREE</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Unique</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Key</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
</tbody>
</table>
CREATE INDEX Statement

<table>
<thead>
<tr>
<th>Index Class</th>
<th>Index Type</th>
<th>Stores NULL VALUES</th>
<th>Permits Multiple NULL Values</th>
<th>IS NULL Scan Type</th>
<th>IS NOT NULL Scan Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FULLTEXT</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
<td>Table</td>
<td>Table</td>
</tr>
<tr>
<td>SPATIAL</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 13.4 MEMORY Storage Engine Index Characteristics

<table>
<thead>
<tr>
<th>Index Class</th>
<th>Index Type</th>
<th>Stores NULL VALUES</th>
<th>Permits Multiple NULL Values</th>
<th>IS NULL Scan Type</th>
<th>IS NOT NULL Scan Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary key</td>
<td>BTREE</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Unique</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Key</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Primary key</td>
<td>HASH</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Unique</td>
<td>HASH</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Key</td>
<td>HASH</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
</tbody>
</table>

Table 13.5 NDB Storage Engine Index Characteristics

<table>
<thead>
<tr>
<th>Index Class</th>
<th>Index Type</th>
<th>Stores NULL VALUES</th>
<th>Permits Multiple NULL Values</th>
<th>IS NULL Scan Type</th>
<th>IS NOT NULL Scan Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary key</td>
<td>BTREE</td>
<td>No</td>
<td>No</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Unique</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Key</td>
<td>BTREE</td>
<td>Yes</td>
<td>Yes</td>
<td>Index</td>
<td>Index</td>
</tr>
<tr>
<td>Primary key</td>
<td>HASH</td>
<td>No</td>
<td>No</td>
<td>Table (see note 1)</td>
<td>Table (see note 1)</td>
</tr>
<tr>
<td>Unique</td>
<td>HASH</td>
<td>Yes</td>
<td>Yes</td>
<td>Table (see note 1)</td>
<td>Table (see note 1)</td>
</tr>
<tr>
<td>Key</td>
<td>HASH</td>
<td>Yes</td>
<td>Yes</td>
<td>Table (see note 1)</td>
<td>Table (see note 1)</td>
</tr>
</tbody>
</table>

Table note:
1. If USING HASH is specified that prevents creation of an implicit ordered index.

- WITH PARSER parser_name

   This option can be used only with FULLTEXT indexes. It associates a parser plugin with the index if full-text indexing and searching operations need special handling. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

- COMMENT 'string'

   Index definitions can include an optional comment of up to 1024 characters.

Table Copying and Locking Options

Indexes on variable-width columns of NDBCLUSTER tables are created online; that is, without any table copying. The table is not locked against access from other NDB Cluster API nodes, although it is locked against other operations on the same API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.5 releases, it is not possible to override the server when it determines that an index is to be created without table copying. In NDB Cluster, you can create indexes offline (which causes the
table to be locked to all API nodes in the cluster) using the `OFFLINE` keyword. The rules and limitations governing `CREATE OFFLINE INDEX` and `CREATE ONLINE INDEX` are the same as for `ALTER OFFLINE TABLE ... ADD INDEX` and `ALTER ONLINE TABLE ... ADD INDEX`. You cannot cause the noncopying creation of an index that would normally be created offline by using the `ONLINE` keyword: If it is not possible to perform the `CREATE INDEX` operation without table copying, the server ignores the `ONLINE` keyword. For more information, see Section 18.5.13, “Online Operations with ALTER TABLE in NDB Cluster”.

The `ONLINE` and `OFFLINE` keywords are available only in NDB Cluster; attempting to use these keywords in standard MySQL Server 5.5 releases results in a syntax error.

### 13.1.14 CREATE LOGFILE GROUP Statement

```
CREATE LOGFILE GROUP logfile_group
  ADD UNDOFILE 'undo_file'
  [INITIAL_SIZE [=] initial_size]
  [UNDO_BUFFER_SIZE [=] undo_buffer_size]
  [REDO_BUFFER_SIZE [=] redo_buffer_size]
  [NODEGROUP [=] nodegroup_id]
  [WAIT]
  [COMMENT [=] 'string']
  ENGINE [=] engine_name
```

This statement creates a new log file group named `logfile_group` having a single `UNDO` file named `undo_file`. A `CREATE LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. For rules covering the naming of log file groups, see Section 9.2, “Schema Object Names”.

**Note**

All NDB Cluster Disk Data objects share the same namespace. This means that each Disk Data object must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

In MySQL NDB Cluster 7.2, you can have only one log file group per Cluster at any given time. (See Bug #16386)

The optional `INITIAL_SIZE` parameter sets the `UNDO` file's initial size; if not specified, it defaults to 128M (128 megabytes). The optional `UNDO_BUFFER_SIZE` parameter sets the size used by the `UNDO` buffer for the log file group; The default value for `UNDO_BUFFER_SIZE` is 8M (eight megabytes); this value cannot exceed the amount of system memory available. Both of these parameters are specified in bytes. In MySQL NDB Cluster 7.2.14 and later, you may optionally follow either or both of these with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters M (for megabytes) or G (for gigabytes). Prior to MySQL NDB Cluster 7.2.14, the values for these options could only be specified using digits. (Bug #13116514, Bug #16104705, Bug #62858)

Memory used for `UNDO_BUFFER_SIZE` comes from the global pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter. This includes any default value implied for this option by the setting of the `InitialLogFileGroup` data node configuration parameter.

The maximum permitted for `UNDO_BUFFER_SIZE` is 629145600 (600 MB).

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is 4294967296 (4 GB). (Bug #29186)

The minimum allowed value for `INITIAL_SIZE` is 1048576 (1 MB).

The `ENGINE` option determines the storage engine to be used by this log file group, with `engine_name` being the name of the storage engine. In MySQL 5.5, this must be `NDB` (or `NDBCluster`). If `ENGINE` is not
CREATE PROCEDURE and CREATE FUNCTION Statements

set, MySQL tries to use the engine specified by the default_storage_engine server system variable (formerly storage_engine). In any case, if the engine is not specified as NDB or NDBCLUSTER, the CREATE LOGFILE GROUP statement appears to succeed but actually fails to create the log file group, as shown here:

```sql
mysql> CREATE LOGFILE GROUP lg1
    -> ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+------------------------------------------------------------------------------------------------+
| Level | Code | Message                                                                                        |
+-------+------+------------------------------------------------------------------------------------------------+
| Error | 1478 | Table storage engine 'InnoDB' does not support the create option 'TABLESPACE or LOGFILE GROUP' |
+-------+------+------------------------------------------------------------------------------------------------+
1 row in set (0.00 sec)

mysql> DROP LOGFILE GROUP lg1 ENGINE = NDB;
ERROR 1529 (HY000): Failed to drop LOGFILE GROUP

mysql> CREATE LOGFILE GROUP lg1
    -> ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M
    -> ENGINE = NDB;
Query OK, 0 rows affected (2.97 sec)
```

The fact that the CREATE LOGFILE GROUP statement does not actually return an error when a non-NDB storage engine is named, but rather appears to succeed, is a known issue which we hope to address in a future release of NDB Cluster.

REDO_BUFFER_SIZE, NODEGROUP, WAIT, and COMMENT are parsed but ignored, and so have no effect in MySQL 5.5. These options are intended for future expansion.

When used with ENGINE [=] NDB, a log file group and associated UNDO log file are created on each Cluster data node. You can verify that the UNDO files were created and obtain information about them by querying the INFORMATION_SCHEMA.FILES table. For example:

```sql
mysql> SELECT LOGFILE_GROUP_NAME, LOGFILE_GROUP_NUMBER, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE FILE_NAME = 'undo_10.dat';
+--------------------+----------------+----------------+
| LOGFILE_GROUP_NAME | LOGFILE_GROUP_NUMBER | EXTRA          |
|--------------------|----------------+----------------|
| lg_3               |                   11 | CLUSTER_NODE=3 |
| lg_3               |                   11 | CLUSTER_NODE=4 |
+--------------------+----------------+----------------+
2 rows in set (0.06 sec)
```

CREATE LOGFILE GROUP is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.15 CREATE PROCEDURE and CREATE FUNCTION Statements

CREATE

[DEFINER = user]
PROCEDURE sp_name ([proc_parameter[,]])
[characteristic ...] routine_body

CREATE

[DEFINER = user]
FUNCTION sp_name ([func_parameter,])
RETURNS type
[characteristic ...] routine_body
CREATE PROCEDURE and CREATE FUNCTION Statements

**proc_parameter:**

<table>
<thead>
<tr>
<th>IN</th>
<th>OUT</th>
<th>INOUT</th>
</tr>
</thead>
</table>
\[ param_name type

**func_parameter:**

\[ param_name type

**type:**

Any valid MySQL data type

**characteristic:**

- COMMENT 'string'
- LANGUAGE SQL
- [NOT] DETERMINISTIC
- { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
- SQL SECURITY { DEFINER | INVOKER }

**routine_body:**

Valid SQL routine statement

These statements create stored routines. By default, a routine is associated with the default database. To associate the routine explicitly with a given database, specify the name as *db_name.sp_name* when you create it.

The **CREATE FUNCTION** statement is also used in MySQL to support UDFs (user-defined functions). See Section 24.4, “Adding Functions to MySQL”. A UDF can be regarded as an external stored function. Stored functions share their namespace with UDFs. See Section 9.2.5, “Function Name Parsing and Resolution”, for the rules describing how the server interprets references to different kinds of functions.

To invoke a stored procedure, use the **CALL** statement (see Section 13.2.1, “CALL Statement”). To invoke a stored function, refer to it in an expression. The function returns a value during expression evaluation.

**CREATE PROCEDURE** and **CREATE FUNCTION** require the **CREATE ROUTINE** privilege. If the **DEFINER** clause is present, the privileges required depend on the *user* value, as discussed in Section 20.6, “Stored Object Access Control”. If binary logging is enabled, **CREATE FUNCTION** might require the **SUPER** privilege, as discussed in Section 20.7, “Stored Program Binary Logging”.

By default, MySQL automatically grants the **ALTER ROUTINE** and **EXECUTE** privileges to the routine creator. This behavior can be changed by disabling the **automatic_sp_privileges** system variable. See Section 20.2.2, “Stored Routines and MySQL Privileges”.

The **DEFINER** and **SQL SECURITY** clauses specify the security context to be used when checking access privileges at routine execution time, as described later in this section.

If the routine name is the same as the name of a built-in SQL function, a syntax error occurs unless you use a space between the name and the following parenthesis when defining the routine or invoking it later. For this reason, avoid using the names of existing SQL functions for your own stored routines.

The **IGNORE_SPACE** SQL mode applies to built-in functions, not to stored routines. It is always permissible to have spaces after a stored routine name, regardless of whether **IGNORE_SPACE** is enabled.

The parameter list enclosed within parentheses must always be present. If there are no parameters, an empty parameter list of () should be used. Parameter names are not case-sensitive.

Each parameter is an **IN** parameter by default. To specify otherwise for a parameter, use the keyword **OUT** or **INOUT** before the parameter name.

**Note**

Specifying a parameter as **IN**, **OUT**, or **INOUT** is valid only for a **PROCEDURE**. For a **FUNCTION**, parameters are always regarded as **IN** parameters.
CREATE PROCEDURE and CREATE FUNCTION Statements

An **IN** parameter passes a value into a procedure. The procedure might modify the value, but the modification is not visible to the caller when the procedure returns. An **OUT** parameter passes a value from the procedure back to the caller. Its initial value is **NULL** within the procedure, and its value is visible to the caller when the procedure returns. An **INOUT** parameter is initialized by the caller, can be modified by the procedure, and any change made by the procedure is visible to the caller when the procedure returns.

For each **OUT** or **INOUT** parameter, pass a user-defined variable in the **CALL** statement that invokes the procedure so that you can obtain its value when the procedure returns. If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an **OUT** or **INOUT** parameter. If you are calling the procedure from within a trigger, you can also pass **NEW.col_name** as an **OUT** or **INOUT** parameter.

For information about the effect of unhandled conditions on procedure parameters, see Section 13.6.7.5, “Condition Handling and OUT or INOUT Parameters”.

Routine parameters cannot be referenced in statements prepared within the routine; see Section 20.8, “Restrictions on Stored Programs”.

The following example shows a simple stored procedure that uses an **OUT** parameter:

```sql
mysql> delimiter //
mysql> CREATE PROCEDURE simpleproc (OUT param1 INT)
    -> BEGIN
    -> SELECT COUNT(*) INTO param1 FROM t;
    -> END;//
Query OK, 0 rows affected (0.00 sec)
mysql> delimiter ;
mysql> CALL simpleproc(@a);
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT @a;
+-----+
<table>
<thead>
<tr>
<th>@a</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>
+-----+
1 row in set (0.00 sec)
```

The example uses the `mysql` client `delimiter` command to change the statement delimiter from `;` to `//` while the procedure is being defined. This enables the `;` delimiter used in the procedure body to be passed through to the server rather than being interpreted by `mysql` itself. See Section 20.1, “Defining Stored Programs”.

The **RETURNS** clause may be specified only for a **FUNCTION**, for which it is mandatory. It indicates the return type of the function, and the function body must contain a `RETURN value` statement. If the `RETURN` statement returns a value of a different type, the value is coerced to the proper type. For example, if a function specifies an **ENUM** or **SET** value in the **RETURNS** clause, but the `RETURN` statement returns an integer, the value returned from the function is the string for the corresponding **ENUM** member of set of **SET** members.

The following example function takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```sql
mysql> CREATE FUNCTION hello (s CHAR(20))
mysql> RETURNS CHAR(50) DETERMINISTIC
```
Parameter types and function return types can be declared to use any valid data type. The `COLLATE` attribute can be used if preceded by a `CHARACTER SET` specification.

The `routine_body` consists of a valid SQL routine statement. This can be a simple statement such as `SELECT` or `INSERT`, or a compound statement written using `BEGIN` and `END`. Compound statements can contain declarations, loops, and other control structure statements. The syntax for these statements is described in Section 13.6, “Compound-Statements”. In practice, stored functions tend to use compound statements, unless the body consists of a single `RETURN` statement.

MySQL permits routines to contain DDL statements, such as `CREATE` and `DROP`. MySQL also permits stored procedures (but not stored functions) to contain SQL transaction statements such as `COMMIT`. Stored functions may not contain statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.

Statements that return a result set can be used within a stored procedure but not within a stored function. This prohibition includes `SELECT` statements that do not have an `INTO var_list` clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. For statements that can be determined at function definition time to return a result set, a `Not allowed to return a result set from a function` error occurs (`ER_SP_NO_RETSET`). For statements that can be determined only at runtime to return a result set, a `PROCEDURE %s can't return a result set in the given context` error occurs (`ER_SP_BADSELECT`).

`USE` statements within stored routines are not permitted. When a routine is invoked, an implicit `USE db_name` is performed (and undone when the routine terminates). The causes the routine to have the given default database while it executes. References to objects in databases other than the routine default database should be qualified with the appropriate database name.

For additional information about statements that are not permitted in stored routines, see Section 20.8, “Restrictions on Stored Programs”.

For information about invoking stored procedures from within programs written in a language that has a MySQL interface, see Section 13.2.1, “CALL Statement”.

MySQL stores the `sql_mode` system variable setting in effect when a routine is created or altered, and always executes the routine with this setting in force, `regardless of the current server SQL mode when the routine begins executing`.

The switch from the SQL mode of the invoker to that of the routine occurs after evaluation of arguments and assignment of the resulting values to routine parameters. If you define a routine in strict SQL mode but invoke it in nonstrict mode, assignment of arguments to routine parameters does not take place in strict mode. If you require that expressions passed to a routine be assigned in strict SQL mode, you should invoke the routine with strict mode in effect.

The `COMMENT` characteristic is a MySQL extension, and may be used to describe the stored routine. This information is displayed by the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements.
The **LANGUAGE** characteristic indicates the language in which the routine is written. The server ignores this characteristic; only SQL routines are supported.

A routine is considered "deterministic" if it always produces the same result for the same input parameters, and "not deterministic" otherwise. If neither **DETERMINISTIC** nor **NOT DETERMINISTIC** is given in the routine definition, the default is **NOT DETERMINISTIC**. To declare that a function is deterministic, you must specify **DETERMINISTIC** explicitly.

Assessment of the nature of a routine is based on the “honesty” of the creator: MySQL does not check that a routine declared **DETERMINISTIC** is free of statements that produce nondeterministic results. However, misdeclaring a routine might affect results or affect performance. Declaring a nondeterministic routine as **DETERMINISTIC** might lead to unexpected results by causing the optimizer to make incorrect execution plan choices. Declaring a deterministic routine as **NONDETERMINISTIC** might diminish performance by causing available optimizations not to be used.

If binary logging is enabled, the **DETERMINISTIC** characteristic affects which routine definitions MySQL accepts. See Section 20.7, “Stored Program Binary Logging”.

A routine that contains the **NOW()** function (or its synonyms) or **RAND()** is nondeterministic, but it might still be replication-safe. For **NOW()**, the binary log includes the timestamp and replicates correctly. **RAND()** also replicates correctly as long as it is called only a single time during the execution of a routine. (You can consider the routine execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

Several characteristics provide information about the nature of data use by the routine. In MySQL, these characteristics are advisory only. The server does not use them to constrain what kinds of statements a routine will be permitted to execute.

- **CONTAINS SQL** indicates that the routine does not contain statements that read or write data. This is the default if none of these characteristics is given explicitly. Examples of such statements are `SET @x = 1` or `DO RELEASE_LOCK('abc')`, which execute but neither read nor write data.

- **NO SQL** indicates that the routine contains no SQL statements.

- **READS SQL DATA** indicates that the routine contains statements that read data (for example, **SELECT**), but not statements that write data.

- **MODIFIES SQL DATA** indicates that the routine contains statements that may write data (for example, **INSERT** or **DELETE**).

The **SQL SECURITY** characteristic can be **DEFINER** or **INVOKER** to specify the security context; that is, whether the routine executes using the privileges of the account named in the routine **DEFINER** clause or the user who invokes it. This account must have permission to access the database with which the routine is associated. The default value is **DEFINER**. The user who invokes the routine must have the **EXECUTE** privilege for it, as must the **DEFINER** account if the routine executes in definer security context.

The **DEFINER** clause specifies the MySQL account to be used when checking access privileges at routine execution time for routines that have the **SQL SECURITY DEFINER** characteristic.

If the **DEFINER** clause is present, the **user** value should be a MySQL account specified as `'user_name'@'host_name'`, **CURRENT_USER**, or **CURRENT_USER()**. The permitted **user** values depend on the privileges you hold, as discussed in Section 20.6, “Stored Object Access Control”. Also see that section for additional information about stored routine security.

If the **DEFINER** clause is omitted, the default definer is the user who executes the **CREATE PROCEDURE** or **CREATE FUNCTION** statement. This is the same as specifying **DEFINER = CURRENT_USER** explicitly.
Within the body of a stored routine that is defined with the SQL SECURITY DEFINER characteristic, the CURRENT_USER function returns the routine's DEFINER value. For information about user auditing within stored routines, see Section 6.2.14, “SQL-Based Account Activity Auditing”.

Consider the following procedure, which displays a count of the number of MySQL accounts listed in the mysql.user system table:

```sql
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
BEGIN
    SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure is assigned a DEFINER account of 'admin'@'localhost' no matter which user defines it. It executes with the privileges of that account no matter which user invokes it (because the default security characteristic is DEFINER). The procedure succeeds or fails depending on whether invoker has the EXECUTE privilege for it and 'admin'@'localhost' has the SELECT privilege for the mysql.user system table.

Now suppose that the procedure is defined with the SQL SECURITY INVOKER characteristic:

```sql
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
SQL SECURITY INVOKER
BEGIN
    SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure still has a DEFINER of 'admin'@'localhost', but in this case, it executes with the privileges of the invoking user. Thus, the procedure succeeds or fails depending on whether the invoker has the EXECUTE privilege for it and the SELECT privilege for the mysql.user system table.

The server handles the data type of a routine parameter, local routine variable created with DECLARE, or function return value as follows:

- Assignments are checked for data type mismatches and overflow. Conversion and overflow problems result in warnings, or errors in strict SQL mode.

- Only scalar values can be assigned. For example, a statement such as SET x = (SELECT 1, 2) is invalid.

- For character data types, if CHARACTER_SET is included in the declaration, the specified character set and its default collation is used. If the COLLATE attribute is also present, that collation is used rather than the default collation.

Prior to MySQL 5.5.3, if there is a CHARACTER_SET attribute in the declaration, the COLLATE attribute is not supported, and the character set's default collation is used. (This includes use of BINARY, which in this context specifies the binary collation of the character set.) If there is no CHARACTER_SET attribute, the database character set and its default collation (rather than the database collation) are used.

If CHARACTER_SET and COLLATE are not present, the database character set and collation in effect at routine creation time are used. To avoid having the server use the database character set and collation, provide an explicit CHARACTER_SET and a COLLATE attribute for character data parameters.

If you change the database default character set or collation, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults.

The database character set and collation are given by the value of the character_set_database and collation_database system variables. For more information, see Section 10.3.3, “Database Character Set and Collation”. 
13.1.16 CREATE SERVER Statement

CREATE SERVER server_name
FOREIGN DATA WRAPPER wrapper_name
OPTIONS (option [, option] ...)

option:
| HOST character-literal |
| DATABASE character-literal |
| USER character-literal |
| PASSWORD character-literal |
| SOCKET character-literal |
| OWNER character-literal |
| PORT numeric-literal |

This statement creates the definition of a server for use with the FEDERATED storage engine. The CREATE SERVER statement creates a new row in the servers table in the mysql database. This statement requires the SUPER privilege.

The server_name should be a unique reference to the server. Server definitions are global within the scope of the server, it is not possible to qualify the server definition to a specific database. server_name has a maximum length of 64 characters (names longer than 64 characters are silently truncated), and is case-insensitive. You may specify the name as a quoted string.

The wrapper_name is an identifier and may be quoted with single quotation marks.

For each option you must specify either a character literal or numeric literal. Character literals are UTF-8, support a maximum length of 64 characters and default to a blank (empty) string. String literals are silently truncated to 64 characters. Numeric literals must be a number between 0 and 9999, default value is 0.

Note

The OWNER option is currently not applied, and has no effect on the ownership or operation of the server connection that is created.

The CREATE SERVER statement creates an entry in the mysql.servers table that can later be used with the CREATE TABLE statement when creating a FEDERATED table. The options that you specify will be used to populate the columns in the mysql.servers table. The table columns are Server_name, Host, Db, Username, Password, Port and Socket.

For example:

CREATE SERVER s
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'Remote', HOST '198.51.100.106', DATABASE 'test');

Be sure to specify all options necessary to establish a connection to the server. The user name, host name, and database name are mandatory. Other options might be required as well, such as password.

The data stored in the table can be used when creating a connection to a FEDERATED table:

CREATE TABLE t (s1 INT) ENGINE=FEDERATED CONNECTION='s';

For more information, see Section 15.9, “The FEDERATED Storage Engine”.

CREATE SERVER causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

CREATE SERVER is not written to the binary log, regardless of the logging format that is in use.
13.1.17 CREATE TABLE Statement

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
  (create_definition,...)
  [table_options]
  [partition_options]

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
  [(create_definition,...)]
  [table_options]
  [partition_options]
  [IGNORE | REPLACE]
  [AS] query_expression

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
  { LIKE old_tbl_name | (LIKE old_tbl_name) }

create_definition:
  col_name column_definition
  | [INDEX|KEY] [index_name] [index_type] (key_part,...)
  | [index_option] ...
  | {FULLTEXT|SPATIAL} [INDEX|KEY] [index_name] (key_part,...)
  | [index_option] ...
  | [CONSTRAINT [symbol]] PRIMARY KEY
  | [index_type] (key_part,...)
  | [index_option] ...
  | [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
  | [index_name] [index_type] (key_part,...)
  | [index_option] ...
  | [CONSTRAINT [symbol]] FOREIGN KEY
  | [index_name] (col_name,...)
  reference_definition
  | CHECK (expr)

column_definition:
  data_type [NOT NULL | NULL] [DEFAULT default_value]
  [AUTO_INCREMENT] [UNIQUE [KEY]] [[PRIMARY] KEY]
  [COMMENT 'string']
  [COLLATE collation_name]
  [COLUMN_FORMAT {FIXED|DYNAMIC|DEFAULT}]
  [STORAGE {DISK|MÉMORY}]
  [reference_definition]

data_type:
  (see Chapter 11, Data Types)

key_part:
  col_name [(length)] [ASC | DESC]

index_type:
  USING {BTREE | HASH}

index_option:
  KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name
  | COMMENT 'string'

reference_definition:
  REFERENCES tbl_name (key_part,...)
  [MATCH FULL | MATCH PARTIAL | MATCH SIMPLE]
  [ON DELETE reference_option]
  [ON UPDATE reference_option]

reference_option:
  RESTRICT | CASCADE | SET NULL | NO ACTION | SET DEFAULT
CREATE TABLE Statement

**table_options:**
- table_option \([,] \) table_option ...  

**table_option:**
- AUTO_INCREMENT \([\text{-}]\) value  
- AVG_ROW_LENGTH \([\text{-}]\) value  
- [DEFAULT] CHARACTER SET \([\text{-}]\) charset_name  
- CHECKSUM \([\text{-}]\) \([0 \mid 1]\)  
- [DEFAULT] COLLATE \([\text{-}]\) collation_name  
- COMMENT \([\text{-}]\) 'string'  
- CONNECTION \([\text{-}]\) 'connect_string'  
- DATA|INDEX DIRECTORY \([\text{-}]\) 'absolute path to directory'  
- DELAY_KEY_WRITE \([\text{-}]\) \([0 \mid 1]\)  
- ENGINE \([\text{-}]\) engine_name  
- INSERT_METHOD \([\text{-}]\) \([\text{NO \mid FIRST \mid LAST}]\)  
- KEY_BLOCK_SIZE \([\text{-}]\) value  
- MAX_ROWS \([\text{-}]\) value  
- MIN_ROWS \([\text{-}]\) value  
- PACK_KEYS \([\text{-}]\) \([0 \mid 1 \mid \text{DEFAULT}]\)  
- PASSWORD \([\text{-}]\) 'string'  
- ROW_FORMAT \([\text{-}]\) \([\text{DEFAULT\midDYNAMIC\midFIXED\midCOMPRESSED\midREDUNDANT\midCOMPACT}]\)  
- TABLESPACE tablespace_name \([\text{STORAGE \{DISK\midMEMORY\}}]\)  
- UNION \([\text{-}]\) ( \(\text{tbl_name}[\text{,} \text{tbl_name}]\)...  

**partition_options:**
- PARTITION BY  
  - \([\text{LINEAR}] \) HASH(expr)  
  - \([\text{LINEAR}] \) KEY [ALGORITHM=\([1\mid2]\)] \(\) column_list\)  
  - RANGE\(\)\(\)expr\(\) \(\mid\) COLUMNS\(\)\(\)column_list\)\(\)\)  
  - LIST\(\)\(\)expr\(\) \(\mid\) COLUMNS\(\)\(\)column_list\)\(\)\)  

\([\text{PARTITIONS num}]\)  
- [SUBPARTITION BY  
  - \([\text{LINEAR}] \) HASH(expr)  
  - \([\text{LINEAR}] \) KEY [ALGORITHM=\([1\mid2]\)] \(\) column_list\)\)  

\([\text{SUBPARTITIONS num}]\)  
- \((\text{partition_definition}[\text{,} \text{partition_definition}] \ldots)\)  

**partition_definition:**
- PARTITION partition_name  
  - VALUES  
    - LESS THAN \((\text{expr} | \text{value_list}) \mid \text{MAXVALUE}\)  
    - IN \((\text{value_list})\)\)  
  - \([\text{STORAGE}] \) ENGINE \([\text{-}]\) engine_name  
  - [COMMENT \([\text{-}]\) 'string' ]  
  - DATA DIRECTORY \([\text{-}]\) 'data_dir'  
  - INDEX DIRECTORY \([\text{-}]\) 'index_dir'  
  - MAX_ROWS \([\text{-}]\) max_number_of_rows  
  - MIN_ROWS \([\text{-}]\) min_number_of_rows  
  - TABLESPACE \([\text{-}]\) tablespace_name  
  - NODEGROUP \([\text{-}]\) node_group_id  

\([\text{subpartition_definition}[\text{,} \text{subpartition_definition}] \ldots)\)  

**subpartition_definition:**
- SUBPARTITION logical_name  
  - \([\text{STORAGE}] \) ENGINE \([\text{-}]\) engine_name  
  - [COMMENT \([\text{-}]\) 'string' ]  
  - DATA DIRECTORY \([\text{-}]\) 'data_dir'  
  - INDEX DIRECTORY \([\text{-}]\) 'index_dir'  
  - MAX_ROWS \([\text{-}]\) max_number_of_rows  
  - MIN_ROWS \([\text{-}]\) min_number_of_rows  
  - TABLESPACE \([\text{-}]\) tablespace_name  
  - NODEGROUP \([\text{-}]\) node_group_id  

query_expression:
CREATE TABLE creates a table with the given name. You must have the CREATE privilege for the table.

By default, tables are created in the default database, using the InnoDB storage engine. An error occurs if the table exists, if there is no default database, or if the database does not exist.

MySQL has no limit on the number of tables. The underlying file system may have a limit on the number of files that represent tables. Individual storage engines may impose engine-specific constraints. InnoDB permits up to 4 billion tables.

For information about the physical representation of a table, see Section 13.1.17.2, “Files Created by CREATE TABLE”.

The original CREATE TABLE statement, including all specifications and table options are stored by MySQL when the table is created. For more information, see Section 13.1.17.1, “CREATE TABLE Statement Retention”.

There are several aspects to the CREATE TABLE statement, described under the following topics in this section:

- Table Name
- Temporary Tables
- Table Cloning and Copying
- Column Data Types and Attributes
- Indexes and Foreign Keys
- Table Options
- Table Partitioning

Table Name

- tbl_name

The table name can be specified as db_name.tbl_name to create the table in a specific database. This works regardless of whether there is a default database, assuming that the database exists. If you use quoted identifiers, quote the database and table names separately. For example, write `mydb`.`mytbl`, not `mydb.mytbl`.

Rules for permissible table names are given in Section 9.2, “Schema Object Names”.

- IF NOT EXISTS

Prevents an error from occurring if the table exists. However, there is no verification that the existing table has a structure identical to that indicated by the CREATE TABLE statement.

Temporary Tables

You can use the TEMPORARY keyword when creating a table. A TEMPORARY table is visible only within the current session, and is dropped automatically when the session is closed. For more information, see Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”.

Table Cloning and Copying

- LIKE
Use `CREATE TABLE ... LIKE` to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```sql
CREATE TABLE new_tbl LIKE orig_tbl;
```

For more information, see Section 13.1.17.4, “CREATE TABLE ... LIKE Statement”.

- **[AS] query_expression**

To create one table from another, add a `SELECT` statement at the end of the `CREATE TABLE` statement:

```sql
CREATE TABLE new_tbl AS SELECT * FROM orig_tbl;
```

For more information, see Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”.

- **IGNORE|REPLACE**

The `IGNORE` and `REPLACE` options indicate how to handle rows that duplicate unique key values when copying a table using a `SELECT` statement.

For more information, see Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”.

### Column Data Types and Attributes

There is a hard limit of 4096 columns per table, but the effective maximum may be less for a given table and depends on the factors discussed in Section 8.4.7, “Limits on Table Column Count and Row Size”.

- **data_type**

  `data_type` represents the data type in a column definition. For a full description of the syntax available for specifying column data types, as well as information about the properties of each type, see Chapter 11, `Data Types`.

  - Some attributes do not apply to all data types. `AUTO_INCREMENT` applies only to integer and floating-point types. `DEFAULT` does not apply to the `BLOB` or `TEXT` types.

  - Character data types (`CHAR`, `VARCHAR`, the `TEXT` types, `ENUM`, `SET`, and any synonyms) can include `CHARACTER SET` to specify the character set for the column. `CHARSET` is a synonym for `CHARACTER SET`. A collation for the character set can be specified with the `COLLATE` attribute, along with any other attributes. For details, see Chapter 10, `Character Sets, Collations, Unicode`. Example:

    ```sql
    CREATE TABLE t (c CHAR(20) CHARACTER SET utf8 COLLATE utf8_bin);
    ```

    MySQL 5.5 interprets length specifications in character column definitions in characters. Lengths for `BINARY` and `VARBINARY` are in bytes.

  - For `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY` columns, indexes can be created that use only the leading part of column values, using `col_name(length)` syntax to specify an index prefix length. `BLOB` and `TEXT` columns also can be indexed, but a prefix length must be given. Prefix lengths are given in characters for nonbinary string types and in bytes for binary string types. That is, index entries consist of the first `length` characters of each column value for `CHAR`, `VARCHAR`, and `TEXT` columns, and the first `length` bytes of each column value for `BINARY`, `VARBINARY`, and `BLOB` columns. Indexing only a prefix of column values like this can make the index file much smaller. For additional information about index prefixes, see Section 13.1.13, “CREATE INDEX Statement”.

    Only the `InnoDB` and `MyISAM` storage engines support indexing on `BLOB` and `TEXT` columns. For example:
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));

- **NOT NULL | NULL**

  If neither **NULL** nor **NOT NULL** is specified, the column is treated as though **NULL** had been specified.

  In MySQL 5.5, only the **InnoDB, MyISAM, and MEMORY** storage engines support indexes on columns that can have **NULL** values. In other cases, you must declare indexed columns as **NOT NULL** or an error results.

- **DEFAULT**

  Specifies a default value for a column. For more information about default value handling, including the case that a column definition includes no explicit **DEFAULT** value, see Section 11.5, "Data Type Default Values".

  **CREATE TABLE** fails if a date-valued default is not correct according to the **NO_ZERO_IN_DATE** SQL mode, even if strict SQL mode is not enabled. For example, `c1 DATE DEFAULT '2010-00-00'` causes **CREATE TABLE** to fail with **Invalid default value for 'c1'**.

- **AUTO_INCREMENT**

  An integer or floating-point column can have the additional attribute **AUTO_INCREMENT**. When you insert a value of **NULL** (recommended) or **0** into an indexed **AUTO_INCREMENT** column, the column is set to the next sequence value. Typically this is **value+1**, where **value** is the largest value for the column currently in the table. **AUTO_INCREMENT** sequences begin with **1**.

  To retrieve an **AUTO_INCREMENT** value after inserting a row, use the **LAST_INSERT_ID()** SQL function or the **mysql_insert_id()** C API function. See Section 12.15, "Information Functions", and Section 23.7.6.37, "mysql_insert_id()".

  If the **NO_AUTO_VALUE_ON_ZERO** SQL mode is enabled, you can store **0** in **AUTO_INCREMENT** columns as **0** without generating a new sequence value. See Section 5.1.10, "Server SQL Modes".

  There can be only one **AUTO_INCREMENT** column per table, it must be indexed, and it cannot have a **DEFAULT** value. An **AUTO_INCREMENT** column works properly only if it contains only positive values. Inserting a negative number is regarded as inserting a very large positive number. This is done to avoid precision problems when numbers "wrap" over from positive to negative and also to ensure that you do not accidentally get an **AUTO_INCREMENT** column that contains **0**.

  For **MyISAM** tables, you can specify an **AUTO_INCREMENT** secondary column in a multiple-column key. See Section 3.6.9, "Using AUTO_INCREMENT".

  To make MySQL compatible with some ODBC applications, you can find the **AUTO_INCREMENT** value for the last inserted row with the following query:

  ```sql
  SELECT * FROM tbl_name WHERE auto_col IS NULL
  ```

  This method requires that **sql_auto_is_null** variable is not set to 0. See Section 5.1.7, "Server System Variables".

  For information about **InnoDB and AUTO_INCREMENT**, see Section 14.9.1.4, "AUTO_INCREMENT Handling in InnoDB". For information about **AUTO_INCREMENT** and MySQL Replication, see Section 17.4.1.1, "Replication and AUTO_INCREMENT".
CREATE TABLE Statement

• COMMENT

A comment for a column can be specified with the COMMENT option, up to 1024 characters long (255 characters before MySQL 5.5.3). The comment is displayed by the SHOW CREATE TABLE and SHOW FULL COLUMNS statements.

• COLUMN_FORMAT

In NDB Cluster, it is also possible to specify a data storage format for individual columns of NDB tables using COLUMN_FORMAT. Permissible column formats are FIXED, DYNAMIC, and DEFAULT. FIXED is used to specify fixed-width storage, DYNAMIC permits the column to be variable-width, and DEFAULT causes the column to use fixed-width or variable-width storage as determined by the column’s data type (possibly overridden by a ROW_FORMAT specifier).

For NDB tables, the default value for COLUMN_FORMAT is DEFAULT.

In NDB Cluster, the maximum possible offset for a column defined with COLUMN_FORMAT=FIXED is 8188 bytes. For more information and possible workarounds, see Section 18.1.7.5, "Limits Associated with Database Objects in NDB Cluster". COLUMN_FORMAT currently has no effect on columns of tables using storage engines other than NDB. In MySQL 5.5 and later, COLUMN_FORMAT is silently ignored.

• STORAGE

For NDB tables, it is possible to specify whether the column is stored on disk or in memory by using a STORAGE clause. STORAGE_DISK causes the column to be stored on disk, and STORAGE_MEMORY causes in-memory storage to be used. The CREATE TABLE statement used must still include a TABLESPACE clause:

```
mysql> CREATE TABLE t1 (
    -> c1 INT STORAGE DISK,
    -> c2 INT STORAGE MEMORY
    -> ) ENGINE NDB;
ERROR 1005 (HY000): Can't create table 'c.t1' (errno: 140)
```

```
mysql> CREATE TABLE t1 (
    -> c1 INT STORAGE DISK,
    -> c2 INT STORAGE MEMORY
    -> ) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.06 sec)
```

For NDB tables, STORAGE_DEFAULT is equivalent to STORAGE_MEMORY.

The STORAGE clause has no effect on tables using storage engines other than NDB. The STORAGE keyword is supported only in the build of mysqld that is supplied with NDB Cluster; it is not recognized in any other version of MySQL, where any attempt to use the STORAGE keyword causes a syntax error.

Indexes and Foreign Keys

Several keywords apply to creation of indexes and foreign keys. For general background in addition to the following descriptions, see Section 13.1.13, “CREATE INDEX Statement”, and Section 13.1.17.6, “FOREIGN KEY Constraints”.

• CONSTRAINT symbol

The CONSTRAINT symbol clause may be given to name a constraint. If the clause is not given, or a symbol is not included following the CONSTRAINT keyword, MySQL automatically generates a constraint name. The symbol value, if used, must be unique per schema (database), per constraint
CREATE TABLE Statement type. A duplicate symbol results in an error. See also the discussion about length limits of generated constraint identifiers at Section 9.2.1, “Identifier Length Limits”.

The SQL standard specifies that all types of constraints (primary key, unique index, foreign key, check) belong to the same namespace. In MySQL, each constraint type has its own namespace per schema. Consequently, names for each type of constraint must be unique per schema.

- **PRIMARY KEY**

A unique index where all key columns must be defined as NOT NULL. If they are not explicitly declared as NOT NULL, MySQL declares them so implicitly (and silently). A table can have only one PRIMARY KEY. The name of a PRIMARY KEY is always PRIMARY, which thus cannot be used as the name for any other kind of index.

If you do not have a PRIMARY KEY and an application asks for the PRIMARY KEY in your tables, MySQL returns the first UNIQUE index that has no NULL columns as the PRIMARY KEY.

In InnoDB tables, keep the PRIMARY KEY short to minimize storage overhead for secondary indexes. Each secondary index entry contains a copy of the primary key columns for the corresponding row. (See Section 14.9.2.1, “Clustered and Secondary Indexes”.

In the created table, a PRIMARY KEY is placed first, followed by all UNIQUE indexes, and then the nonunique indexes. This helps the MySQL optimizer to prioritize which index to use and also more quickly to detect duplicated UNIQUE keys.

A PRIMARY KEY can be a multiple-column index. However, you cannot create a multiple-column index using the PRIMARY KEY key attribute in a column specification. Doing so only marks that single column as primary. You must use a separate PRIMARY KEY(key_part, ...) clause.

If a table has a PRIMARY KEY or UNIQUE NOT NULL index that consists of a single column that has an integer type, you can use _rowid to refer to the indexed column in SELECT statements, as described in Unique Indexes.

In MySQL, the name of a PRIMARY KEY is PRIMARY. For other indexes, if you do not assign a name, the index is assigned the same name as the first indexed column, with an optional suffix (_2, _3, ...) to make it unique. You can see index names for a table using SHOW INDEX FROM tbl_name. See Section 13.7.5.23, “SHOW INDEX Statement”.

- **KEY | INDEX**

KEY is normally a synonym for INDEX. The key attribute PRIMARY KEY can also be specified as just KEY when given in a column definition. This was implemented for compatibility with other database systems.

- **UNIQUE**

A UNIQUE index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. For all engines, a UNIQUE index permits multiple NULL values for columns that can contain NULL. If you specify a prefix value for a column in a UNIQUE index, the column values must be unique within the prefix length.

If a table has a PRIMARY KEY or UNIQUE NOT NULL index that consists of a single column that has an integer type, you can use _rowid to refer to the indexed column in SELECT statements, as described in Unique Indexes.
CREATE TABLE Statement

• **FULLTEXT**

A **FULLTEXT** index is a special type of index used for full-text searches. Only the **MyISAM** storage engine supports **FULLTEXT** indexes. They can be created only from **CHAR**, **VARCHAR**, and **TEXT** columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, “Full-Text Search Functions”, for details of operation. A **WITH PARSER** clause can be specified as an **index_option** value to associate a parser plugin with the index if full-text indexing and searching operations need special handling. This clause is valid only for **FULLTEXT** indexes. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

• **SPATIAL**

You can create **SPATIAL** indexes on spatial data types. Spatial types are supported only for **MyISAM** tables and indexed columns must be declared as **NOT NULL**. See Section 11.4, “Spatial Data Types”.

• **FOREIGN KEY**

MySQL supports foreign keys, which let you cross-reference related data across tables, and foreign key constraints, which help keep this spread-out data consistent. For definition and option information, see **reference_definition**, and **reference_option**.

Partitioned tables employing the **InnoDB** storage engine do not support foreign keys. See Section 19.5, “Restrictions and Limitations on Partitioning”, for more information.

• **CHECK**

The **CHECK** clause is parsed but ignored by all storage engines.

• **key_part**

• A **key_part** specification can end with **ASC** or **DESC**. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

• Prefixes, defined by the **length** attribute, can be up to 767 bytes long for **InnoDB** tables or 3072 bytes if the **innodb_large_prefix** option is enabled. For **MyISAM** tables, the prefix length limit is 1000 bytes.

Prefix **limits** are measured in bytes. However, prefix **lengths** for index specifications in **CREATE TABLE**, **ALTER TABLE**, and **CREATE INDEX** statements are interpreted as number of characters for nonbinary string types (**CHAR**, **VARCHAR**, **TEXT**) and number of bytes for binary string types (**BINARY**, **VARBINARY**, **BLOB**). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

• **index_type**

Some storage engines permit you to specify an index type when creating an index. The syntax for the **index_type** specifier is **USING** **type_name**.

Example:

```
CREATE TABLE lookup
(id INT, INDEX USING BTREE (id))
ENGINE = MEMORY;
```

The preferred position for **USING** is after the index column list. It can be given before the column list, but support for use of the option in that position is deprecated and will be removed in a future MySQL release.
CREATE TABLE Statement

- **index_option**
  
  *index_option* values specify additional options for an index.

- **KEY_BLOCK_SIZE**
  
  For **MyISAM** tables, **KEY_BLOCK_SIZE** optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A **KEY_BLOCK_SIZE** value specified for an individual index definition overrides the table-level **KEY_BLOCK_SIZE** value.

  For information about the table-level **KEY_BLOCK_SIZE** attribute, see Table Options.

- **WITH PARSER**
  
  A **WITH PARSER** clause can be specified as an *index_option* value to associate a parser plugin with the index if full-text indexing and searching operations need special handling. This clause is valid only for **FULLTEXT** indexes. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

- **COMMENT**
  
  As of MySQL 5.5.3, index definitions can include an optional comment of up to 1024 characters.

  For more information about permissible **index_option** values, see Section 13.1.13, “CREATE INDEX Statement”. For more information about indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

- **reference_definition**
  
  For **reference_definition** syntax details and examples, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

  **InnoDB** tables support checking of foreign key constraints. The columns of the referenced table must always be explicitly named. Both **ON DELETE** and **ON UPDATE** actions on foreign keys. For more detailed information and examples, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

  For other storage engines, MySQL Server parses and ignores the **FOREIGN KEY** and **REFERENCES** syntax in **CREATE TABLE** statements. See Section 1.7.2.3, “FOREIGN KEY Constraint Differences”.

---

**Important**

For users familiar with the ANSI/ISO SQL Standard, please note that no storage engine, including **InnoDB**, recognizes or enforces the **MATCH** clause used in referential integrity constraint definitions. Use of an explicit **MATCH** clause will not have the specified effect, and also causes **ON DELETE** and **ON UPDATE** clauses to be ignored. For these reasons, specifying **MATCH** should be avoided.

The **MATCH** clause in the SQL standard controls how **NULL** values in a composite (multiple-column) foreign key are handled when comparing to a primary key. **InnoDB** essentially implements the semantics defined by **MATCH SIMPLE**, which permit a foreign key to be all or partially **NULL**. In that case, the (child table) row containing such a foreign key is permitted to be inserted, and does not match any row in the referenced (parent) table. It is possible to implement other semantics using triggers.

Additionally, MySQL requires that the referenced columns be indexed for performance. However, **InnoDB** does not enforce any requirement that the referenced columns be declared **UNIQUE** or **NOT NULL**. The handling of foreign
key references to nonunique keys or keys that contain NULL values is not well defined for operations such as UPDATE or DELETE CASCADE. You are advised to use foreign keys that reference only keys that are both UNIQUE (or PRIMARY) and NOT NULL.

MySQL parses but ignores “inline REFERENCES specifications” (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts REFERENCES clauses only when specified as part of a separate FOREIGN KEY specification.

- reference_option

For information about the RESTRICT, CASCADE, SET NULL, NO ACTION, and SET DEFAULT options, see Section 13.1.17.6, “FOREIGN KEY Constraints”.

Table Options

Table options are used to optimize the behavior of the table. In most cases, you do not have to specify any of them. These options apply to all storage engines unless otherwise indicated. Options that do not apply to a given storage engine may be accepted and remembered as part of the table definition. Such options then apply if you later use ALTER TABLE to convert the table to use a different storage engine.

- ENGINE

Specifies the storage engine for the table, using one of the names shown in the following table. The engine name can be unquoted or quoted. The quoted name `DEFAULT` is equivalent to specifying the default storage engine name.

<table>
<thead>
<tr>
<th>Storage Engine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>InnoDB</td>
<td>Transaction-safe tables with row locking and foreign keys. The default storage engine for new tables. See Chapter 14, The InnoDB Storage Engine, and in particular Section 14.1, “Introduction to InnoDB” if you have MySQL experience but are new to InnoDB.</td>
</tr>
<tr>
<td>MyISAM</td>
<td>The binary portable storage engine that is primarily used for read-only or read-mostly workloads. See Section 15.3, “The MyISAM Storage Engine”.</td>
</tr>
<tr>
<td>MEMORY</td>
<td>The data for this storage engine is stored only in memory. See Section 15.4, “The MEMORY Storage Engine”.</td>
</tr>
<tr>
<td>CSV</td>
<td>Tables that store rows in comma-separated values format. See Section 15.5, “The CSV Storage Engine”.</td>
</tr>
<tr>
<td>ARCHIVE</td>
<td>The archiving storage engine. See Section 15.6, “The ARCHIVE Storage Engine”.</td>
</tr>
<tr>
<td>EXAMPLE</td>
<td>An example engine. See Section 15.10, “The EXAMPLE Storage Engine”.</td>
</tr>
<tr>
<td>FEDERATED</td>
<td>Storage engine that accesses remote tables. See Section 15.9, “The FEDERATED Storage Engine”.</td>
</tr>
<tr>
<td>HEAP</td>
<td>This is a synonym for MEMORY.</td>
</tr>
<tr>
<td>MERGE</td>
<td>A collection of MyISAM tables used as one table. Also known as MRG_MyISAM. See Section 15.8, “The MERGE Storage Engine”.</td>
</tr>
<tr>
<td>NDBCLUSTER</td>
<td>Clustered, fault-tolerant, memory-based tables. Also known as NDB. See Chapter 18, MySQL NDB Cluster 7.2.</td>
</tr>
</tbody>
</table>
If a storage engine is specified that is not available, MySQL uses the default engine instead. Normally, this is \texttt{MyISAM}. For example, if a table definition includes the \texttt{ENGINE=INNODB} option but the MySQL server does not support \texttt{INNODB} tables, the table is created as a \texttt{MyISAM} table. This makes it possible to have a replication setup where you have transactional tables on the master but tables created on the slave are nontransactional (to get more speed). In MySQL 5.5, a warning occurs if the storage engine specification is not honored.

Engine substitution can be controlled by the setting of the \texttt{NO_ENGINE_SUBSTITUTION} SQL mode, as described in Section 5.1.10, “Server SQL Modes”.

\begin{itemize}
  \item \textbf{AUTO_INCREMENT}

  The initial \texttt{AUTO_INCREMENT} value for the table. In MySQL 5.5, this works for \texttt{MyISAM}, \texttt{MEMORY}, \texttt{InnoDB}, and \texttt{ARCHIVE} tables. To set the first auto-increment value for engines that do not support the \texttt{AUTO_INCREMENT} table option, insert a “dummy” row with a value one less than the desired value after creating the table, and then delete the dummy row.

  For engines that support the \texttt{AUTO_INCREMENT} table option in \texttt{CREATE TABLE} statements, you can also use \texttt{ALTER TABLE tbl_name AUTO_INCREMENT = N} to reset the \texttt{AUTO_INCREMENT} value. The value cannot be set lower than the maximum value currently in the column.

  \item \textbf{AVG_ROW_LENGTH}

  An approximation of the average row length for your table. You need to set this only for large tables with variable-size rows.

  When you create a \texttt{MyISAM} table, MySQL uses the product of the \texttt{MAX_ROWS} and \texttt{AVG_ROW_LENGTH} options to decide how big the resulting table is. If you don’t specify either option, the maximum size for \texttt{MyISAM} data and index files is 256TB by default. (If your operating system does not support files that large, table sizes are constrained by the file size limit.) If you want to keep down the pointer sizes to make the index smaller and faster and you don’t really need big files, you can decrease the default pointer size by setting the \texttt{myisam_data_pointer_size} system variable. (See Section 5.1.7, “Server System Variables”.) If you want all your tables to be able to grow above the default limit and are willing to have your tables slightly slower and larger than necessary, you can increase the default pointer size by setting this variable. Setting the value to 7 permits table sizes up to 65,536TB.

  \item \textbf{[DEFAULT]} CHARACTER SET

  Specifies a default character set for the table. \texttt{CHARSET} is a synonym for \texttt{CHARACTER SET}. If the character set name is \texttt{DEFAULT}, the database character set is used.

  \item \textbf{CHECKSUM}

  Set this to 1 if you want MySQL to maintain a live checksum for all rows (that is, a checksum that MySQL updates automatically as the table changes). This makes the table a little slower to update, but also makes it easier to find corrupted tables. The \texttt{CHECKSUM TABLE} statement reports the checksum. (\texttt{MyISAM} only.)
\end{itemize}
CREATE TABLE Statement

• **[DEFAULT] COLLATE**
  
  Specifies a default collation for the table.

• **COMMENT**
  
  A comment for the table, up to 2048 characters long (60 characters before MySQL 5.5.3).

• **CONNECTION**
  
  The connection string for a FEDERATED table.

  **Note**

  Older versions of MySQL used a COMMENT option for the connection string.

• **DATA DIRECTORY, INDEX DIRECTORY**
  
  By using **DATA DIRECTORY='directory'** or **INDEX DIRECTORY='directory'** you can specify where the MyISAM storage engine should put a table’s data file and index file. The directory must be the full path name to the directory, not a relative path.

  As of MySQL 5.5.54, you must have the **FILE** privilege to use the **DATA DIRECTORY** or **INDEX DIRECTORY** table option.

  **Important**

  Table-level **DATA DIRECTORY** and **INDEX DIRECTORY** options are ignored for partitioned tables. (Bug #32091)

  These options work only when you are not using the --skip-symbolic-links option. Your operating system must also have a working, thread-safe **realpath()** call. See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”, for more complete information.

  If a MyISAM table is created with no **DATA DIRECTORY** option, the .MYD file is created in the database directory. By default, if MyISAM finds an existing .MYD file in this case, it overwrites it. The same applies to .MYI files for tables created with no **INDEX DIRECTORY** option. To suppress this behavior, start the server with the --keep_files_on_create option, in which case MyISAM will not overwrite existing files and returns an error instead.

  If a MyISAM table is created with a **DATA DIRECTORY** or **INDEX DIRECTORY** option and an existing .MYD or .MYI file is found, MyISAM always returns an error. It will not overwrite a file in the specified directory.

  **Important**

  You cannot use path names that contain the MySQL data directory with **DATA DIRECTORY** or **INDEX DIRECTORY**. This includes partitioned tables and individual table partitions. (See Bug #32167.)

• **DELAY_KEY_WRITE**
  
  Set this to 1 if you want to delay key updates for the table until the table is closed. See the description of the **delay_key_write** system variable in Section 5.1.7, “Server System Variables”. (MyISAM only.)
CREATE TABLE Statement

- **INSERT_METHOD**

  If you want to insert data into a MERGE table, you must specify with `INSERT_METHOD` the table into which the row should be inserted. `INSERT_METHOD` is an option useful for MERGE tables only. Use a value of `FIRST` or `LAST` to have inserts go to the first or last table, or a value of `NO` to prevent inserts. See Section 15.8, “The MERGE Storage Engine”.

- **KEY_BLOCK_SIZE**

  For **MyISAM** tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides the table-level `KEY_BLOCK_SIZE` value.

  For **InnoDB** tables, `KEY_BLOCK_SIZE` specifies the page size in kilobytes to use for compressed **InnoDB** tables. The `KEY_BLOCK_SIZE` value is treated as a hint; a different size could be used by **InnoDB** if necessary. Valid `KEY_BLOCK_SIZE` values include 0, 1, 2, 4, 8, and 16. A value of 0 represents the default compressed page size, which is half of the **InnoDB** page size.

  Oracle recommends enabling `innodb_strict_mode` when specifying `KEY_BLOCK_SIZE` for **InnoDB** tables. When `innodb_strict_mode` is enabled, specifying an invalid `KEY_BLOCK_SIZE` value returns an error. If `innodb_strict_mode` is disabled, an invalid `KEY_BLOCK_SIZE` value results in a warning, and the `KEY_BLOCK_SIZE` option is ignored.

  The `Create_options` column in response to `SHOW TABLE STATUS` reports the originally specified `KEY_BLOCK_SIZE` option, as does `SHOW CREATE TABLE`.

  **InnoDB** only supports `KEY_BLOCK_SIZE` at the table level.

- **MAX_ROWS**

  The maximum number of rows you plan to store in the table. This is not a hard limit, but rather a hint to the storage engine that the table must be able to store at least this many rows.

  The **NDB** storage engine treats this value as a maximum. If you plan to create very large NDB Cluster tables (containing millions of rows), you should use this option to insure that **NDB** allocates sufficient number of index slots in the hash table used for storing hashes of the table’s primary keys by setting `MAX_ROWS = 2 * rows`, where `rows` is the number of rows that you expect to insert into the table.

  The maximum `MAX_ROWS` value is 4294967295; larger values are truncated to this limit.

- **MIN_ROWS**

  The minimum number of rows you plan to store in the table. The **MEMORY** storage engine uses this option as a hint about memory use.

- **PACK_KEYS**

  Takes effect only with **MyISAM** tables. Set this option to 1 if you want to have smaller indexes. This usually makes updates slower and reads faster. Setting the option to 0 disables all packing of
CREATE TABLE Statement

keys. Setting it to DEFAULT tells the storage engine to pack only long CHAR, VARCHAR, BINARY, or VARBINARY columns.

If you do not use PACK_KEYS, the default is to pack strings, but not numbers. If you use PACK_KEYS=1, numbers are packed as well.

When packing binary number keys, MySQL uses prefix compression:

• Every key needs one extra byte to indicate how many bytes of the previous key are the same for the next key.

• The pointer to the row is stored in high-byte-first order directly after the key, to improve compression.

This means that if you have many equal keys on two consecutive rows, all following “same” keys usually only take two bytes (including the pointer to the row). Compare this to the ordinary case where the following keys takes storage_size_for_key + pointer_size (where the pointer size is usually 4). Conversely, you get a significant benefit from prefix compression only if you have many numbers that are the same. If all keys are totally different, you use one byte more per key, if the key is not a key that can have NULL values. (In this case, the packed key length is stored in the same byte that is used to mark if a key is NULL.)

• PASSWORD

This option is unused. If you have a need to scramble your .frm files and make them unusable to any other MySQL server, please contact our sales department.

• ROW_FORMAT

Defines the physical format in which the rows are stored.

When executing a CREATE TABLE statement with strict mode disabled, if you specify a row format that is not supported by the storage engine that is used for the table, the table is created using that storage engine’s default row format. The information reported in the Row_format column in response to SHOW TABLE STATUS is the actual row format used. This may differ from the value in the Create_options column because the original CREATE TABLE definition is retained during creation. SHOW CREATE TABLE also reports the row format used in the original CREATE TABLE statement.

Row format choices differ depending on the storage engine used for the table.

For InnoDB tables:

• Rows are stored in compact format (ROW_FORMAT=COMPACT) by default.

• The noncompact format used in older versions of MySQL can still be requested by specifying ROW_FORMAT=REDUNDANT.

• To enable compression for InnoDB tables, specify ROW_FORMAT=COMPRESSED and follow the procedures in Section 14.12, “InnoDB Table Compression”.

• For more efficient InnoDB storage of data types, especially BLOB types, specify ROW_FORMAT=DYNAMIC and follow the procedures in DYNAMIC Row Format. Both the
**CREATE TABLE Statement**

**COMPRESSED and DYNAMIC row formats** require creating the table with the configuration settings `innodb_file_per_table=1` and `innodb_file_format=barracuda`.

- When you specify a non-default `ROW_FORMAT` clause, consider also enabling the `innodb_strict_mode` configuration option.

- `ROW_FORMAT=FIXED` is not supported. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is disabled, InnoDB issues a warning and assumes `ROW_FORMAT=COMPACT`. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is enabled, InnoDB returns an error.

- For additional information about InnoDB row formats, see Section 14.14, “InnoDB Row Formats”.

For **MyISAM** tables, the option value can be `FIXED` or `DYNAMIC` for static or variable-length row format. `myisampack` sets the type to `COMPRESSED`. See Section 15.3.3, “MyISAM Table Storage Formats”.

- **TABLESPACE**

The `TABLESPACE` and `STORAGE` table options are employed only with **NDBCLUSTER** tables. The tablespace named `tablespace_name` must already have been created using `CREATE TABLESPACE`. `STORAGE` determines the type of storage used (disk or memory), and can be either `DISK` or `MEMORY`.

`TABLESPACE ... STORAGE DISK` assigns a table to an NDB Cluster Disk Data tablespace. See Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.

**Important**

A `STORAGE` clause cannot be used in a `CREATE TABLE` statement without a `TABLESPACE` clause.

- **UNION**

Used to access a collection of identical **MyISAM** tables as one. This works only with **MERGE** tables. See Section 15.8, “The MERGE Storage Engine”.

You must have `SELECT`, `UPDATE`, and `DELETE` privileges for the tables you map to a **MERGE** table.

**Note**

Formerly, all tables used had to be in the same database as the **MERGE** table itself. This restriction no longer applies.

**Table Partitioning**

`partition_options` can be used to control partitioning of the table created with `CREATE TABLE`.

Not all options shown in the syntax for `partition_options` at the beginning of this section are available for all partitioning types. Please see the listings for the following individual types for information specific to each type, and see Chapter 19, **Partitioning**, for more complete information about the workings of and uses for partitioning in MySQL, as well as additional examples of table creation and other statements relating to MySQL partitioning.

- **PARTITION BY**

If used, a `partition_options` clause begins with `PARTITION BY`. This clause contains the function that is used to determine the partition; the function returns an integer value ranging from 1 to `num`, where `num` is the number of partitions. (The maximum number of user-defined partitions which a table
may contain is 1024; the number of subpartitions—discussed later in this section—is included in this maximum.)

Partitions can be modified, merged, added to tables, and dropped from tables. For basic information about the MySQL statements to accomplish these tasks, see Section 13.1.7, “ALTER TABLE Statement”. For more detailed descriptions and examples, see Section 19.3, “Partition Management”.

**Note**

The expression \( \text{expr} \) used in a `PARTITION BY` clause cannot refer to any columns not in the table being created; such references are specifically not permitted and cause the statement to fail with an error. (Bug #29444)

- **HASH(\text{expr})**

Hashes one or more columns to create a key for placing and locating rows. \( \text{expr} \) is an expression using one or more table columns. This can be any valid MySQL expression (including MySQL functions) that yields a single integer value. For example, these are both valid `CREATE TABLE` statements using `PARTITION BY HASH`:

```sql
CREATE TABLE t1 (col1 INT, col2 CHAR(5))
PARTITION BY HASH(col1);

CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATETIME)
PARTITION BY HASH ( YEAR(col3) );
```

You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY HASH`.

`PARTITION BY HASH` uses the remainder of \( \text{expr} \) divided by the number of partitions (that is, the modulus). For examples and additional information, see Section 19.2.4, “HASH Partitioning”.

The **LINEAR** keyword entails a somewhat different algorithm. In this case, the number of the partition in which a row is stored is calculated as the result of one or more logical `AND` operations. For discussion and examples of linear hashing, see Section 19.2.4.1, “LINEAR HASH Partitioning”.

- **KEY [ALGORITHM={1|2}] (column_list)**: This is similar to `HASH`, except that MySQL supplies the hashing function so as to guarantee an even data distribution. The `column_list` argument is simply a list of 1 or more table columns (maximum: 16). This example shows a simple table partitioned by key, with 4 partitions:

```sql
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
PARTITION BY KEY(col3)
PARTITIONS 4;
```

For tables that are partitioned by key, you can employ linear partitioning by using the **LINEAR** keyword. This has the same effect as with tables that are partitioned by `HASH`. That is, the partition number is found using the \( \& \) operator rather than the modulus (see Section 19.2.4.1, “LINEAR HASH Partitioning”, and Section 19.2.5, “KEY Partitioning”, for details). This example uses linear partitioning by key to distribute data between 5 partitions:

```sql
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
PARTITION BY LINEAR KEY(col3)
PARTITIONS 5;
```

The `ALGORITHM={1|2}` option is supported with `SUBPARTITION BY [LINEAR] KEY` beginning with MySQL 5.5.31. `ALGORITHM=1` causes the server to use the same key-hashing functions as MySQL 5.1; `ALGORITHM=2` means that the server employs the key-hashing functions implemented and used by default for new `KEY` partitioned tables in MySQL 5.5 and later. (Partitioned tables created with the
key-hashing functions employed in MySQL 5.5 and later cannot be used by a MySQL 5.1 server.) Not specifying the option has the same effect as using `ALGORITHM=2`. This option is intended for use chiefly when upgrading or downgrading [LINEAR] KEY partitioned tables between MySQL 5.1 and later MySQL versions, or for creating tables partitioned by KEY or LINEAR KEY on a MySQL 5.5 or later server which can be used on a MySQL 5.1 server. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

`mysqldump` in MySQL 5.5.31 and later writes this option encased in versioned comments, like this:

```sql
CREATE TABLE t1 (a INT)    
/*!50100 PARTITION BY KEY */    
/*!50531 ALGORITHM = 1 */    
/*!50100 () PARTITIONS 3 */
```

This causes MySQL 5.5.30 and earlier servers to ignore the option, which would otherwise cause a syntax error in those versions. If you plan to load a dump made on a MySQL 5.5.31 or later MySQL 5.5 server where you use tables that are partitioned or subpartitioned by KEY into a MySQL 5.6 server previous to version 5.6.11, be sure to consult Changes in MySQL 5.6, before proceeding. (The information found there also applies if you are loading a dump containing KEY partitioned or subpartitioned tables made from a MySQL 5.6.11 or later server into a MySQL 5.5.30 or earlier server.)

Also in MySQL 5.5.31 and later, `ALGORITHM=1` is shown when necessary in the output of `SHOW CREATE TABLE` using versioned comments in the same manner as `mysqldump`. `ALGORITHM=2` is always omitted from `SHOW CREATE TABLE` output, even if this option was specified when creating the original table.

You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY KEY`.

- **RANGE(expr)**

  In this case, `expr` shows a range of values using a set of `VALUES LESS THAN` operators. When using range partitioning, you must define at least one partition using `VALUES LESS THAN`. You cannot use `VALUES IN` with range partitioning.

  **Note**

  For tables partitioned by `RANGE, VALUES LESS THAN` must be used with either an integer literal value or an expression that evaluates to a single integer value. In MySQL 5.5, you can overcome this limitation in a table that is defined using `PARTITION BY RANGE COLUMNS`, as described later in this section.

Suppose that you have a table that you wish to partition on a column containing year values, according to the following scheme.

<table>
<thead>
<tr>
<th>Partition Number</th>
<th>Years Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1990 and earlier</td>
</tr>
<tr>
<td>1</td>
<td>1991 to 1994</td>
</tr>
<tr>
<td>2</td>
<td>1995 to 1998</td>
</tr>
<tr>
<td>3</td>
<td>1999 to 2002</td>
</tr>
<tr>
<td>4</td>
<td>2003 to 2005</td>
</tr>
<tr>
<td>Partition Number:</td>
<td>Years Range:</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>5</td>
<td>2006 and later</td>
</tr>
</tbody>
</table>

A table implementing such a partitioning scheme can be realized by the `CREATE TABLE` statement shown here:

```sql
CREATE TABLE t1 (
    year_col  INT,
    some_data INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999),
    PARTITION p3 VALUES LESS THAN (2002),
    PARTITION p4 VALUES LESS THAN (2006),
    PARTITION p5 VALUES LESS THAN MAXVALUE
);
```

`PARTITION ... VALUES LESS THAN ...` statements work in a consecutive fashion. `VALUES LESS THAN MAXVALUE` works to specify “leftover” values that are greater than the maximum value otherwise specified.

`VALUES LESS THAN` clauses work sequentially in a manner similar to that of the `case` portions of a `switch ... case` block (as found in many programming languages such as C, Java, and PHP). That is, the clauses must be arranged in such a way that the upper limit specified in each successive `VALUES LESS THAN` is greater than that of the previous one, with the one referencing `MAXVALUE` coming last of all in the list.

- **RANGE COLUMNS(column_list)**

  This variant on `RANGE` was introduced in MySQL 5.5.0 to facilitate partition pruning for queries using range conditions on multiple columns (that is, having conditions such as `WHERE a = 1 AND b < 10` or `WHERE a = 1 AND b = 10 AND c < 10`). It enables you to specify value ranges in multiple columns by using a list of columns in the `COLUMNS` clause and a set of column values in each `PARTITION ... VALUES LESS THAN (value_list)` partition definition clause. (In the simplest case, this set consists of a single column.) The maximum number of columns that can be referenced in the `column_list` and `value_list` is 16.

  The `column_list` used in the `COLUMNS` clause may contain only names of columns; each column in the list must be one of the following MySQL data types: the integer types; the string types; and time or date column types. Columns using `BLOB`, `TEXT`, `SET`, `ENUM`, `BIT`, or spatial data types are not permitted; columns that use floating-point number types are also not permitted. You also may not use functions or arithmetic expressions in the `COLUMNS` clause.

  The `VALUES LESS THAN` clause used in a partition definition must specify a literal value for each column that appears in the `COLUMNS()` clause; that is, the list of values used for each `VALUES LESS THAN` clause must contain the same number of values as there are columns listed in the `COLUMNS` clause. An attempt to use more or fewer values in a `VALUES LESS THAN` clause than there are in the `COLUMNS` clause causes the statement to fail with the error `Inconsistency in usage of column lists for partitioning...`. You cannot use `NULL` for any value appearing in `VALUES LESS THAN`. It is possible to use `MAXVALUE` more than once for a given column other than the first, as shown in this example:

```sql
CREATE TABLE rc (
    a INT NOT NULL,
    b INT NOT NULL
)
```
CREATE TABLE Statement
PARTITION BY RANGE COLUMNS(a,b) {
  PARTITION p0 VALUES LESS THAN (10,5),
  PARTITION p1 VALUES LESS THAN (20,10),
  PARTITION p2 VALUES LESS THAN (50,MAXVALUE),
  PARTITION p3 VALUES LESS THAN (65,MAXVALUE),
  PARTITION p4 VALUES LESS THAN (MAXVALUE,MAXVALUE)
};

Each value used in a VALUES LESS THAN value list must match the type of the corresponding column exactly; no conversion is made. For example, you cannot use the string '1' for a value that matches a column that uses an integer type (you must use the numeral 1 instead), nor can you use the numeral 1 for a value that matches a column that uses a string type (in such a case, you must use a quoted string: '1').

For more information, see Section 19.2.1, “RANGE Partitioning”, and Section 19.4, “Partition Pruning”.

• LIST(expr)

This is useful when assigning partitions based on a table column with a restricted set of possible values, such as a state or country code. In such a case, all rows pertaining to a certain state or country can be assigned to a single partition, or a partition can be reserved for a certain set of states or countries. It is similar to RANGE, except that only VALUES IN may be used to specify permissible values for each partition.

VALUES IN is used with a list of values to be matched. For instance, you could create a partitioning scheme such as the following:

CREATE TABLE client_firms (id INT, name VARCHAR(35))
PARTITION BY LIST (id) {
  PARTITION r0 VALUES IN (1, 5, 9, 13, 17, 21),
  PARTITION r1 VALUES IN (2, 6, 10, 14, 18, 22),
  PARTITION r2 VALUES IN (3, 7, 11, 15, 19, 23),
  PARTITION r3 VALUES IN (4, 8, 12, 16, 20, 24)
};

When using list partitioning, you must define at least one partition using VALUES IN. You cannot use VALUES LESS THAN with PARTITION BY LIST.

Note
For tables partitioned by LIST, the value list used with VALUES IN must consist of integer values only. In MySQL 5.5, you can overcome this limitation using partitioning by LIST COLUMNS, which is described later in this section.

• LIST COLUMNS(column_list)

This variant on LIST was introduced in MySQL 5.5.0 to facilitate partition pruning for queries using comparison conditions on multiple columns (that is, having conditions such as WHERE a = 5 AND b = 5 or WHERE a = 1 AND b = 10 AND c = 5). It enables you to specify values in multiple columns by using a list of columns in the COLUMNS clause and a set of column values in each PARTITION ... VALUES IN (value_list) partition definition clause.

The rules governing regarding data types for the column list used in LIST COLUMNS(column_list) and the value list used in VALUES IN(value_list) are the same as those for the column list used
in `RANGE COLUMNS(column_list)` and the value list used in `VALUES LESS THAN(value_list)`, respectively, except that in the `VALUES IN` clause, `MAXVALUE` is not permitted, and you may use `NULL`.

There is one important difference between the list of values used for `VALUES IN` with `PARTITION BY LIST COLUMNS` as opposed to when it is used with `PARTITION BY LIST`. When used with `PARTITION BY LIST COLUMNS`, each element in the `VALUES IN` clause must be a set of column values; the number of values in each set must be the same as the number of columns used in the `COLUMNS` clause, and the data types of these values must match those of the columns (and occur in the same order). In the simplest case, the set consists of a single column. The maximum number of columns that can be used in the `column_list` and in the elements making up the `value_list` is 16.

The table defined by the following `CREATE TABLE` statement provides an example of a table using `LIST COLUMNS` partitioning:

```
CREATE TABLE lc (  
a INT NULL,  
b INT NULL  
)  
PARTITION BY LIST COLUMNS(a,b) (  
   PARTITION p0 VALUES IN( (0,0), (NULL,NULL) ),  
   PARTITION p1 VALUES IN( (0,1), (0,2), (0,3), (1,1), (1,2) ),  
   PARTITION p2 VALUES IN( (1,0), (2,0), (2,1), (3,0), (3,1) ),  
   PARTITION p3 VALUES IN( (1,3), (2,2), (2,3), (3,2), (3,3) )  
);
```

- **PARTITIONS num**

  The number of partitions may optionally be specified with a `PARTITIONS num` clause, where `num` is the number of partitions. If both this clause and any `PARTITION` clauses are used, `num` must be equal to the total number of any partitions that are declared using `PARTITION` clauses.

  **Note**

  Whether or not you use a `PARTITIONS` clause in creating a table that is partitioned by `RANGE` or `LIST`, you must still include at least one `PARTITION VALUES` clause in the table definition (see below).

- **SUBPARTITION BY**

  A partition may optionally be divided into a number of subpartitions. This can be indicated by using the optional `SUBPARTITION BY` clause. Subpartitioning may be done by `HASH` or `KEY`. Either of these may be `LINEAR`. These work in the same way as previously described for the equivalent partitioning types. (It is not possible to subpartition by `LIST` or `RANGE`.)

  The number of subpartitions can be indicated using the `SUBPARTITIONS` keyword followed by an integer value.

  - Rigorous checking of the value used in `PARTITIONS` or `SUBPARTITIONS` clauses is applied and this value must adhere to the following rules:

    - The value must be a positive, nonzero integer.
    - No leading zeros are permitted.
    - The value must be an integer literal, and cannot not be an expression. For example, `PARTITIONS 0.2E+01` is not permitted, even though `0.2E+01` evaluates to `2`. (Bug #15890)
CREATE TABLE Statement

• **partition_definition**

Each partition may be individually defined using a **partition_definition** clause. The individual parts making up this clause are as follows:

• **PARTITION partition_name**

  Specifies a logical name for the partition.

• **VALUES**

  For range partitioning, each partition must include a **VALUES LESS THAN** clause; for list partitioning, you must specify a **VALUES IN** clause for each partition. This is used to determine which rows are to be stored in this partition. See the discussions of partitioning types in Chapter 19, **Partitioning**, for syntax examples.

• **COMMENT**

  An optional **COMMENT** clause may be used to specify a string that describes the partition. Example:

  ```
  COMMENT = 'Data for the years previous to 1999'
  ```

• **DATA DIRECTORY** and **INDEX DIRECTORY**

  **DATA DIRECTORY** and **INDEX DIRECTORY** may be used to indicate the directory where, respectively, the data and indexes for this partition are to be stored. Both the `data_dir` and the `index_dir` must be absolute system path names.

  As of MySQL 5.5.54, you must have the **FILE** privilege to use the **DATA DIRECTORY** or **INDEX DIRECTORY** partition option.

  Example:

  ```
  CREATE TABLE th (id INT, name VARCHAR(30), adate DATE)
  PARTITION BY LIST(YEAR(adate))
  DATA DIRECTORY = '/var/appdata/95/data'
  INDEX DIRECTORY = '/var/appdata/95/idx',
  DATA DIRECTORY = '/var/appdata/96/data'
  INDEX DIRECTORY = '/var/appdata/96/idx',
  DATA DIRECTORY = '/var/appdata/97/data'
  INDEX DIRECTORY = '/var/appdata/97/idx',
  DATA DIRECTORY = '/var/appdata/98/data'
  INDEX DIRECTORY = '/var/appdata/98/idx'
  ```
CREATE TABLE Statement

DATA DIRECTORY and INDEX DIRECTORY behave in the same way as in the CREATE TABLE statement's table_option clause as used for MyISAM tables.

One data directory and one index directory may be specified per partition. If left unspecified, the data and indexes are stored by default in the table's database directory.

On Windows, the DATA DIRECTORY and INDEX DIRECTORY options are not supported for individual partitions or subpartitions. These options are ignored on Windows, except that a warning is generated. (Bug #30459)

Note
The DATA DIRECTORY and INDEX DIRECTORY options are ignored for creating partitioned tables if NO_DIR_IN_CREATE is in effect. (Bug #24633)

- MAX_ROWS and MIN_ROWS

May be used to specify, respectively, the maximum and minimum number of rows to be stored in the partition. The values for max_number_of_rows and min_number_of_rows must be positive integers. As with the table-level options with the same names, these act only as “suggestions” to the server and are not hard limits.

- TABLESPACE

The optional TABLESPACE clause may be used to designate a tablespace for the partition. Used for NDB Cluster only.

- [STORAGE] ENGINE

The partitioning handler accepts a [STORAGE] ENGINE option for both PARTITION and SUBPARTITION. Currently, the only way in which this can be used is to set all partitions or all subpartitions to the same storage engine, and an attempt to set different storage engines for partitions or subpartitions in the same table will give rise to the error ERROR 1469 (HY000): The mix of handlers in the partitions is not permitted in this version of MySQL. We expect to lift this restriction on partitioning in a future MySQL release.

- NODEGROUP

The NODEGROUP option can be used to make this partition act as part of the node group identified by node_group_id. This option is applicable only to NDB Cluster.

- subpartition_definition

The partition definition may optionally contain one or more subpartition_definition clauses. Each of these consists at a minimum of the SUBPARTITION name, where name is an identifier for the subpartition. Except for the replacement of the PARTITION keyword with SUBPARTITION, the syntax for a subpartition definition is identical to that for a partition definition.

Subpartitioning must be done by HASH or KEY, and can be done only on RANGE or LIST partitions. See Section 19.2.6, “Subpartitioning”.

13.1.17.1 CREATE TABLE Statement Retention

The original CREATE TABLE statement, including all specifications and table options are stored by MySQL when the table is created. The information is retained so that if you change storage engines, collations or
other settings using an `ALTER TABLE` statement, the original table options specified are retained. This enables you to change between InnoDB and MyISAM table types even though the row formats supported by the two engines are different.

Because the text of the original statement is retained, but due to the way that certain values and options may be silently reconfigured (such as the `ROW_FORMAT`), the active table definition (accessible through `DESCRIBE` or with `SHOW TABLE STATUS`) and the table creation string (accessible through `SHOW CREATE TABLE`) will report different values.

### 13.1.17.2 Files Created by CREATE TABLE

MySQL represents each table by an `.frm` table format (definition) file in the database directory. The storage engine for the table might create other files as well.

For InnoDB tables, the file storage is controlled by the `innodb_file_per_table` configuration option. For each InnoDB table created when this option is turned on, the table data and all associated indexes are stored in a `.ibd` file located inside the database directory. When this option is turned off, all InnoDB tables and indexes are stored in the system tablespace, represented by one or more `ibdata*` files.

For MyISAM tables, the storage engine creates data and index files. Thus, for each MyISAM table `tbl_name`, there are three disk files.

<table>
<thead>
<tr>
<th>File</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tbl_name.frm</code></td>
<td>Table format (definition) file</td>
</tr>
<tr>
<td><code>tbl_name.MYD</code></td>
<td>Data file</td>
</tr>
<tr>
<td><code>tbl_name.MYI</code></td>
<td>Index file</td>
</tr>
</tbody>
</table>

Chapter 15, *Alternative Storage Engines*, describes what files each storage engine creates to represent tables. If a table name contains special characters, the names for the table files contain encoded versions of those characters as described in Section 9.2.4, "Mapping of Identifiers to File Names".

### Limits Imposed by .frm File Structure

As described previously, each table has an `.frm` file that contains the table definition. The server uses the following expression to check some of the table information stored in the file against an upper limit of 64KB:

```
if (info_length+(ulong) create_fields.elements*FCOMP+288+ n_length+int_length+com_length > 65535L || int_count > 255)
```

The portion of the information stored in the `.frm` file that is checked against the expression cannot grow beyond the 64KB limit, so if the table definition reaches this size, no more columns can be added.

The relevant factors in the expression are:

- `info_length` is space needed for "screens." This is related to MySQL’s Unireg heritage.
- `create_fields.elements` is the number of columns.
- `FCOMP` is 17.
- `n_length` is the total length of all column names, including one byte per name as a separator.
- `int_length` is related to the list of values for ENUM and SET columns. In this context, “int” does not mean “integer.” It means “interval,” a term that refers collectively to ENUM and SET columns.
CREATE TABLE Statement

- int_count is the number of unique ENUM and SET definitions.
- com_length is the total length of column comments.

The expression just described has several implications for permitted table definitions:

- Using long column names can reduce the maximum number of columns, as can the inclusion of ENUM or SET columns, or use of column comments.
- A table can have no more than 255 unique ENUM and SET definitions. Columns with identical element lists are considered the same against this limit. For example, if a table contains these two columns, they count as one (not two) toward this limit because the definitions are identical:

  ```
e1 ENUM('a','b','c')
e2 ENUM('a','b','c')
  ```

- The sum of the length of element names in the unique ENUM and SET definitions counts toward the 64KB limit, so although the theoretical limit on number of elements in a given ENUM column is 65,535, the practical limit is less than 3000.

### 13.1.17.3 CREATE TEMPORARY TABLE Statement

You can use the TEMPORARY keyword when creating a table. A TEMPORARY table is visible only within the current session, and is dropped automatically when the session is closed. This means that two different sessions can use the same temporary table name without conflicting with each other or with an existing non-TEMPORARY table of the same name. (The existing table is hidden until the temporary table is dropped.)

CREATE TABLE causes an implicit commit, except when used with the TEMPORARY keyword. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

TEMPORARY tables have a very loose relationship with databases (schemas). Dropping a database does not automatically drop any TEMPORARY tables created within that database. Also, you can create a TEMPORARY table in a nonexistent database if you qualify the table name with the database name in the CREATE TABLE statement. In this case, all subsequent references to the table must be qualified with the database name.

To create a temporary table, you must have the CREATE TEMPORARY TABLES privilege. However, other operations on a temporary table, such as INSERT, UPDATE, or SELECT, require additional privileges for those operations for the database containing the temporary table, or for the nontemporary table of the same name.

To keep privileges for temporary and nontemporary tables separate, a common workaround for this situation is to create a database dedicated to the use of temporary tables. Then for that database, a user can be granted the CREATE TEMPORARY TABLES privilege, along with any other privileges required for temporary table operations done by that user.

### 13.1.17.4 CREATE TABLE ... LIKE Statement

Use CREATE TABLE ... LIKE to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

The copy is created using the same version of the table storage format as the original table. The SELECT privilege is required on the original table.
LIKE works only for base tables, not for views.

Important

Beginning with MySQL 5.5.3, you cannot execute CREATE TABLE or CREATE TABLE ... LIKE while a LOCK TABLES statement is in effect.

Also as of MySQL 5.5.3, CREATE TABLE ... LIKE makes the same checks as CREATE TABLE and does not just copy the .frm file. This means that if the current SQL mode is different from the mode in effect when the original table was created, the table definition might be considered invalid for the new mode and the statement will fail.

CREATE TABLE ... LIKE does not preserve any DATA DIRECTORY or INDEX DIRECTORY table options that were specified for the original table, or any foreign key definitions.

If the original table is a TEMPORARY table, CREATE TABLE ... LIKE does not preserve TEMPORARY. To create a TEMPORARY destination table, use CREATE TEMPORARY TABLE ... LIKE.

13.1.17.5 CREATE TABLE ... SELECT Statement

You can create one table from another by adding a SELECT statement at the end of the CREATE TABLE statement:

```
CREATE TABLE new_tbl [AS] SELECT * FROM orig_tbl;
```

MySQL creates new columns for all elements in the SELECT. For example:

```
mysql> CREATE TABLE test (a INT NOT NULL AUTO_INCREMENT,
  >             PRIMARY KEY (a), KEY(b))
  > ENGINE=MyISAM SELECT b,c FROM test2;
```

This creates a MyISAM table with three columns, a, b, and c. The ENGINE option is part of the CREATE TABLE statement, and should not be used following the SELECT; this would result in a syntax error. The same is true for other CREATE TABLE options such as CHARSET.

Notice that the columns from the SELECT statement are appended to the right side of the table, not overlapped onto it. Take the following example:

```
mysql> SELECT * FROM foo;
+---+
| n |
+---+
| 1 |
+---+
mysql> CREATE TABLE bar (m INT) SELECT n FROM foo;
Query OK, 1 row affected (0.02 sec)
Records: 1  Duplicates: 0  Warnings: 0
mysql> SELECT * FROM bar;
+------+---+
| m    | n |
+------+---+
| NULL | 1 |
+------+---+
1 row in set (0.00 sec)
```

For each row in table foo, a row is inserted in bar with the values from foo and default values for the new columns.
In a table resulting from `CREATE TABLE ... SELECT`, columns named only in the `CREATE TABLE` part come first. Columns named in both parts or only in the `SELECT` part come after that. The data type of `SELECT` columns can be overridden by also specifying the column in the `CREATE TABLE` part.

If any errors occur while copying the data to the table, it is automatically dropped and not created.

You can precede the `SELECT` by `IGNORE` or `REPLACE` to indicate how to handle rows that duplicate unique key values. With `IGNORE`, rows that duplicate an existing row on a unique key value are discarded. With `REPLACE`, new rows replace rows that have the same unique key value. If neither `IGNORE` nor `REPLACE` is specified, duplicate unique key values result in an error.

Because the ordering of the rows in the underlying `SELECT` statements cannot always be determined, `CREATE TABLE ... IGNORE SELECT` and `CREATE TABLE ... REPLACE SELECT` statements in MySQL 5.5.18 and later are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using `MIXED` mode. See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

`CREATE TABLE ... SELECT` does not automatically create any indexes for you. This is done intentionally to make the statement as flexible as possible. If you want to have indexes in the created table, you should specify these before the `SELECT` statement:

```sql
mysql> CREATE TABLE bar (UNIQUE (n)) SELECT n FROM foo;
```

Some conversion of data types might occur. For example, the `AUTO_INCREMENT` attribute is not preserved, and `VARCHAR` columns become `CHAR` columns. Retained attributes are `NULL` (or `NOT NULL`) and, for those columns that have them, `CHARACTER SET`, `COLLATION`, `COMMENT`, and the `DEFAULT` clause.

When creating a table with `CREATE TABLE ... SELECT`, make sure to alias any function calls or expressions in the query. If you do not, the `CREATE` statement might fail or result in undesirable column names.

```sql
CREATE TABLE artists_and_works
    SELECT artist.name, COUNT(work.artist_id) AS number_of_works
    FROM artist LEFT JOIN work ON artist.id = work.artist_id
    GROUP BY artist.id;
```

You can also explicitly specify the data type for a column in the created table:

```sql
CREATE TABLE foo (a TINYINT NOT NULL) SELECT b+1 AS a FROM bar;
```

For `CREATE TABLE ... SELECT`, if `IF NOT EXISTS` is given and the destination table already exists, the result is version dependent. Before MySQL 5.5.6, MySQL handles the statement as follows:

- The table definition given in the `CREATE TABLE` part is ignored. No error occurs, even if the definition does not match that of the existing table. MySQL attempts to insert the rows from the `SELECT` part anyway.

- If there is a mismatch between the number of columns in the table and the number of columns produced by the `SELECT` part, the selected values are assigned to the rightmost columns. For example, if the table contains \( n \) columns and the `SELECT` produces \( m \) columns, where \( m < n \), the selected values are assigned to the \( m \) rightmost columns in the table. Each of the initial \( n - m \) columns is assigned its default value, either that specified explicitly in the column definition or the implicit column data type default if the definition contains no default. If the `SELECT` part produces too many columns (\( m > n \)), an error occurs.

- If strict SQL mode is enabled and any of these initial columns do not have an explicit default value, the statement fails with an error.
The following example illustrates `IF NOT EXISTS` handling:

```sql
mysql> CREATE TABLE t1 (i1 INT DEFAULT 0, i2 INT, i3 INT, i4 INT);
Query OK, 0 rows affected (0.05 sec)

mysql> CREATE TABLE IF NOT EXISTS t1 (c1 CHAR(10)) SELECT 1, 2;
Query OK, 1 row affected, 1 warning (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1;
+------+------+------+------+
<table>
<thead>
<tr>
<th>i1</th>
<th>i2</th>
<th>i3</th>
<th>i4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NULL</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
+------+------+------+------+
1 row in set (0.00 sec)
```

As of MySQL 5.5.6, handling of `CREATE TABLE IF NOT EXISTS ... SELECT` statements was changed for the case that the destination table already exists. This change also involves a change in MySQL 5.1 beginning with 5.1.51.

- Previously, for `CREATE TABLE IF NOT EXISTS ... SELECT`, MySQL produced a warning that the table exists, but inserted the rows and wrote the statement to the binary log anyway. By contrast, `CREATE TABLE ... SELECT` (without `IF NOT EXISTS`) failed with an error, but MySQL inserted no rows and did not write the statement to the binary log.

- MySQL now handles both statements the same way when the destination table exists, in that neither statement inserts rows or is written to the binary log. The difference between them is that MySQL produces a warning when `IF NOT EXISTS` is present and an error when it is not.

This change means that, for the preceding example, the `CREATE TABLE IF NOT EXISTS ... SELECT` statement inserts nothing into the destination table as of MySQL 5.5.6.

This change in handling of `IF NOT EXISTS` results in an incompatibility for statement-based replication from a MySQL 5.1 master with the original behavior and a MySQL 5.5 slave with the new behavior. Suppose that `CREATE TABLE IF NOT EXISTS ... SELECT` is executed on the master and the destination table exists. The result is that rows are inserted on the master but not on the slave. (Row-based replication does not have this problem.)

To address this issue, statement-based binary logging for `CREATE TABLE IF NOT EXISTS ... SELECT` is changed in MySQL 5.1 as of 5.1.51:

- If the destination table does not exist, there is no change: The statement is logged as is.

- If the destination table does exist, the statement is logged as the equivalent pair of `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements. (If the `SELECT` in the original statement is preceded by `IGNORE` or `REPLACE`, the `INSERT` becomes `INSERT IGNORE` or `REPLACE`, respectively.)

This change provides forward compatibility for statement-based replication from MySQL 5.1 to 5.5 because when the destination table exists, the rows will be inserted on both the master and slave. To take advantage of this compatibility measure, the 5.1 server must be at least 5.1.51 and the 5.5 server must be at least 5.5.6.

To upgrade an existing 5.1-to-5.5 replication scenario, upgrade the master first to 5.1.51 or higher. Note that this differs from the usual replication upgrade advice of upgrading the slave first.

A workaround for applications that wish to achieve the original effect (rows inserted regardless of whether the destination table exists) is to use `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements rather than `CREATE TABLE IF NOT EXISTS ... SELECT` statements.
Along with the change just described, the following related change was made: Previously, if an existing view was named as the destination table for `CREATE TABLE IF NOT EXISTS ... SELECT`, rows were inserted into the underlying base table and the statement was written to the binary log. As of MySQL 5.1.51 and 5.5.6, nothing is inserted or logged.

To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts during `CREATE TABLE ... SELECT`.

### 13.1.17.6 FOREIGN KEY Constraints

MySQL supports foreign keys, which permit cross-referencing related data across tables, and foreign key constraints, which help keep the related data consistent.

A foreign key relationship involves a parent table that holds the initial column values, and a child table with column values that reference the parent column values. A foreign key constraint is defined on the child table.

The essential syntax for a defining a foreign key constraint in a `CREATE TABLE` or `ALTER TABLE` statement includes the following:

```
[CONSTRAINT [symbol]] FOREIGN KEY
[index_name] (col_name, ...)
REFERENCES tbl_name (col_name,...)
[ON DELETE reference_option]
[ON UPDATE reference_option]
```

`reference_option`:  
- RESTRICT | CASCADE | SET NULL | NO ACTION | SET DEFAULT

Foreign key constraint usage is described under the following topics in this section:

- Identifiers
- Conditions and Restrictions
- Referential Actions
- Foreign Key Constraint Examples
- Adding Foreign Key Constraints
- Dropping Foreign Key Constraints
- Foreign Key Checks
- Foreign Key Definitions and Metadata
- Foreign Key Errors

#### Identifiers

Foreign key constraint naming is governed by the following rules:

- The `CONSTRAINT symbol` value is used, if defined.

- If the `CONSTRAINT symbol` clause is not defined, or a symbol is not included following the `CONSTRAINT` keyword, a constraint name name is generated automatically.

- The `CONSTRAINT symbol` value, if defined, must be unique in the database. A duplicate symbol results in an error similar to: `ERROR 1005 (HY000): Can't create table 'test.fk1' (errno: 121).`
CREATE TABLE Statement

Table and column identifiers in a `FOREIGN KEY ... REFERENCES` clause can be quoted within backticks (``). Alternatively, double quotation marks (") can be used if the `ANSI_QUOTES` SQL mode is enabled. The `lower_case_table_names` system variable setting is also taken into account.

Conditions and Restrictions

Foreign key constraints are subject to the following conditions and restrictions:

- Parent and child tables must use the same storage engine, and they cannot be defined as temporary tables.
- Creating a foreign key constraint requires at least one of the `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `REFERENCES` privileges on the parent table as of 5.5.41.
- Corresponding columns in the foreign key and the referenced key must have similar data types. The `size and sign of integer types must be the same`. The length of string types need not be the same. For nonbinary (character) string columns, the character set and collation must be the same.
- MySQL supports foreign key references between one column and another within a table. (A column cannot have a foreign key reference to itself.) In these cases, a “child table record” refers to a dependent record within the same table.
- MySQL requires indexes on foreign keys and referenced keys so that foreign key checks can be fast and not require a table scan. In the referencing table, there must be an index where the foreign key columns are listed as the `first` columns in the same order. Such an index is created on the referencing table automatically if it does not exist. This index might be silently dropped later if you create another index that can be used to enforce the foreign key constraint. `index_name`, if given, is used as described previously.
- `InnoDB` permits a foreign key to reference any index column or group of columns. However, in the referenced table, there must be an index where the referenced columns are the `first` columns in the same order. Hidden columns that `InnoDB` adds to an index are also considered (see Section 14.9.2.1, “Clustered and Secondary Indexes”).
- `InnoDB` does not require an explicit unique key (or primary key) on any column referenced as a foreign key, which is an extension of standard SQL.
- Index prefixes on foreign key columns are not supported. Consequently, `BLOB` and `TEXT` columns cannot be included in a foreign key because indexes on those columns must always include a prefix length.
- `InnoDB` does not currently support foreign keys for tables with user-defined partitioning. This includes both parent and child tables.
- A table in a foreign key relationship cannot be altered to use another storage engine. To change the storage engine, you must drop any foreign key constraints first.

For information about how the MySQL implementation of foreign key constraints differs from the SQL standard, see Section 1.7.2.3, “FOREIGN KEY Constraint Differences”.

Referential Actions

When an `UPDATE` or `DELETE` operation affects a key value in the parent table that has matching rows in the child table, the result depends on the referential action specified by `ON UPDATE` and `ON DELETE` subclauses of the `FOREIGN KEY` clause. Referential actions include:

- **CASCADE**: Delete or update the row from the parent table and automatically delete or update the matching rows in the child table. Both `ON DELETE CASCADE` and `ON UPDATE CASCADE` are supported.
Between two tables, do not define several `ON UPDATE CASCADE` clauses that act on the same column in the parent table or in the child table.

**Note**
Cascaded foreign key actions do not activate triggers.

- **SET NULL**: Delete or update the row from the parent table and set the foreign key column or columns in the child table to `NULL`. Both `ON DELETE SET NULL` and `ON UPDATE SET NULL` clauses are supported.

  If you specify a `SET NULL` action, **make sure that you have not declared the columns in the child table as `NOT NULL`**.

- **RESTRICT**: Rejects the delete or update operation for the parent table. Specifying `RESTRICT` (or `NO ACTION`) is the same as omitting the `ON DELETE` or `ON UPDATE` clause.

- **NO ACTION**: A keyword from standard SQL. In MySQL, equivalent to `RESTRICT`. The MySQL Server rejects the delete or update operation for the parent table if there is a related foreign key value in the referenced table. Some database systems have deferred checks, and `NO ACTION` is a deferred check. In MySQL, foreign key constraints are checked immediately, so `NO ACTION` is the same as `RESTRICT`.

- **SET DEFAULT**: This action is recognized by the MySQL parser, but InnoDB rejects table definitions containing `ON DELETE SET DEFAULT` or `ON UPDATE SET DEFAULT` clauses.

For storage engines that support foreign keys, MySQL rejects any `INSERT` or `UPDATE` operation that attempts to create a foreign key value in a child table if there is no matching candidate key value in the parent table.

For an `ON DELETE` or `ON UPDATE` that is not specified, the default action is always `RESTRICT`.

InnoDB performs cascading operations using a depth-first search algorithm on the records of the index that corresponds to the foreign key constraint.

**Foreign Key Constraint Examples**

This simple example relates `parent` and `child` tables through a single-column foreign key:

```sql
CREATE TABLE parent (  
  id INT NOT NULL,  
  PRIMARY KEY (id)  
) ENGINE=INNODB;

CREATE TABLE child (  
  id INT,  
  parent_id INT,  
  INDEX par_ind (parent_id),  
  FOREIGN KEY (parent_id)  
    REFERENCES parent(id)  
    ON DELETE CASCADE  
) ENGINE=INNODB;
```

This is a more complex example in which a `product_order` table has foreign keys for two other tables. One foreign key references a two-column index in the `product` table. The other references a single-column index in the `customer` table:

```sql
CREATE TABLE product (  
  category INT NOT NULL, id INT NOT NULL,  
  price DECIMAL,  
  PRIMARY KEY(category, id)  
)
```
Adding Foreign Key Constraints

You can add a foreign key constraint to an existing table using the following `ALTER TABLE` syntax:

```
ALTER TABLE `tbl_name`
ADD [CONSTRAINT `[symbol]`]
FOREIGN KEY
`[index_name]` (`col_name`, ...)
REFERENCES `tbl_name` (`col_name`,...)
[ON DELETE `reference_option`]
[ON UPDATE `reference_option`]
```

The foreign key can be self referential (referring to the same table). When you add a foreign key constraint to a table using `ALTER TABLE`, remember to first create an index on the column(s) referenced by the foreign key.

Dropping Foreign Key Constraints

You can drop a foreign key constraint using the following `ALTER TABLE` syntax:

```
ALTER TABLE `tbl_name` DROP FOREIGN KEY `fk_symbol`;
```

If the `FOREIGN KEY` clause defined a `CONSTRAINT` name when you created the constraint, you can refer to that name to drop the foreign key constraint. Otherwise, a constraint name was generated internally, and you must use that value. To determine the foreign key constraint name, use `SHOW CREATE TABLE`:

```
mysql> SHOW CREATE TABLE child\G
*************************** 1. row ***************************
Table: child
Create Table: CREATE TABLE `child` (  
`id` int(11) DEFAULT NULL,  
`parent_id` int(11) DEFAULT NULL,  
KEY `par_ind` (`parent_id`),  
CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`)  
REFERENCES `parent` (`id`) ON DELETE CASCADE  
) ENGINE=InnoDB DEFAULT CHARSET=latin1
mysql> ALTER TABLE child DROP FOREIGN KEY `child_ibfk_1`;
```

Adding and dropping a foreign key in separate clauses of a single `ALTER TABLE` statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.
CREATE TABLE Statement

If an `ALTER TABLE` statement results in changes to column values (for example, because a column is truncated), MySQL’s foreign key constraint checks do not notice possible violations caused by changing the values.

**Foreign Key Checks**

Foreign key checking is controlled by the `foreign_key_checks` variable, which is enabled by default. Typically, you leave this variable enabled during normal operation to enforce referential integrity.

The `foreign_key_checks` variable is dynamic and supports both global and session scopes. For information about using system variables, see Section 5.1.8, “Using System Variables”.

Disabling foreign key checking is useful when:

- Dropping a table that is referenced by a foreign key constraint. A referenced table can only be dropped after `foreign_key_checks` is disabled. When you drop a table, constraints defined on the table are also dropped.
- Reloading tables in different order than required by their foreign key relationships. For example, `mysqldump` produces correct definitions of tables in the dump file, including foreign key constraints for child tables. To make it easier to reload dump files for tables with foreign key relationships, `mysqldump` automatically includes a statement in the dump output that disables `foreign_key_checks`. This enables you to import the tables in any order in case the dump file contains tables that are not correctly ordered for foreign keys. Disabling `foreign_key_checks` also speeds up the import operation by avoiding foreign key checks.
- Executing `LOAD DATA` operations, to avoid foreign key checking.
- Performing an `ALTER TABLE` operation on a table that has a foreign key relationship.

When `foreign_key_checks` is disabled, foreign key constraints are ignored, with the following exceptions:

- Recreating a table that was previously dropped returns an error if the table definition does not conform to the foreign key constraints that reference the table. The table must have the correct column names and types. It must also have indexes on the referenced keys. If these requirements are not satisfied, MySQL returns Error 1005 that refers to errno: 150 in the error message, which means that a foreign key constraint was not correctly formed.
- Altering a table returns an error (errno: 150) if a foreign key definition is incorrectly formed for the altered table.
- Dropping an index required by a foreign key constraint. The foreign key constraint must be removed before dropping the index.
- Creating a foreign key constraint where a column references a nonmatching column type.

Disabling `foreign_key_checks` has these additional implications:

- It is permitted to drop a database that contains tables with foreign keys that are referenced by tables outside the database.
- It is permitted to drop a table with foreign keys referenced by other tables.
- Enabling `foreign_key_checks` does not trigger a scan of table data, which means that rows added to a table while `foreign_key_checks` is disabled are not checked for consistency when `foreign_key_checks` is re-enabled.
CREATE TABLE Statement

Foreign Key Definitions and Metadata

To view a foreign key definition, use `SHOW CREATE TABLE`:

```
mysql> SHOW CREATE TABLE child\G
*************************** 1. row ***************************
Table: child
Create Table: CREATE TABLE `child` (  `id` int(11) DEFAULT NULL,
  `parent_id` int(11) DEFAULT NULL,
  KEY `par_ind` (`parent_id`),
  CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`)  
REFERENCES `parent` (`id`) ON DELETE CASCADE
) ENGINE=InnoDB DEFAULT CHARSET=latin1
```

You can obtain information about foreign keys from the `INFORMATION_SCHEMA.KEY_COLUMN_USAGE` table. An example of a query against this table is shown here:

```
mysql> SELECT TABLE_SCHEMA, TABLE_NAME, COLUMN_NAME, CONSTRAINT_NAME  
FROM INFORMATION_SCHEMA.KEY_COLUMN_USAGE  
WHERE REFERENCED_TABLE_SCHEMA IS NOT NULL;
+--------------+------------+-------------+-----------------+
<table>
<thead>
<tr>
<th>TABLE_SCHEMA</th>
<th>TABLE_NAME</th>
<th>COLUMN_NAME</th>
<th>CONSTRAINT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>test</td>
<td>child</td>
<td>parent_id</td>
<td>child_ibfk_1</td>
</tr>
</tbody>
</table>
+--------------+------------+-------------+-----------------+
```

Foreign Key Errors

In the event of a foreign key error involving InnoDB tables (usually Error 150 in the MySQL Server), information about the latest foreign key error can be obtained by checking `SHOW ENGINE INNODB STATUS` output.

```
mysql> SHOW ENGINE INNODB STATUS\G
...  
LATEST FOREIGN KEY ERROR
--------------------
141016 15:37:30 Transaction:
TRANSACTION 3D005, ACTIVE 0 sec inserting
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1248, 3 row lock(s), undo log entries 3
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 70 localhost root
update
INSERT INTO child VALUES  
(NULL, 1)
, (NULL, 2)
, (NULL, 3)
, (NULL, 4)
, (NULL, 5)
, (NULL, 6)
Foreign key constraint fails for table `mysql`.`child`:

  CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`) REFERENCES `parent` (`id`)  
ON DELETE CASCADE ON UPDATE CASCADE
Trying to add in child table, in index `par_ind` tuple:
DATA TUPLE: 2 fields;
0: len 4; hex 80000003; asc     ;;
1: len 4; hex 80000003; asc     ;;

But in parent table `mysql`.`parent`, in index `PRIMARY`,
the closest match we can find is record:
PHYSICAL RECORD: n_fields 3; compact format; info bits 0
0: len 4; hex 80000004; asc     ;;
1: len 6; hex 00000003d002; asc       ;;
2: len 7; hex 8300001d480137; asc     H 7;;
```
Warning

ER_NO_REFERENCED_ROW_2 and ER_ROW_IS_REFERENCED_2 error messages for foreign key operations expose information about parent tables, even if the user has no parent table access privileges. To hide information about parent tables, include the appropriate condition handlers in application code and stored programs.

13.1.17.7 Silent Column Specification Changes

In some cases, MySQL silently changes column specifications from those given in a CREATE TABLE or ALTER TABLE statement. These might be changes to a data type, to attributes associated with a data type, or to an index specification.

All changes are subject to the internal row-size limit of 65,535 bytes, which may cause some attempts at data type changes to fail. See Section 8.4.7, “Limits on Table Column Count and Row Size”.

- TIMESTAMP display sizes are discarded.
  Also note that TIMESTAMP columns are NOT NULL by default.

- Columns that are part of a PRIMARY KEY are made NOT NULL even if not declared that way.

- Trailing spaces are automatically deleted from ENUM and SET member values when the table is created.

- MySQL maps certain data types used by other SQL database vendors to MySQL types. See Section 11.8, “Using Data Types from Other Database Engines”.

- If you include a USING clause to specify an index type that is not permitted for a given storage engine, but there is another index type available that the engine can use without affecting query results, the engine uses the available type.

- If strict SQL mode is not enabled, a VARCHAR column with a length specification greater than 65535 is converted to TEXT, and a VARBINARY column with a length specification greater than 65535 is converted to BLOB. Otherwise, an error occurs in either of these cases.

- Specifying the CHARACTER SET binary attribute for a character data type causes the column to be created as the corresponding binary data type: CHAR becomes BINARY, VARCHAR becomes VARBINARY, and TEXT becomes BLOB. For the ENUM and SET data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

```sql
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET binary,
  c2 TEXT CHARACTER SET binary,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

The resulting table has this definition:

```sql
CREATE TABLE t
(
  c1 VARBINARY(10),
  c2 BLOB,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

To see whether MySQL used a data type other than the one you specified, issue a DESCRIBE or SHOW CREATE TABLE statement after creating or altering the table.
CREATE TABLESPACE Statement

Certain other data type changes can occur if you compress a table using `myisampack`. See Section 15.3.3.3, “Compressed Table Characteristics”.

13.1.18 CREATE TABLESPACE Statement

```
CREATE TABLESPACE tablespace_name
    ADD DATAFILE 'file_name'
    USE LOGFILE GROUP logfile_group
    [EXTENT_SIZE [=] extent_size]
    [INITIAL_SIZE [=] initial_size]
    [AUTOEXTEND_SIZE [=] autoextend_size]
    [MAX_SIZE [=] max_size]
    [NODEGROUP [=] nodegroup_id]
    [WAIT]
    [COMMENT [=] comment_text]
    ENGINE [=] engine_name
```

This statement is used to create a tablespace, which can contain one or more data files, providing storage space for tables. One data file is created and added to the tablespace using this statement. Additional data files may be added to the tablespace by using the `ALTER TABLESPACE` statement (see Section 13.1.8, “ALTER TABLESPACE Statement”). For rules covering the naming of tablespaces, see Section 9.2, “Schema Object Names”.

**Note**

All NDB Cluster Disk Data objects share the same namespace. This means that each Disk Data object must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

A log file group of one or more UNDO log files must be assigned to the tablespace to be created with the `USE LOGFILE GROUP` clause. `logfile_group` must be an existing log file group created with `CREATE LOGFILE GROUP` (see Section 13.1.14, “CREATE LOGFILE GROUP Statement”). Multiple tablespaces may use the same log file group for UNDO logging.

The `EXTENT_SIZE` sets the size, in bytes, of the extents used by any files belonging to the tablespace. The default value is 1M. The minimum size is 32K, and theoretical maximum is 2G, although the practical maximum size depends on a number of factors. In most cases, changing the extent size does not have any measurable effect on performance, and the default value is recommended for all but the most unusual situations.

An `extent` is a unit of disk space allocation. One extent is filled with as much data as that extent can contain before another extent is used. In theory, up to 65,535 (64K) extents may used per data file; however, the recommended maximum is 32,768 (32K). The recommended maximum size for a single data file is 32G—that is, 32K extents × 1 MB per extent. In addition, once an extent is allocated to a given partition, it cannot be used to store data from a different partition; an extent cannot store data from more than one partition. This means, for example that a tablespace having a single datafile whose `INITIAL_SIZE` is 256 MB and whose `EXTENT_SIZE` is 128M has just two extents, and so can be used to store data from at most two different disk data table partitions.

You can see how many extents remain free in a given data file by querying the `INFORMATION_SCHEMA.FILES` table, and so derive an estimate for how much space remains free in the file. For further discussion and examples, see Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.

The `INITIAL_SIZE` parameter sets the data file’s total size in bytes. Once the file has been created, its size cannot be changed; however, you can add more data files to the tablespace using `ALTER TABLESPACE ... ADD DATAFILE`. See Section 13.1.8, “ALTER TABLESPACE Statement”.

1464
**CREATE TRIGGER Statement**

**INITIAL_SIZE** is optional; its default value is 134217728 (128 MB).

On 32-bit systems, the maximum supported value for **INITIAL_SIZE** is 4294967296 (4 GB). (Bug #29186)

When setting **EXTENT_SIZE**, you may optionally follow the number with a one-letter abbreviation for an order of magnitude, similar to those used in **my.cnf**. Generally, this is one of the letters **M** (for megabytes) or **G** (for gigabytes). In MySQL NDB Cluster 7.2.14 and later, these abbreviations are also supported when specifying **INITIAL_SIZE** as well. (Bug #13116514, Bug #16104705, Bug #62858)

**INITIAL_SIZE**, **EXTENT_SIZE**, and **UNDO_BUFFER_SIZE** are subject to rounding as follows:

- **EXTENT_SIZE** and **UNDO_BUFFER_SIZE** are each rounded up to the nearest whole multiple of 32K.
- **INITIAL_SIZE** is rounded down to the nearest whole multiple of 32K.

For data files, **INITIAL_SIZE** is subject to further rounding; the result just obtained is rounded up to the nearest whole multiple of **EXTENT_SIZE** (after any rounding).

The rounding just described is done explicitly, and a warning is issued by the MySQL Server when any such rounding is performed. The rounded values are also used by the NDB kernel for calculating **INFORMATION_SCHEMA.FILES** column values and other purposes. However, to avoid an unexpected result, we suggest that you always use whole multiples of 32K in specifying these options.

**AUTOEXTEND_SIZE**, **MAX_SIZE**, **NODEGROUP**, **WAIT**, and **COMMENT** are parsed but ignored, and so currently have no effect. These options are intended for future expansion.

The **ENGINE** parameter determines the storage engine which uses this tablespace, with **engine_name** being the name of the storage engine. Currently, **engine_name** must be one of the values **NDB** or **NDBCLUSTER**.

When **CREATE TABLESPACE** is used with **ENGINE = NDB**, a tablespace and associated data file are created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the **INFORMATION_SCHEMA.FILES** table. For example:

```sql
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
```

```
+--------------------+-------------+----------------+
<table>
<thead>
<tr>
<th>LOGFILE_GROUP_NAME</th>
<th>FILE_NAME</th>
<th>EXTRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>lg_3</td>
<td>newdata.dat</td>
<td>CLUSTER_NODE=3</td>
</tr>
<tr>
<td>lg_3</td>
<td>newdata.dat</td>
<td>CLUSTER_NODE=4</td>
</tr>
</tbody>
</table>
+--------------------+-------------+----------------+
```

2 rows in set (0.01 sec)

(See Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.)

**CREATE TABLESPACE** is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.19 CREATE TRIGGER Statement

```sql
CREATE [DEFINER = user] TRIGGER trigger_name
    trigger_time trigger_event
    ON tbl_name FOR EACH ROW
    trigger_body

trigger_time: { BEFORE | AFTER }
```
CREATE TRIGGER Statement

**trigger_event**: { INSERT | UPDATE | DELETE }

This statement creates a new trigger. A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. The trigger becomes associated with the table named `tbl_name`, which must refer to a permanent table. You cannot associate a trigger with a TEMPORARY table or a view.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

This section describes CREATE TRIGGER syntax. For additional discussion, see Section 20.3.1, “Trigger Syntax and Examples”.

CREATE TRIGGER requires the TRIGGER privilege for the table associated with the trigger. If the DEFINER clause is present, the privileges required depend on the user value, as discussed in Section 20.6, “Stored Object Access Control”. If binary logging is enabled, CREATE TRIGGER might require the SUPER privilege, as discussed in Section 20.7, “Stored Program Binary Logging”.

The DEFINER clause determines the security context to be used when checking access privileges at trigger activation time, as described later in this section.

**trigger_time** is the trigger action time. It can be BEFORE or AFTER to indicate that the trigger activates before or after each row to be modified.

Basic column value checks occur prior to trigger activation, so you cannot use BEFORE triggers to convert values inappropriate for the column type to valid values.

**trigger_event** indicates the kind of operation that activates the trigger. These trigger_event values are permitted:

- **INSERT**: The trigger activates whenever a new row is inserted into the table (for example, through INSERT, LOAD DATA, and REPLACE statements).
- **UPDATE**: The trigger activates whenever a row is modified (for example, through UPDATE statements).
- **DELETE**: The trigger activates whenever a row is deleted from the table (for example, through DELETE and REPLACE statements). DROP TABLE and TRUNCATE TABLE statements on the table do not activate this trigger, because they do not use DELETE. Dropping a partition does not activate DELETE triggers, either.

The **trigger_event** does not represent a literal type of SQL statement that activates the trigger so much as it represents a type of table operation. For example, an INSERT trigger activates not only for INSERT statements but also LOAD DATA statements because both statements insert rows into a table.

A potentially confusing example of this is the INSERT INTO ... ON DUPLICATE KEY UPDATE ... syntax: a BEFORE INSERT trigger activates for every row, followed by either an AFTER INSERT trigger or both the BEFORE UPDATE and AFTER UPDATE triggers, depending on whether there was a duplicate key for the row.

**Note**

Cascaded foreign key actions do not activate triggers.

There cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two BEFORE UPDATE triggers for a table. But you can have a BEFORE UPDATE and a BEFORE INSERT trigger, or a BEFORE UPDATE and an AFTER UPDATE trigger.
**CREATE VIEW Statement**

*trigger_body* is the statement to execute when the trigger activates. To execute multiple statements, use the `BEGIN ... END` compound statement construct. This also enables you to use the same statements that are permissible within stored routines. See Section 13.6.1, “BEGIN ... END Compound Statement”. Some statements are not permitted in triggers; see Section 20.8, “Restrictions on Stored Programs”.

Within the trigger body, you can refer to columns in the subject table (the table associated with the trigger) by using the aliases `OLD` and `NEW`. `OLD.col_name` refers to a column of an existing row before it is updated or deleted. `NEW.col_name` refers to the column of a new row to be inserted or an existing row after it is updated.

MySQL stores the `sql_mode` system variable setting in effect when a trigger is created, and always executes the trigger body with this setting in force, *regardless of the current server SQL mode when the trigger begins executing*.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at trigger activation time. If the `DEFINER` clause is present, the `user` value should be a MySQL account specified as `user_name@host_name`, `CURRENT_USER`, or `CURRENT_USER()`. The permitted `user` values depend on the privileges you hold, as discussed in Section 20.6, “Stored Object Access Control”. Also see that section for additional information about trigger security.

If the `DEFINER` clause is omitted, the default definer is the user who executes the `CREATE TRIGGER` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

MySQL takes the `DEFINER` user into account when checking trigger privileges as follows:

- At `CREATE TRIGGER` time, the user who issues the statement must have the `TRIGGER` privilege.

- At trigger activation time, privileges are checked against the `DEFINER` user. This user must have these privileges:
  - The `TRIGGER` privilege for the subject table.
  - The `SELECT` privilege for the subject table if references to table columns occur using `OLD.col_name` or `NEW.col_name` in the trigger body.
  - The `UPDATE` privilege for the subject table if table columns are targets of `SET NEW.col_name = value` assignments in the trigger body.
  - Whatever other privileges normally are required for the statements executed by the trigger.

Within a trigger body, the `CURRENT_USER` function returns the account used to check privileges at trigger activation time. This is the `DEFINER` user, not the user whose actions caused the trigger to be activated. For information about user auditing within triggers, see Section 6.2.14, “SQL-Based Account Activity Auditing”.

If you use `LOCK TABLES` to lock a table that has triggers, the tables used within the trigger are also locked, as described in `LOCK TABLES` and Triggers.

For additional discussion of trigger use, see Section 20.3.1, “Trigger Syntax and Examples”.

### 13.1.20 CREATE VIEW Statement

```sql
CREATE [OR REPLACE] [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}] [DEFINER = user]
```
The **CREATE VIEW** statement creates a new view, or replaces an existing view if the **OR REPLACE** clause is given. If the view does not exist, **CREATE OR REPLACE VIEW** is the same as **CREATE VIEW**. If the view does exist, **CREATE OR REPLACE VIEW** replaces it.

For information about restrictions on view use, see Section 20.9, “Restrictions on Views”.

The **select_statement** is a **SELECT** statement that provides the definition of the view. (Selecting from the view selects, in effect, using the **SELECT** statement.) The **select_statement** can select from base tables or other views.

The view definition is “frozen” at creation time and is not affected by subsequent changes to the definitions of the underlying tables. For example, if a view is defined as **SELECT * on a table, new columns added to the table later do not become part of the view, and columns dropped from the table will result in an error when selecting from the view.

The **ALGORITHM** clause affects how MySQL processes the view. The **DEFINER** and **SQL SECURITY** clauses specify the security context to be used when checking access privileges at view invocation time. The **WITH CHECK OPTION** clause can be given to constrain inserts or updates to rows in tables referenced by the view. These clauses are described later in this section.

The **CREATE VIEW** statement requires the **CREATE VIEW** privilege for the view, and some privilege for each column selected by the **SELECT** statement. For columns used elsewhere in the **SELECT** statement, you must have the **SELECT** privilege. If the **OR REPLACE** clause is present, you must also have the **DROP** privilege for the view. If the **DEFINER** clause is present, the privileges required depend on the **user** value, as discussed in Section 20.6, “Stored Object Access Control”.

When a view is referenced, privilege checking occurs as described later in this section.

A view belongs to a database. By default, a new view is created in the default database. To create the view explicitly in a given database, use **db_name.view_name** syntax to qualify the view name with the database name:

```
CREATE VIEW test.v AS SELECT * FROM t;
```

Unqualified table or view names in the **SELECT** statement are also interpreted with respect to the default database. A view can refer to tables or views in other databases by qualifying the table or view name with the appropriate database name.

Within a database, base tables and views share the same namespace, so a base table and a view cannot have the same name.

Columns retrieved by the **SELECT** statement can be simple references to table columns, or expressions that use functions, constant values, operators, and so forth.

A view must have unique column names with no duplicates, just like a base table. By default, the names of the columns retrieved by the **SELECT** statement are used for the view column names. To define explicit names for the view columns, specify the optional **column_list** clause as a list of comma-separated identifiers. The number of names in **column_list** must be the same as the number of columns retrieved by the **SELECT** statement.

A view can be created from many kinds of **SELECT** statements. It can refer to base tables or other views. It can use joins, **UNION**, and subqueries. The **SELECT** need not even refer to any tables:
CREATE VIEW Statement

CREATE VIEW v_today (today) AS SELECT CURRENT_DATE;

The following example defines a view that selects two columns from another table as well as an expression calculated from those columns:

```sql
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
<table>
<thead>
<tr>
<th>qty</th>
<th>price</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>50</td>
<td>150</td>
</tr>
</tbody>
</table>
+------+-------+-------+
```

A view definition is subject to the following restrictions:

- The `SELECT` statement cannot contain a subquery in the `FROM` clause.
- The `SELECT` statement cannot refer to system variables or user-defined variables.
- Within a stored program, the `SELECT` statement cannot refer to program parameters or local variables.
- The `SELECT` statement cannot refer to prepared statement parameters.
- Any table or view referred to in the definition must exist. If, after the view has been created, a table or view that the definition refers to is dropped, use of the view results in an error. To check a view definition for problems of this kind, use the `CHECK TABLE` statement.
- The definition cannot refer to a `TEMPORARY` table, and you cannot create a `TEMPORARY` view.
- You cannot associate a trigger with a view.
- Aliases for column names in the `SELECT` statement are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

`ORDER BY` is permitted in a view definition, but it is ignored if you select from a view using a statement that has its own `ORDER BY` or filtering or grouping. When `ORDER BY` is combined with `LIMIT` or `OFFSET` in a view definition, the ordering is always enforced before the query result is used by the outer query, but it does not guarantee that the same ordering is used in the end result. As a workaround, add an `ORDER BY` clause to the outer query.

For other options or clauses in the definition, they are added to the options or clauses of the statement that references the view, but the effect is undefined. For example, if a view definition includes a `LIMIT` clause, and you select from the view using a statement that has its own `LIMIT` clause, it is undefined which limit applies. This same principle applies to options such as `ALL`, `DISTINCT`, or `SQL_SMALL_RESULT` that follow the `SELECT` keyword, and to clauses such as `INTO`, `FOR UPDATE`, `LOCK IN SHARE MODE`, and `PROCEDURE`.

The results obtained from a view may be affected if you change the query processing environment by changing system variables:

```sql
mysql> CREATE VIEW v (mycol) AS SELECT 'abc';
Query OK, 0 rows affected (0.01 sec)
mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT "mycol" FROM v;
+-----+
| abc |
+-----+
```
The **DEFINER** and **SQL SECURITY** clauses determine which MySQL account to use when checking access privileges for the view when a statement is executed that references the view. The valid **SQL SECURITY** characteristic values are **DEFINER** (the default) and **INVOKER**. These indicate that the required privileges must be held by the user who defined or invoked the view, respectively.

If the **DEFINER** clause is present, the **user** value should be a MySQL account specified as `'user_name'@'host_name'`, **CURRENT_USER**, or **CURRENT_USER()**. The permitted **user** values depend on the privileges you hold, as discussed in Section 20.6, “Stored Object Access Control”. Also see that section for additional information about view security.

If the **DEFINER** clause is omitted, the default definer is the user who executes the **CREATE VIEW** statement. This is the same as specifying **DEFINER = CURRENT_USER** explicitly.

Within a view definition, the **CURRENT_USER** function returns the view’s **DEFINER** value by default. For views defined with the **SQL SECURITY INVOKER** characteristic, **CURRENT_USER** returns the account for the view’s invoker. For information about user auditing within views, see Section 6.2.14, “SQL-Based Account Activity Auditing”.

Within a stored routine that is defined with the **SQL SECURITY DEFINER** characteristic, **CURRENT_USER** returns the routine’s **DEFINER** value. This also affects a view defined within such a routine, if the view definition contains a **DEFINER** value of **CURRENT_USER**.

MySQL checks view privileges like this:

- At view definition time, the view creator must have the privileges needed to use the top-level objects accessed by the view. For example, if the view definition refers to table columns, the creator must have some privilege for each column in the select list of the definition, and the **SELECT** privilege for each column used elsewhere in the definition. If the definition refers to a stored function, only the privileges needed to invoke the function can be checked. The privileges required at function invocation time can be checked only as it executes: For different invocations, different execution paths within the function might be taken.

- The user who references a view must have appropriate privileges to access it (**SELECT** to select from it, **INSERT** to insert into it, and so forth.)

- When a view has been referenced, privileges for objects accessed by the view are checked against the privileges held by the view **DEFINER** account or invoker, depending on whether the **SQL SECURITY** characteristic is **DEFINER** or **INVOKER**, respectively.

- If reference to a view causes execution of a stored function, privilege checking for statements executed within the function depend on whether the function **SQL SECURITY** characteristic is **DEFINER** or **INVOKER**. If the security characteristic is **DEFINER**, the function runs with the privileges of the **DEFINER**
account. If the characteristic is INVOKER, the function runs with the privileges determined by the view's SQL SECURITY characteristic.

Example: A view might depend on a stored function, and that function might invoke other stored routines. For example, the following view invokes a stored function `f()`:

```sql
CREATE VIEW v AS SELECT * FROM t WHERE t.id = f(t.name);
```

Suppose that `f()` contains a statement such as this:

```sql
IF name IS NULL then
  CALL p1();
ELSE
  CALL p2();
END IF;
```

The privileges required for executing statements within `f()` need to be checked when `f()` executes. This might mean that privileges are needed for `p1()` or `p2()`, depending on the execution path within `f()`. Those privileges must be checked at runtime, and the user who must possess the privileges is determined by the SQL SECURITY values of the view `v` and the function `f()`.

The DEFINER and SQL SECURITY clauses for views are extensions to standard SQL. In standard SQL, views are handled using the rules for SQL SECURITY DEFINER. The standard says that the definer of the view, which is the same as the owner of the view's schema, gets applicable privileges on the view (for example, SELECT) and may grant them. MySQL has no concept of a schema "owner", so MySQL adds a clause to identify the definer. The DEFINER clause is an extension where the intent is to have what the standard has; that is, a permanent record of who defined the view. This is why the default DEFINER value is the account of the view creator.

The optional ALGORITHM clause is a MySQL extension to standard SQL. It affects how MySQL processes the view. ALGORITHM takes three values: MERGE, TEMPTABLE, or UNDEFINED. The default algorithm is UNDEFINED if no ALGORITHM clause is present. For more information, see Section 20.5.2, "View Processing Algorithms", as well as Optimizing Derived Tables.

Some views are updatable. That is, you can use them in statements such as UPDATE, DELETE, or INSERT to update the contents of the underlying table. For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable.

The WITH CHECK OPTION clause can be given for an updatable view to prevent inserts or updates to rows except those for which the WHERE clause in the select_statement is true.

In a WITH CHECK OPTION clause for an updatable view, the LOCAL and CASCADED keywords determine the scope of check testing when the view is defined in terms of another view. The LOCAL keyword restricts the CHECK OPTION only to the view being defined. CASCADED causes the checks for underlying views to be evaluated as well. When neither keyword is given, the default is CASCADED.

For more information about updatable views and the WITH CHECK OPTION clause, see Section 20.5.3, "Updatable and Insertable Views", and Section 20.5.4, "The View WITH CHECK OPTION Clause".

### 13.1.21 DROP DATABASE Statement

```sql
DROP {DATABASE | SCHEMA} [IF EXISTS] db_name
```

DROP DATABASE drops all tables in the database and deletes the database. Be very careful with this statement! To use DROP DATABASE, you need the DROP privilege on the database. DROP SCHEMA is a synonym for DROP DATABASE.
When a database is dropped, privileges granted specifically for the database are not automatically dropped. They must be dropped manually. See Section 13.7.1.3, “GRANT Statement”.

**IF EXISTS** is used to prevent an error from occurring if the database does not exist.

If the default database is dropped, the default database is unset (the `DATABASE()` function returns `NULL`).

If you use `DROP DATABASE` on a symbolically linked database, both the link and the original database are deleted.

`DROP DATABASE` returns the number of tables that were removed. This corresponds to the number of `.frm` files removed.

The `DROP DATABASE` statement removes from the given database directory those files and directories that MySQL itself may create during normal operation:

- All files with the following extensions:
  - `.frm`
  - `.BAK`
  - `.DAT`
  - `.HSH`
  - `.MRG`
  - `.MYD`
  - `.MYI`
  - `.TRG`
  - `.TRN`
  - `.db`
  - `.ibd`
  - `.ndb`
  - `.par`

- The `db.opt` file, if it exists.

If other files or directories remain in the database directory after MySQL removes those just listed, the database directory cannot be removed. In this case, you must remove any remaining files or directories manually and issue the `DROP DATABASE` statement again.

Dropping a database does not remove any `TEMPORARY` tables that were created in that database. `TEMPORARY` tables are automatically removed when the session that created them ends. See Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”.

You can also drop databases with `mysqladmin`. See Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”.
13.1.22 DROP EVENT Statement

```
DROP EVENT [IF EXISTS] event_name
```

This statement drops the event named `event_name`. The event immediately ceases being active, and is deleted completely from the server.

If the event does not exist, the error `ERROR 1517 (HY000): Unknown event 'event_name'` results. You can override this and cause the statement to generate a warning for nonexistent events instead using `IF EXISTS`.

This statement requires the `EVENT` privilege for the schema to which the event to be dropped belongs.

13.1.23 DROP FUNCTION Statement

The `DROP FUNCTION` statement is used to drop stored functions and user-defined functions (UDFs):

- For information about dropping stored functions, see Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”.
- For information about dropping user-defined functions, see Section 13.7.3.2, “DROP FUNCTION Statement”.

13.1.24 DROP INDEX Statement

```
DROP [ONLINE|OFFLINE] INDEX index_name ON tbl_name
```

`DROP INDEX` drops the index named `index_name` from the table `tbl_name`. This statement is mapped to an `ALTER TABLE` statement to drop the index. See Section 13.1.7, “ALTER TABLE Statement”.

To drop a primary key, the index name is always `PRIMARY`, which must be specified as a quoted identifier because `PRIMARY` is a reserved word:

```
DROP INDEX `PRIMARY` ON t;
```

Indexes on variable-width columns of `NDB` tables are dropped online; that is, without any table copying. The table is not locked against access from other NDB Cluster API nodes, although it is locked against other operations on the same API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.5 releases, it is not possible to override the server when it determines that an index is to be dropped without table copying. In NDB Cluster, you can drop indexes offline (which causes the table to be locked for all API nodes in the cluster) using the `OFFLINE` keyword. The rules and limitations governing `DROP OFFLINE INDEX` and `DROP ONLINE INDEX` are the same as for `ALTER OFFLINE TABLE ... DROP INDEX` and `ALTER ONLINE TABLE ... DROP INDEX`. You cannot cause the noncopying dropping of an index that would normally be dropped offline by using the `ONLINE` keyword: If it is not possible to perform the `DROP` operation without table copying, the server ignores the `ONLINE` keyword. For more information, see Section 18.5.13, “Online Operations with ALTER TABLE in NDB Cluster”.

The `ONLINE` and `OFFLINE` keywords are available only in NDB Cluster; attempting to use these keywords in standard MySQL Server 5.5 releases results in a syntax error.

13.1.25 DROP LOGFILE GROUP Statement

```
DROP LOGFILE GROUP logfile_group
ENGINE [=] engine_name
```

These keywords are available only in NDB Cluster; attempting to use them in standard MySQL Server 5.5 releases results in a syntax error.
This statement drops the log file group named `logfile_group`. The log file group must already exist or an error results. (For information on creating log file groups, see Section 13.1.14, "CREATE LOGFILE GROUP Statement").

Important

Before dropping a log file group, you must drop all tablespaces that use that log file group for UNDO logging.

The required `ENGINE` clause provides the name of the storage engine used by the log file group to be dropped. Currently, the only permitted values for `engine_name` are `NDB` and `NDBCLUSTER`.

`DROP LOGFILE GROUP` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, "NDB Cluster Disk Data Tables".

### 13.1.26 DROP PROCEDURE and DROP FUNCTION Statements

```
DROP {PROCEDURE | FUNCTION} [IF EXISTS] sp_name
```

This statement is used to drop a stored procedure or function. That is, the specified routine is removed from the server. You must have the `ALTER ROUTINE` privilege for the routine. (If the `automatic_sp_privileges` system variable is enabled, that privilege and `EXECUTE` are granted automatically to the routine creator when the routine is created and dropped from the creator when the routine is dropped. See Section 20.2.2, "Stored Routines and MySQL Privileges").

The `IF EXISTS` clause is a MySQL extension. It prevents an error from occurring if the procedure or function does not exist. A warning is produced that can be viewed with `SHOW WARNINGS`.

`DROP FUNCTION` is also used to drop user-defined functions (see Section 13.7.3.2, "DROP FUNCTION Statement").

### 13.1.27 DROP SERVER Statement

```
DROP SERVER [ IF EXISTS ] server_name
```

Drops the server definition for the server named `server_name`. The corresponding row in the `mysql.servers` table is deleted. This statement requires the `SUPER` privilege.

Dropping a server for a table does not affect any `FEDERATED` tables that used this connection information when they were created. See Section 13.1.16, "CREATE SERVER Statement".

`DROP SERVER` causes an implicit commit. See Section 13.3.3, "Statements That Cause an Implicit Commit".

`DROP SERVER` is not written to the binary log, regardless of the logging format that is in use.

### 13.1.28 DROP TABLE Statement

```
DROP [TEMPORARY] TABLE [IF EXISTS] tbl_name [, tbl_name] ...
[RESTRICT | CASCADE]
```

`DROP TABLE` removes one or more tables. You must have the `DROP` privilege for each table.

*Be careful* with this statement! For each table, it removes the table definition and all table data. If the table is partitioned, the statement removes the table definition, all its partitions, all data stored in those partitions, and all partition definitions associated with the dropped table.
Dropping a table also drops any triggers for the table. The `DROP TABLE` statement causes an implicit commit, except when used with the `TEMPORARY` keyword. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

**Important**

When a table is dropped, privileges granted specifically for the table are *not* automatically dropped. They must be dropped manually. See Section 13.7.1.3, “GRANT Statement”.

If any tables named in the argument list do not exist, `DROP TABLE` behavior depends on whether the `IF EXISTS` clause is given:

- **Without `IF EXISTS`,** the statement drops all named tables that do exist, and returns an error indicating which nonexisting tables it was unable to drop.
- **With `IF EXISTS`,** no error occurs for nonexisting tables. The statement drops all named tables that do exist, and generates a `NOTE` diagnostic for each nonexistent table. These notes can be displayed with `SHOW WARNINGS`. See Section 13.7.5.41, “SHOW WARNINGS Statement”.

`IF EXISTS` can also be useful for dropping tables in unusual circumstances under which there is an `.frm` file but no table managed by the storage engine. (For example, if an abnormal server exit occurs after removal of the table from the storage engine but before `.frm` file removal.)

The `TEMPORARY` keyword has the following effects:

- The statement drops only `TEMPORARY` tables.
- The statement does not cause an implicit commit.
- No access rights are checked. A `TEMPORARY` table is visible only with the session that created it, so no check is necessary.

Including the `TEMPORARY` keyword is a good way to prevent accidentally dropping non-`TEMPORARY` tables.

The `RESTRICT` and `CASCADE` keywords do nothing. They are permitted to make porting easier from other database systems.

### 13.1.29 DROP TABLESPACE Statement

**DROP TABLESPACE**

```
DROP TABLESPACE tablespace_name
ENGINE [=] engine_name
```

This statement drops a tablespace that was previously created using `CREATE TABLESPACE` (see Section 13.1.18, “CREATE TABLESPACE Statement”).

**Important**

The tablespace to be dropped must not contain any data files; in other words, before you can drop a tablespace, you must first drop each of its data files using `ALTER TABLESPACE ... DROP DATAFILE` (see Section 13.1.8, “ALTER TABLESPACE Statement”).

The `ENGINE` clause (required) specifies the storage engine used by the tablespace. Currently, the only accepted values for `engine_name` are `NDB` and `NDBCLUSTER`.

`DROP TABLESPACE` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.
13.1.30 DROP TRIGGER Statement

\[\text{DROP TRIGGER [IF EXISTS] [schema_name.]} \text{ trigger_name}\]

This statement drops a trigger. The schema (database) name is optional. If the schema is omitted, the trigger is dropped from the default schema. \text{DROP TRIGGER} requires the \text{TRIGGER} privilege for the table associated with the trigger.

Use \text{IF EXISTS} to prevent an error from occurring for a trigger that does not exist. A \text{NOTE} is generated for a nonexistent trigger when using \text{IF EXISTS}. See Section 13.7.5.41, “SHOW WARNINGS Statement”.

Triggers for a table are also dropped if you drop the table.

**Note**

When upgrading from a version of MySQL older than MySQL 5.0.10 to 5.0.10 or higher—including all MySQL 5.5 releases—you must drop all triggers and re-create them. Otherwise, \text{DROP TRIGGER} does not work for older triggers after the upgrade. See Section 2.11.3, “Changes in MySQL 5.5”, for a suggested upgrade procedure.

13.1.31 DROP VIEW Statement

\[\text{DROP VIEW [IF EXISTS]} \\ view_name \ [, \ view_name] \ldots \\ [\text{RESTRICT | CASCADE}]\]

\text{DROP VIEW} removes one or more views. You must have the \text{DROP} privilege for each view.

If any views named in the argument list do not exist, the statement returns an error indicating by name which nonexisting views it was unable to drop, but also drops all views in the list that do exist.

The \text{IF EXISTS} clause prevents an error from occurring for views that don’t exist. When this clause is given, a \text{NOTE} is generated for each nonexistent view. See Section 13.7.5.41, “SHOW WARNINGS Statement”.

\text{RESTRICT} and \text{CASCADE}, if given, are parsed and ignored.

13.1.32 RENAME TABLE Statement

\[\text{RENAME TABLE} \\ \ \text{tbl_name} \ \ \text{TO} \ \ \text{new_tbl_name} \\ \ [, \ \ \text{tbl_name2} \ \text{TO} \ \text{new_tbl_name2}] \ldots\]

\text{RENAME TABLE} renames one or more tables. You must have \text{ALTER} and \text{DROP} privileges for the original table, and \text{CREATE} and \text{INSERT} privileges for the new table.

For example, to rename a table named \text{old_table} to \text{new_table}, use this statement:

\text{RENAME TABLE old_table TO new_table;}

That statement is equivalent to the following \text{ALTER TABLE} statement:

\text{ALTER TABLE old_table RENAME new_table;}

\text{RENAME TABLE}, unlike \text{ALTER TABLE}, can rename multiple tables within a single statement:

\text{RENAME TABLE old_table1 TO new_table1,}
TRUNCATE TABLE Statement

```sql
old_table2 TO new_table2,
old_table3 TO new_table3;
```

Renaming operations are performed left to right. Thus, to swap two table names, do this (assuming that a table with the intermediary name `tmp_table` does not already exist):

```sql
RENAME TABLE old_table TO tmp_table,
new_table TO old_table,
tmp_table TO new_table;
```

Metadata locks on tables are acquired in name order, which in some cases can make a difference in operation outcome when multiple transactions execute concurrently. See Section 8.11.4, “Metadata Locking”.

To execute `RENAME TABLE`, there must be no active transactions or tables locked with `LOCK TABLES`. With the transaction table locking conditions satisfied, the rename operation is done atomically; no other session can access any of the tables while the rename is in progress.

If any errors occur during a `RENAME TABLE`, the statement fails and no changes are made.

You can use `RENAME TABLE` to move a table from one database to another:

```sql
RENAME TABLE current_db.tbl_name TO other_db.tbl_name;
```

Using this method to move all tables from one database to a different one in effect renames the database (an operation for which MySQL has no single statement), except that the original database continues to exist, albeit with no tables.

Like `RENAME TABLE`, `ALTER TABLE ... RENAME` can also be used to move a table to a different database. Regardless of the statement used, if the rename operation would move the table to a database located on a different file system, the success of the outcome is platform specific and depends on the underlying operating system calls used to move table files.

If a table has triggers, attempts to rename the table into a different database fail with a `Trigger in wrong schema` (`ER_TRG_IN_WRONG_SCHEMA`) error.

To rename `TEMPORARY` tables, `RENAME TABLE` does not work. Use `ALTER TABLE` instead.

`RENAME TABLE` works for views, except that views cannot be renamed into a different database.

Any privileges granted specifically for a renamed table or view are not migrated to the new name. They must be changed manually.

`RENAME TABLE tbl_name TO new_tbl_name` changes internally generated foreign key constraint names and user-defined foreign key constraint names that begin with the string “tbl_name_ibfk_” to reflect the new table name. InnoDB interprets foreign key constraint names that begin with the string “tbl_name_ibfk_” as internally generated names.

Foreign key constraint names that point to the renamed table are automatically updated unless there is a conflict, in which case the statement fails with an error. A conflict occurs if the renamed constraint name already exists. In such cases, you must drop and re-create the foreign keys for them to function properly.

13.1.33 TRUNCATE TABLE Statement

```sql
TRUNCATE [TABLE] tbl_name
```

`TRUNCATE TABLE` empties a table completely. It requires the `DROP` privilege.
Data Manipulation Statements

Logically, **TRUNCATE TABLE** is similar to a **DELETE** statement that deletes all rows, or a sequence of **DROP TABLE** and **CREATE TABLE** statements. To achieve high performance, it bypasses the DML method of deleting data. Thus, it cannot be rolled back, it does not cause **ON DELETE** triggers to fire, and it cannot be performed for **InnoDB** tables with parent-child foreign key relationships.

Although **TRUNCATE TABLE** is similar to **DELETE**, it is classified as a DDL statement rather than a DML statement. It differs from **DELETE** in the following ways:

- Truncate operations drop and re-create the table, which is much faster than deleting rows one by one, particularly for large tables.
- Truncate operations cause an implicit commit, and so cannot be rolled back. See Section 13.3.3, “Statements That Cause an Implicit Commit”.
- Truncation operations cannot be performed if the session holds an active table lock.
- **TRUNCATE TABLE** fails for an **InnoDB** table if there are any **FOREIGN KEY** constraints from other tables that reference the table. Foreign key constraints between columns of the same table are permitted.
- Truncation operations do not return a meaningful value for the number of deleted rows. The usual result is “0 rows affected,” which should be interpreted as “no information.”
- As long as the table format file `tbl_name.frm` is valid, the table can be re-created as an empty table with **TRUNCATE TABLE**, even if the data or index files have become corrupted.
- Any **AUTO_INCREMENT** value is reset to its start value. This is true even for **MyISAM** and **InnoDB**, which normally do not reuse sequence values.
- When used with partitioned tables, **TRUNCATE TABLE** preserves the partitioning; that is, the data and index files are dropped and re-created, while the partition definitions (.par) file is unaffected.
- The **TRUNCATE TABLE** statement does not invoke **ON DELETE** triggers.

**TRUNCATE TABLE** for a table closes all handlers for the table that were opened with **HANDLER OPEN**.

**TRUNCATE TABLE** is treated for purposes of binary logging and replication as **DROP TABLE** followed by **CREATE TABLE**—that is, as DDL rather than DML. This is due to the fact that, when using **InnoDB** and other transactional storage engines where the transaction isolation level does not permit statement-based logging (**READ COMMITTED** or **READ UNCOMMITTED**), the statement was not logged and replicated when using **STATEMENT** or **MIXED** logging mode. (Bug #36763) However, it is still applied on replication slaves using **InnoDB** in the manner described previously.

On a system with a large **InnoDB** buffer pool and **innodb_adaptive_hash_index** enabled, **TRUNCATE TABLE** operations may cause a temporary drop in system performance due to an LRU scan that occurs when removing an **InnoDB** table's adaptive hash index entries. The problem was addressed for **DROP TABLE** in MySQL 5.5.23 (Bug #13704145, Bug #64284) but remains a known issue for **TRUNCATE TABLE** (Bug #68184).

**TRUNCATE TABLE** can be used with Performance Schema summary tables, but the effect is to reset the summary columns to 0 or **NULL**, not to remove rows. See Section 22.10.5, “Performance Schema Summary Tables”.

13.2 Data Manipulation Statements

13.2.1 CALL Statement

```
CALL sp_name([parameter[,...]])
```
CALL Statement

CALL `sp_name`()

The CALL statement invokes a stored procedure that was defined previously with CREATE PROCEDURE.

Stored procedures that take no arguments can be invoked without parentheses. That is, CALL `p()` and CALL `p` are equivalent.

CALL can pass back values to its caller using parameters that are declared as OUT or INOUT parameters. When the procedure returns, a client program can also obtain the number of rows affected for the final statement executed within the routine: At the SQL level, call the `ROW_COUNT()` function; from the C API, call the `mysql_affected_rows()` function.

For information about the effect of unhandled conditions on procedure parameters, see Section 13.6.7.5, “Condition Handling and OUT or INOUT Parameters”.

To get back a value from a procedure using an OUT or INOUT parameter, pass the parameter by means of a user variable, and then check the value of the variable after the procedure returns. (If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an IN or INOUT parameter.) For an INOUT parameter, initialize its value before passing it to the procedure. The following procedure has an OUT parameter that the procedure sets to the current server version, and an INOUT value that the procedure increments by one from its current value:

```sql
CREATE PROCEDURE p (OUT ver_param VARCHAR(25), INOUT incr_param INT)
BEGIN
    # Set value of OUT parameter
    SELECT VERSION() INTO ver_param;
    # Increment value of INOUT parameter
    SET incr_param = incr_param + 1;
END;
```

Before calling the procedure, initialize the variable to be passed as the INOUT parameter. After calling the procedure, the values of the two variables will have been set or modified:

```sql
mysql> SET @increment = 10;
mysql> CALL p(@version, @increment);
mysql> SELECT @version, @increment;
```

<table>
<thead>
<tr>
<th>@version</th>
<th>@increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.58-debug-log</td>
<td>11</td>
</tr>
</tbody>
</table>

In prepared CALL statements used with PREPARE and EXECUTE, placeholders can be used for IN parameters, OUT, and INOUT parameters. These types of parameters can be used as follows:

```sql
mysql> SET @increment = 10;
mysql> PREPARE s FROM 'CALL p(?, ?)';
mysql> EXECUTE s USING @version, @increment;
mysql> SELECT @version, @increment;
```

<table>
<thead>
<tr>
<th>@version</th>
<th>@increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.58-debug-log</td>
<td>11</td>
</tr>
</tbody>
</table>

To write C programs that use the CALL SQL statement to execute stored procedures that produce result sets, the CLIENT_MULTI_RESULTS flag must be enabled. This is because each CALL returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. CLIENT_MULTI_RESULTS must also be enabled if CALL is used to execute any stored procedure that contains prepared statements. It cannot be determined when such a procedure is loaded whether those statements will produce result sets, so it is necessary to assume that they will.
CLIENT_MULTI_RESULTS can be enabled when you call mysql_real_connect(), either explicitly by passing the CLIENT_MULTI_RESULTS flag itself, or implicitly by passing CLIENT_MULTI_STATEMENTS (which also enables CLIENT_MULTI_RESULTS). CLIENT_MULTI_RESULTS is enabled by default.

To process the result of a CALL statement executed using mysql_query() or mysql_real_query(), use a loop that calls mysql_next_result() to determine whether there are more results. For an example, see Section 23.7.15, “C API Multiple Statement Execution Support”.

C programs can use the prepared-statement interface to execute CALL statements and access OUT and INOUT parameters. This is done by processing the result of a CALL statement using a loop that calls mysql_stmt_next_result() to determine whether there are more results. For an example, see Section 23.7.17, “C API Prepared CALL Statement Support”. Languages that provide a MySQL interface can use prepared CALL statements to directly retrieve OUT and INOUT procedure parameters.

13.2.2 DELETE Statement

DELETE is a DML statement that removes rows from a table.

Single-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE] FROM tbl_name
   [WHERE where_condition]
   [ORDER BY ...]
   [LIMIT row_count]
```

Multiple-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
   tbl_name[.*] [, tbl_name[.*]] ... FROM table_references
   [WHERE where_condition]

DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
   FROM tbl_name[.*] [, tbl_name[.*]] ... USING table_references
   [WHERE where_condition]
```

For the single-table syntax, the DELETE statement deletes rows from tbl_name and returns a count of the number of deleted rows. This count can be obtained by calling the ROW_COUNT() function (see Section 12.15, “Information Functions”). The WHERE clause, if given, specifies the conditions that identify which rows to delete. With no WHERE clause, all rows are deleted. If the ORDER BY clause is specified, the rows are deleted in the order that is specified. The LIMIT clause places a limit on the number of rows that can be deleted.

For the multiple-table syntax, DELETE deletes from each tbl_name the rows that satisfy the conditions. In this case, ORDER BY and LIMIT cannot be used.

where_condition is an expression that evaluates to true for each row to be deleted. It is specified as described in Section 13.2.9, “SELECT Statement”.

You cannot delete from a table and select from the same table in a subquery.

You need the DELETE privilege on a table to delete rows from it. You need only the SELECT privilege for any columns that are only read, such as those named in the WHERE clause.

As stated, a DELETE statement with no WHERE clause deletes all rows. A faster way to do this, when you do not need to know the number of deleted rows, is to use TRUNCATE TABLE. However, within a transaction or if you have a lock on the table, TRUNCATE TABLE cannot be used whereas DELETE can.
DELETE Statement

See Section 13.1.33, “TRUNCATE TABLE Statement”, and Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”.

If you delete the row containing the maximum value for an AUTO_INCREMENT column, the value is not reused for a MyISAM or InnoDB table. If you delete all rows in the table with DELETE FROM tbl_name (without a WHERE clause) in autocommit mode, the sequence starts over for all storage engines except InnoDB and MyISAM. There are some exceptions to this behavior for InnoDB tables, as discussed in Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”.

For MyISAM tables, you can specify an AUTO_INCREMENT secondary column in a multiple-column key. In this case, reuse of values deleted from the top of the sequence occurs even for MyISAM tables. See Section 3.6.9, “Using AUTO_INCREMENT”.

The DELETE statement supports the following modifiers:

• If you specify the LOW_PRIORITY modifier, the server delays execution of the DELETE until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as MyISAM, MEMORY, and MERGE).

• For MyISAM tables, if you use the QUICK modifier, the storage engine does not merge index leaves during delete, which may speed up some kinds of delete operations.

• The IGNORE modifier causes MySQL to ignore errors during the process of deleting rows. (Errors encountered during the parsing stage are processed in the usual manner.) Errors that are ignored due to the use of IGNORE are returned as warnings.

The speed of delete operations may also be affected by factors discussed in Section 8.2.4.3, “Optimizing DELETE Statements”.

In MyISAM tables, deleted rows are maintained in a linked list and subsequent INSERT operations reuse old row positions. To reclaim unused space and reduce file sizes, use the OPTIMIZE TABLE statement or the myisamchk utility to reorganize tables. OPTIMIZE TABLE is easier to use, but myisamchk is faster. See Section 13.7.2.4, “OPTIMIZE TABLE Statement”, and Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

The QUICK modifier affects whether index leaves are merged for delete operations. DELETE QUICK is most useful for applications where index values for deleted rows are replaced by similar index values from rows inserted later. In this case, the holes left by deleted values are reused.

DELETE QUICK is not useful when deleted values lead to underfilled index blocks spanning a range of index values for which new inserts occur again. In this case, use of QUICK can lead to wasted space in the index that remains unreclaimed. Here is an example of such a scenario:

1. Create a table that contains an indexed AUTO_INCREMENT column.
2. Insert many rows into the table. Each insert results in an index value that is added to the high end of the index.
3. Delete a block of rows at the low end of the column range using DELETE QUICK.

In this scenario, the index blocks associated with the deleted index values become underfilled but are not merged with other index blocks due to the use of QUICK. They remain underfilled when new inserts occur, because new rows do not have index values in the deleted range. Furthermore, they remain underfilled even if you later use DELETE without QUICK, unless some of the deleted index values happen to lie in index blocks within or adjacent to the underfilled blocks. To reclaim unused index space under these circumstances, use OPTIMIZE TABLE.
DELETE Statement

If you are going to delete many rows from a table, it might be faster to use `DELETE QUICK` followed by `OPTIMIZE TABLE`. This rebuilds the index rather than performing many index block merge operations.

The MySQL-specific `LIMIT row_count` option to `DELETE` tells the server the maximum number of rows to be deleted before control is returned to the client. This can be used to ensure that a given `DELETE` statement does not take too much time. You can simply repeat the `DELETE` statement until the number of affected rows is less than the `LIMIT` value.

If the `DELETE` statement includes an `ORDER BY` clause, rows are deleted in the order specified by the clause. This is useful primarily in conjunction with `LIMIT`. For example, the following statement finds rows matching the `WHERE` clause, sorts them by `timestamp_column`, and deletes the first (oldest) one:

```
DELETE FROM somelog WHERE user = 'jcole'
ORDER BY timestamp_column LIMIT 1;
```

`ORDER BY` may also be useful in some cases to delete rows in an order required to avoid referential integrity violations.

If you are deleting many rows from a large table, you may exceed the lock table size for an InnoDB table. To avoid this problem, or simply to minimize the time that the table remains locked, the following strategy (which does not use `DELETE` at all) might be helpful:

1. Select the rows not to be deleted into an empty table that has the same structure as the original table:

   ```
   INSERT INTO t_copy SELECT * FROM t WHERE ... ;
   ```

2. Use `RENAME TABLE` to atomically move the original table out of the way and rename the copy to the original name:

   ```
   RENAME TABLE t TO t_old, t_copy TO t;
   ```

3. Drop the original table:

   ```
   DROP TABLE t_old;
   ```

No other sessions can access the tables involved while `RENAME TABLE` executes, so the rename operation is not subject to concurrency problems. See Section 13.1.32, “RENAME TABLE Statement”.

You can specify multiple tables in a `DELETE` statement to delete rows from one or more tables depending on the condition in the `WHERE` clause. You cannot use `ORDER BY` or `LIMIT` in a multiple-table `DELETE`. The `table_references` clause lists the tables involved in the join, as described in Section 13.2.9.2, “JOIN Clause”.

For the first multiple-table syntax, only matching rows from the tables listed before the `FROM` clause are deleted. For the second multiple-table syntax, only matching rows from the tables listed in the `FROM` clause (before the `USING` clause) are deleted. The effect is that you can delete rows from many tables at the same time and have additional tables that are used only for searching:

```
DELETE t1, t2 FROM t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

Or:

```
DELETE FROM t1, t2 USING t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

These statements use all three tables when searching for rows to delete, but delete matching rows only from tables `t1` and `t2`. 
The preceding examples use INNER JOIN, but multiple-table DELETE statements can use other types of join permitted in SELECT statements, such as LEFT JOIN. For example, to delete rows that exist in \textit{t1} that have no match in \textit{t2}, use a LEFT JOIN:

\begin{verbatim}
DELETE t1 FROM t1 LEFT JOIN t2 ON t1.id=t2.id WHERE t2.id IS NULL;
\end{verbatim}

The syntax permits .\textit{*} after each \textit{tbl_name} for compatibility with Access.

If you use a multiple-table DELETE statement involving InnoDB tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, you should delete from a single table and rely on the \textit{ON DELETE} capabilities that InnoDB provides to cause the other tables to be modified accordingly.

\textbf{Note}

If you declare an alias for a table, you must use the alias when referring to the table:

\begin{verbatim}
DELETE t1 FROM test AS t1, test2 WHERE ...
\end{verbatim}

Table aliases in a multiple-table DELETE should be declared only in the \textit{table_references} part of the statement. Elsewhere, alias references are permitted but not alias declarations.

Correct:

\begin{verbatim}
DELETE a1, a2 FROM t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;
DELETE FROM a1, a2 USING t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;
\end{verbatim}

Incorrect:

\begin{verbatim}
DELETE t1 AS a1, t2 AS a2 FROM t1 INNER JOIN t2
WHERE a1.id=a2.id;
DELETE FROM t1 AS a1, t2 AS a2 USING t1 INNER JOIN t2
WHERE a1.id=a2.id;
\end{verbatim}

13.2.3 DO Statement

\textbf{DO} \textit{expr} [, \textit{expr}] ...

\textbf{DO} executes the expressions but does not return any results. In most respects, \textbf{DO} is shorthand for \textbf{SELECT} \textit{expr}, \textit{...}, but has the advantage that it is slightly faster when you do not care about the result.

\textbf{DO} is useful primarily with functions that have side effects, such as \textit{RELEASE\_LOCK()}.  

Example: This \textbf{SELECT} statement pauses, but also produces a result set:

\begin{verbatim}
mysql> SELECT SLEEP (5);
+----------+
| SLEEP (5) |
+----------+
| 0         |
+----------+
1 row in set (5.02 sec)
\end{verbatim}

\textbf{DO}, on the other hand, pauses without producing a result set.:

\begin{verbatim}
mysql> DO SLEEP (5);
Query OK, 0 rows affected (4.99 sec)
\end{verbatim}
HANDLER Statement

This could be useful, for example in a stored function or trigger, which prohibit statements that produce result sets.

DO only executes expressions. It cannot be used in all cases where SELECT can be used. For example, DO id FROM t1 is invalid because it references a table.

13.2.4 HANDLER Statement

| HANDLER tbl_name OPEN [ [AS] alias] |
| HANDLER tbl_name READ index_name { = | < | <= | > | < > } (value1,value2,...) |
| [ WHERE where_condition ] [LIMIT ... ] |
| HANDLER tbl_name READ index_name { FIRST | NEXT | PREV | LAST } |
| [ WHERE where_condition ] [LIMIT ... ] |
| HANDLER tbl_name READ { FIRST | NEXT } |
| [ WHERE where_condition ] [LIMIT ... ] |
| HANDLER tbl_name CLOSE |

The HANDLER statement provides direct access to table storage engine interfaces. It is available for InnoDB and MyISAM tables.

The HANDLER ... OPEN statement opens a table, making it accessible using subsequent HANDLER ... READ statements. This table object is not shared by other sessions and is not closed until the session calls HANDLER ... CLOSE or the session terminates.

If you open the table using an alias, further references to the open table with other HANDLER statements must use the alias rather than the table name. If you do not use an alias, but open the table using a table name qualified by the database name, further references must use the unqualified table name. For example, for a table opened using mydb.mytable, further references must use mytable.

The first HANDLER ... READ syntax fetches a row where the index specified satisfies the given values and the WHERE condition is met. If you have a multiple-column index, specify the index column values as a comma-separated list. Either specify values for all the columns in the index, or specify values for a leftmost prefix of the index columns. Suppose that an index my_idx includes three columns named col_a, col_b, and col_c, in that order. The HANDLER statement can specify values for all three columns in the index, or for the columns in a leftmost prefix. For example:

HANDLER ... READ my_idx = (col_a_val,col_b_val,col_c_val) ...  
HANDLER ... READ my_idx = (col_a_val,col_b_val) ...  
HANDLER ... READ my_idx = (col_a_val) ...

To employ the HANDLER interface to refer to a table's PRIMARY KEY, use the quoted identifier `PRIMARY`:

| HANDLER tbl_name READ `PRIMARY` ... |

The second HANDLER ... READ syntax fetches a row from the table in index order that matches the WHERE condition.

The third HANDLER ... READ syntax fetches a row from the table in natural row order that matches the WHERE condition. It is faster than HANDLER tbl_name READ index_name when a full table scan is desired. Natural row order is the order in which rows are stored in a MyISAM table data file. This statement works for InnoDB tables as well, but there is no such concept because there is no separate data file.

Without a LIMIT clause, all forms of HANDLER ... READ fetch a single row if one is available. To return a specific number of rows, include a LIMIT clause. It has the same syntax as for the SELECT statement. See Section 13.2.9, “SELECT Statement”.  

1484
There are several reasons to use the `HANDLER` interface instead of normal `SELECT` statements:

- **`HANDLER` is faster than `SELECT`:
  - A designated storage engine handler object is allocated for the `HANDLER ... OPEN`. The object is reused for subsequent `HANDLER` statements for that table; it need not be reinitialized for each one.
  - There is less parsing involved.
  - There is no optimizer or query-checking overhead.
  - The handler interface does not have to provide a consistent look of the data (for example, dirty reads are permitted), so the storage engine can use optimizations that `SELECT` does not normally permit.

- **`HANDLER` makes it easier to port to MySQL applications that use a low-level ISAM-like interface.**

- **`HANDLER` enables you to traverse a database in a manner that is difficult (or even impossible) to accomplish with `SELECT`. The `HANDLER` interface is a more natural way to look at data when working with applications that provide an interactive user interface to the database.**

**`HANDLER`** is a somewhat low-level statement. For example, it does not provide consistency. That is, `HANDLER ... OPEN` does not take a snapshot of the table, and does not lock the table. This means that after a `HANDLER ... OPEN` statement is issued, table data can be modified (by the current session or other sessions) and these modifications might be only partially visible to `HANDLER ... NEXT` or `HANDLER ... PREV` scans.

An open handler can be closed and marked for reopen, in which case the handler loses its position in the table. This occurs when both of the following circumstances are true:

- Any session executes `FLUSH TABLES` or DDL statements on the handler’s table.
- The session in which the handler is open executes non-`HANDLER` statements that use tables.

`TRUNCATE TABLE` for a table closes all handlers for the table that were opened with `HANDLER OPEN`.

If a table is flushed with `FLUSH TABLES tbl_name WITH READ LOCK` was opened with `HANDLER`, the handler is implicitly flushed and loses its position.

**`HANDLER` is not supported with partitioned tables.**

### 13.2.5 INSERT Statement

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
[INTO] tbl_name
[(col_name [, col_name] ...)]
VALUES | VALUE) (
         (VALUES | VALUE) (value_list) [, (value_list)] ...
[ON DUPLICATE KEY UPDATE assignment_list]
```

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
[INTO] tbl_name
SET assignment_list
[ON DUPLICATE KEY UPDATE assignment_list]
```

```
INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
[INTO] tbl_name
[(col_name [, col_name] ...)]
SELECT ...
```
INSERT inserts new rows into an existing table. The INSERT ... VALUES and INSERT ... SET forms of the statement insert rows based on explicitly specified values. The INSERT ... SELECT form inserts rows selected from another table or tables. INSERT with an ON DUPLICATE KEY UPDATE clause enables existing rows to be updated if a row to be inserted would cause a duplicate value in a UNIQUE index or PRIMARY KEY.

For additional information about INSERT ... SELECT and INSERT ... ON DUPLICATE KEY UPDATE, see Section 13.2.5.1, "INSERT ... SELECT Statement", and Section 13.2.5.2, "INSERT ... ON DUPLICATE KEY UPDATE Statement".

Inserting into a table requires the INSERT privilege for the table. If the ON DUPLICATE KEY UPDATE clause is used and a duplicate key causes an UPDATE to be performed instead, the statement requires the UPDATE privilege for the columns to be updated. For columns that are read but not modified you need only the SELECT privilege (such as for a column referenced only on the right hand side of an col_name = expr assignment in an ON DUPLICATE KEY UPDATE clause).

You can use REPLACE instead of INSERT to overwrite old rows. REPLACE is the counterpart to INSERT IGNORE in the treatment of new rows that contain unique key values that duplicate old rows: The new rows replace the old rows rather than being discarded. See Section 13.2.8, “REPLACE Statement”.

tbl_name is the table into which rows should be inserted. Specify the columns for which the statement provides values as follows:

- Provide a parenthesized list of comma-separated column names following the table name. In this case, a value for each named column must be provided by the VALUES list or the SELECT statement.

- If you do not specify a list of column names for INSERT ... VALUES or INSERT ... SELECT, values for every column in the table must be provided by the VALUES list or the SELECT statement. If you do not know the order of the columns in the table, use DESCRIBE tbl_name to find out.

- A SET clause indicates columns explicitly by name, together with the value to assign each one.

Column values can be given in several ways:

- If strict SQL mode is not enabled, any column not explicitly given a value is set to its default (explicit or implicit) value. For example, if you specify a column list that does not name all the columns in the table, unnamed columns are set to their default values. Default value assignment is described in Section 11.5, “Data Type Default Values”. See also Section 1.7.3.3, “Constraints on Invalid Data”.

- If strict SQL mode is enabled, an INSERT statement generates an error if it does not specify an explicit value for every column that has no default value. See Section 5.1.10, “Server SQL Modes”.

- If both the column list and the VALUES list are empty, INSERT creates a row with each column set to its default value:
**INSERT Statement**

```
INSERT INTO tbl_name () VALUES();
```

If strict mode is not enabled, MySQL uses the implicit default value for any column that has no explicitly defined default. If strict mode is enabled, an error occurs if any column has no default value.

- Use the keyword `DEFAULT` to set a column explicitly to its default value. This makes it easier to write `INSERT` statements that assign values to all but a few columns, because it enables you to avoid writing an incomplete `VALUES` list that does not include a value for each column in the table. Otherwise, you must provide the list of column names corresponding to each value in the `VALUES` list.

- In expressions, you can use `DEFAULT(col_name)` to produce the default value for column `col_name`.

- Type conversion of an expression `expr` that provides a column value might occur if the expression data type does not match the column data type. Conversion of a given value can result in different inserted values depending on the column type. For example, inserting the string '1999.0e-2' into an `INT`, `FLOAT`, `DECIMAL(10,6)`, or `YEAR` column inserts the value 1999, 19.9921, 19.992100, or 1999, respectively. The value stored in the `INT` and `YEAR` columns is 1999 because the string-to-number conversion looks only at as much of the initial part of the string as may be considered a valid integer or year. For the `FLOAT` and `DECIMAL` columns, the string-to-number conversion considers the entire string a valid numeric value.

- An expression `expr` can refer to any column that was set earlier in a value list. For example, you can do this because the value for `col2` refers to `col1`, which has previously been assigned:

```
INSERT INTO tbl_name (col1,col2) VALUES(15,col1*2);
```

But the following is not legal, because the value for `col1` refers to `col2`, which is assigned after `col1`:

```
INSERT INTO tbl_name (col1,col2) VALUES(col2*2,15);
```

An exception occurs for columns that contain `AUTO_INCREMENT` values. Because `AUTO_INCREMENT` values are generated after other value assignments, any reference to an `AUTO_INCREMENT` column in the assignment returns a 0.

**INSERT** statements that use `VALUES` syntax can insert multiple rows. To do this, include multiple lists of comma-separated column values, with lists enclosed within parentheses and separated by commas. Example:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3),(4,5,6),(7,8,9);
```

Each values list must contain exactly as many values as are to be inserted per row. The following statement is invalid because it contains one list of nine values, rather than three lists of three values each:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3,4,5,6,7,8,9);
```

`VALUE` is a synonym for `VALUES` in this context. Neither implies anything about the number of values lists, nor about the number of values per list. Either may be used whether there is a single values list or multiple lists, and regardless of the number of values per list.

The affected-rows value for an `INSERT` can be obtained using the `ROW_COUNT()` SQL function or the `mysql_affected_rows()` C API function. See Section 12.15, “Information Functions”, and Section 23.7.6.1, “mysql_affected_rows()”.

If you use an `INSERT ... VALUES` statement with multiple value lists or `INSERT ... SELECT`, the statement returns an information string in this format:

```
Records: N1 Duplicates: N2 Warnings: N3
```
INSERT Statement

If you are using the C API, the information string can be obtained by invoking the `mysql_info()` function. See Section 23.7.6.35, "mysql_info()".

Records indicates the number of rows processed by the statement. (This is not necessarily the number of rows actually inserted because Duplicates can be nonzero.) Duplicates indicates the number of rows that could not be inserted because they would duplicate some existing unique index value. Warnings indicates the number of attempts to insert column values that were problematic in some way. Warnings can occur under any of the following conditions:

- Inserting NULL into a column that has been declared NOT NULL. For multiple-row INSERT statements or `INSERT INTO ... SELECT` statements, the column is set to the implicit default value for the column data type. This is 0 for numeric types, the empty string ('') for string types, and the "zero" value for date and time types. `INSERT INTO ... SELECT` statements are handled the same way as multiple-row inserts because the server does not examine the result set from the SELECT to see whether it returns a single row. (For a single-row INSERT, no warning occurs when NULL is inserted into a NOT NULL column. Instead, the statement fails with an error.)

- Setting a numeric column to a value that lies outside the column's range. The value is clipped to the closest endpoint of the range.

- Assigning a value such as '10.34 a' to a numeric column. The trailing nonnumeric text is stripped off and the remaining numeric part is inserted. If the string value has no leading numeric part, the column is set to 0.

- Inserting a string into a string column (CHAR, VARCHAR, TEXT, or BLOB) that exceeds the column's maximum length. The value is truncated to the column's maximum length.

- Inserting a value into a date or time column that is illegal for the data type. The column is set to the appropriate zero value for the type.

- For INSERT examples involving AUTO_INCREMENT column values, see Section 3.6.9, "Using AUTO_INCREMENT".

If INSERT inserts a row into a table that has an AUTO_INCREMENT column, you can find the value used for that column by using the `LAST_INSERT_ID()` SQL function or the `mysql_insert_id()` C API function.

Note

These two functions do not always behave identically. The behavior of INSERT statements with respect to AUTO_INCREMENT columns is discussed further in Section 12.15, "Information Functions", and Section 23.7.6.37, "mysql_insert_id()".

The INSERT statement supports the following modifiers:

- If you use the DELAYED modifier, the server puts the row or rows to be inserted into a buffer, and the client issuing the INSERT DELAYED statement can then continue immediately. If the table is in use, the server holds the rows. When the table is free, the server begins inserting rows, checking periodically to see whether there are any new read requests for the table. If there are, the delayed row queue is suspended until the table becomes free again. See Section 13.2.5.3, "INSERT DELAYED Statement".

  DELAYED is ignored with INSERT ... SELECT or INSERT ... ON DUPLICATE KEY UPDATE.

  DELAYED is also disregarded for an INSERT that uses functions accessing tables or triggers, or that is called from a function or a trigger.
• If you use the **LOW_PRIORITY** modifier, execution of the **INSERT** is delayed until no other clients are reading from the table. This includes other clients that began reading while existing clients are reading, and while the **INSERT LOW_PRIORITY** statement is waiting. It is possible, therefore, for a client that issues an **INSERT LOW_PRIORITY** statement to wait for a very long time (or even forever) in a read-heavy environment. (This is in contrast to **INSERT DELAYED**, which lets the client continue at once.)

**LOW_PRIORITY** affects only storage engines that use only table-level locking (such as **MyISAM**, **MEMORY**, and **MERGE**).

**Note**

**LOW_PRIORITY** should normally not be used with **MyISAM** tables because doing so disables concurrent inserts. See Section 8.11.3, “Concurrent Inserts”.

• If you specify **HIGH_PRIORITY**, it overrides the effect of the **--low-priority-updates** option if the server was started with that option. It also causes concurrent inserts not to be used. See Section 8.11.3, “Concurrent Inserts”.

**HIGH_PRIORITY** affects only storage engines that use only table-level locking (such as **MyISAM**, **MEMORY**, and **MERGE**).

• If you use the **IGNORE** modifier, errors that occur while executing the **INSERT** statement are ignored. For example, without **IGNORE**, a row that duplicates an existing **UNIQUE** index or **PRIMARY KEY** value in the table causes a duplicate-key error and the statement is aborted. With **IGNORE**, the row is discarded and no error occurs. Ignored errors may generate warnings instead, although duplicate-key errors do not.

**IGNORE** has a similar effect on inserts into partitioned tables where no partition matching a given value is found. Without **IGNORE**, such **INSERT** statements are aborted with an error. When **INSERT IGNORE** is used, the insert operation fails silently for rows containing the unmatched value, but inserts rows that are matched. For an example, see Section 19.2.2, “LIST Partitioning”.

Data conversions that would trigger errors abort the statement if **IGNORE** is not specified. With **IGNORE**, invalid values are adjusted to the closest values and inserted; warnings are produced but the statement does not abort. You can determine with the **mysql_info()** C API function how many rows were actually inserted into the table.

• If you specify **ON DUPLICATE KEY UPDATE**, and a row is inserted that would cause a duplicate value in a **UNIQUE** index or **PRIMARY KEY**, an **UPDATE** of the old row occurs. The affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the **CLIENT_FOUND_ROWS** flag to the **mysql_real_connect()** C API function when connecting to **mysqld**, the affected-rows value is 1 (not 0) if an existing row is set to its current values. See Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”.

An **INSERT** statement affecting a partitioned table using a storage engine such as **MyISAM** that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as **InnoDB** that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

### 13.2.5.1 INSERT ... SELECT Statement

```sql
INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
INTO tbl_name
  [(col_name [, col_name] . . .)]
SELECT ...
[ON DUPLICATE KEY UPDATE assignment_list]
value:
  {expr | DEFAULT}
```
**INSERT Statement**

```
assignment:
   col_name = value

assignment_list:
   assignment [, assignment] ...
```

With `INSERT ... SELECT`, you can quickly insert many rows into a table from the result of a `SELECT` statement, which can select from one or many tables. For example:

```
INSERT INTO tbl_temp2 (fld_id)
SELECT tbl_temp1.fld_order_id
FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

The following conditions hold for `INSERT ... SELECT` statements:

- Specify `IGNORE` to ignore rows that would cause duplicate-key violations.
- `DELAYED` is ignored with `INSERT ... SELECT`.
- The target table of the `INSERT` statement may appear in the `FROM` clause of the `SELECT` part of the query. However, you cannot insert into a table and select from the same table in a subquery.

When selecting from and inserting into the same table, MySQL creates an internal temporary table to hold the rows from the `SELECT` and then inserts those rows into the target table. However, you cannot use `INSERT INTO t ... SELECT ... FROM t` when `t` is a `TEMPORARY` table, because `TEMPORARY` tables cannot be referred to twice in the same statement. See Section 8.4.4, “Internal Temporary Table Use in MySQL”, and Section B.4.6.2, “TEMPORARY Table Problems”.

- `AUTO_INCREMENT` columns work as usual.
- To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts for `INSERT ... SELECT` statements (see Section 8.11.3, “Concurrent Inserts”).
- To avoid ambiguous column reference problems when the `SELECT` and the `INSERT` refer to the same table, provide a unique alias for each table used in the `SELECT` part, and qualify column names in that part with the appropriate alias.

For `INSERT ... SELECT` statements, see Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement” for conditions under which the `SELECT` columns can be referred to in an `ON DUPLICATE KEY UPDATE` clause.

The order in which a `SELECT` statement with no `ORDER BY` clause returns rows is nondeterministic. This means that, when using replication, there is no guarantee that such a `SELECT` returns rows in the same order on the master and the slave, which can lead to inconsistencies between them. To prevent this from occurring, always write `INSERT ... SELECT` statements that are to be replicated using an `ORDER BY` clause that produces the same row order on the master and the slave. See also Section 17.4.1.16, “Replication and LIMIT”.

Due to this issue, beginning with MySQL 5.5.18, `INSERT ... SELECT ON DUPLICATE KEY UPDATE` and `INSERT IGNORE ... SELECT` statements are flagged as unsafe for statement-based replication. Such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using `MIXED` mode. (Bug #11758262, Bug #50439)

See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

An `INSERT ... SELECT` statement affecting partitioned tables using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the source and target tables. This does not occur with
tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

### 13.2.5.2 INSERT ... ON DUPLICATE KEY UPDATE Statement

If you specify an ON DUPLICATE KEY UPDATE clause and a row to be inserted would cause a duplicate value in a UNIQUE index or PRIMARY KEY, an UPDATE of the old row occurs. For example, if column a is declared as UNIQUE and contains the value 1, the following two statements have similar effect:

```sql
INSERT INTO t1 (a,b,c) VALUES (1,2,3)
ON DUPLICATE KEY UPDATE c=c+1;
UPDATE t1 SET c=c+1 WHERE a=1;
```

(The effects are not identical for an InnoDB table where a is an auto-increment column. With an auto-increment column, an INSERT statement increases the auto-increment value but UPDATE does not.)

If column b is also unique, the INSERT is equivalent to this UPDATE statement instead:

```sql
UPDATE t1 SET c=c+1 WHERE a=1 OR b=2 LIMIT 1;
```

If a=1 OR b=2 matches several rows, only one row is updated. In general, you should try to avoid using an ON DUPLICATE KEY UPDATE clause on tables with multiple unique indexes.

With ON DUPLICATE KEY UPDATE, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the CLIENT_FOUND_ROWS flag to the mysql_real_connect() C API function when connecting to mysqld, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

If a table contains an AUTO_INCREMENT column and INSERT ... ON DUPLICATE KEY UPDATE inserts or updates a row, the LAST_INSERT_ID() function returns the AUTO_INCREMENT value.

The ON DUPLICATE KEY UPDATE clause can contain multiple column assignments, separated by commas.

In assignment value expressions in the ON DUPLICATE KEY UPDATE clause, you can use the VALUES(col_name) function to refer to column values from the INSERT portion of the INSERT ... ON DUPLICATE KEY UPDATE statement. In other words, VALUES(col_name) in the ON DUPLICATE KEY UPDATE clause refers to the value of col_name that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The VALUES() function is meaningful only in the ON DUPLICATE KEY UPDATE clause or INSERT statements and returns NULL otherwise. Example:

```sql
INSERT INTO t1 (a,b,c) VALUES (1,2,3),(4,5,6)
ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
```

That statement is identical to the following two statements:

```sql
INSERT INTO t1 (a,b,c) VALUES (1,2,3)
ON DUPLICATE KEY UPDATE c=3;
INSERT INTO t1 (a,b,c) VALUES (4,5,6)
ON DUPLICATE KEY UPDATE c=9;
```

The DELAYED option is ignored when you use ON DUPLICATE KEY UPDATE.

For INSERT ... SELECT statements, these rules apply regarding acceptable forms of SELECT query expressions that you can refer to in an ON DUPLICATE KEY UPDATE clause:

- References to columns from queries on a single table, which may be a derived table.
• References to columns from queries on a join over multiple tables.

• References to columns from `DISTINCT` queries.

• References to columns in other tables, as long as the `SELECT` does not use `GROUP BY`. One side effect is that you must qualify references to nonunique column names.

References to columns from a `UNION` do not work reliably. To work around this restriction, rewrite the `UNION` as a derived table so that its rows can be treated as a single-table result set. For example, this statement is problematic:

```sql
INSERT INTO t1 (a, b)
SELECT c, d FROM t2
UNION
SELECT e, f FROM t3
ON DUPLICATE KEY UPDATE b = b + c;
```

Instead, use an equivalent statement that rewrites the `UNION` as a derived table:

```sql
INSERT INTO t1 (a, b)
SELECT * FROM
(SELECT c, d FROM t2
UNION
SELECT e, f FROM t3) AS dt
ON DUPLICATE KEY UPDATE b = b + c;
```

The technique of rewriting a query as a derived table also enables references to columns from `GROUP BY` queries.

Because the results of `INSERT ... SELECT` statements depend on the ordering of rows from the `SELECT` and this order cannot always be guaranteed, it is possible when logging `INSERT ... SELECT` on `DUPLICATE KEY UPDATE` statements for the master and the slave to diverge. Thus, in MySQL 5.5.18 and later, `INSERT ... SELECT` on `DUPLICATE KEY UPDATE` statements are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode and are written to the binary using the row-based format when using `MIXED` mode. In addition, beginning with MySQL 5.5.24, an `INSERT ... ON DUPLICATE KEY UPDATE` statement against a table having more than one unique or primary key is also marked as unsafe. (Bug #11765650, Bug #58637)

See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

An `INSERT ... ON DUPLICATE KEY UPDATE` on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

### 13.2.5.3 INSERT DELAYED Statement

```sql
INSERT DELAYED ...
```

The `DELAYED` option for the `INSERT` statement is a MySQL extension to standard SQL that is very useful if you have clients that cannot or need not wait for the `INSERT` to complete. This is a common situation when you use MySQL for logging and you also periodically run `SELECT` and `UPDATE` statements that take a long time to complete.

When a client uses `INSERT DELAYED`, it gets an okay from the server at once, and the row is queued to be inserted when the table is not in use by any other thread.
Another major benefit of using INSERT DELAYED is that inserts from many clients are bundled together and written in one block. This is much faster than performing many separate inserts.

**Note**

INSERT DELAYED is slower than a normal INSERT if the table is not otherwise in use. There is also the additional overhead for the server to handle a separate thread for each table for which there are delayed rows. This means that you should use INSERT DELAYED only when you are really sure that you need it.

The queued rows are held only in memory until they are inserted into the table. This means that if you terminate mysqld forcibly (for example, with `kill -9`) or if mysqld dies unexpectedly, any queued rows that have not been written to disk are lost.

There are some constraints on the use of DELAYED:

- **INSERT DELAYED** works only with MyISAM, MEMORY, ARCHIVE, and BLACKHOLE tables. For engines that do not support DELAYED, an error occurs.

- An error occurs for INSERT DELAYED if used with a table that has been locked with LOCK TABLES because the insert must be handled by a separate thread, not by the session that holds the lock.

- For MyISAM tables, if there are no free blocks in the middle of the data file, concurrent SELECT and INSERT statements are supported. Under these circumstances, you very seldom need to use INSERT DELAYED with MyISAM.

- INSERT DELAYED should be used only for INSERT statements that specify value lists. The server ignores DELAYED for INSERT ... SELECT or INSERT ... ON DUPLICATE KEY UPDATE statements.

- Because the INSERT DELAYED statement returns immediately, before the rows are inserted, you cannot use LAST_INSERT_ID() to get the AUTO_INCREMENT value that the statement might generate.

- DELAYED rows are not visible to SELECT statements until they actually have been inserted.

- INSERT DELAYED is handled as a simple INSERT (that is, without the DELAYED option) whenever the value of binlog_format is STATEMENT or MIXED. (In the latter case, the statement does not trigger a switch to row-based logging, and so is logged using the statement-based format.)

  This does not apply when using row-based binary logging mode (binlog_format set to ROW), in which INSERT DELAYED statements are always executed using the DELAYED option as specified, and logged as row-update events.

- DELAYED is ignored on slave replication servers, so that INSERT DELAYED is treated as a normal INSERT on slaves. This is because DELAYED could cause the slave to have different data than the master.

- Pending INSERT DELAYED statements are lost if a table is write locked and ALTER TABLE is used to modify the table structure.

- INSERT DELAYED is not supported for views.

- INSERT DELAYED is not supported for partitioned tables.

The following describes in detail what happens when you use the DELAYED option to INSERT or REPLACE. In this description, the “thread” is the thread that received an INSERT DELAYED statement and “handler” is the thread that handles all INSERT DELAYED statements for a particular table.
• When a thread executes a `DELAYED` statement for a table, a handler thread is created to process all `DELAYED` statements for the table, if no such handler already exists.

• The thread checks whether the handler has previously acquired a `DELAYED` lock; if not, it tells the handler thread to do so. The `DELAYED` lock can be obtained even if other threads have a `READ` or `WRITE` lock on the table. However, the handler waits for all `ALTER TABLE` locks or `FLUSH TABLES` statements to finish, to ensure that the table structure is up to date.

• The thread executes the `INSERT` statement, but instead of writing the row to the table, it puts a copy of the final row into a queue that is managed by the handler thread. Any syntax errors are noticed by the thread and reported to the client program.

• The client cannot obtain from the server the number of duplicate rows or the `AUTO_INCREMENT` value for the resulting row, because the `INSERT` returns before the insert operation has been completed. (If you use the C API, the `mysql_info()` function does not return anything meaningful, for the same reason.)

• The binary log is updated by the handler thread when the row is inserted into the table. In case of multiple-row inserts, the binary log is updated when the first row is inserted.

• Each time that `delayed_insert_limit` rows are written, the handler checks whether any `SELECT` statements are still pending. If so, it permits these to execute before continuing.

• When the handler has no more rows in its queue, the table is unlocked. If no new `INSERT DELAYED` statements are received within `delayed_insert_timeout` seconds, the handler terminates.

• If more than `delayed_queue_size` rows are pending in a specific handler queue, the thread requesting `INSERT DELAYED` waits until there is room in the queue. This is done to ensure that `mysqld` does not use all memory for the delayed memory queue.

• The handler thread shows up in the MySQL process list with `delayed_insert` in the `Command` column. It is killed if you execute a `FLUSH TABLES` statement or kill it with `KILL thread_id`. However, before exiting, it first stores all queued rows into the table. During this time it does not accept any new `INSERT` statements from other threads. If you execute an `INSERT DELAYED` statement after this, a new handler thread is created.

   This means that `INSERT DELAYED` statements have higher priority than normal `INSERT` statements if there is an `INSERT DELAYED` handler running. Other update statements have to wait until the `INSERT DELAYED` queue is empty, someone terminates the handler thread (with `KILL thread_id`), or someone executes a `FLUSH TABLES`.

• The following status variables provide information about `INSERT DELAYED` statements.

<table>
<thead>
<tr>
<th>Status Variable</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed_insert_threads</td>
<td>Number of handler threads</td>
</tr>
<tr>
<td>Delayed_writes</td>
<td>Number of rows written with <code>INSERT DELAYED</code></td>
</tr>
<tr>
<td>Not_flushed_delayed_rows</td>
<td>Number of rows waiting to be written</td>
</tr>
</tbody>
</table>

You can view these variables by issuing a `SHOW STATUS` statement or by executing a `mysqladmin extended-status` command.

### 13.2.6 LOAD DATA Statement

```
LOAD DATA
[LOW_PRIORITY | CONCURRENT] [LOCAL]
INFILE 'file_name'
[REPLACE | IGNORE]
```
The `LOAD DATA` statement reads rows from a text file into a table at a very high speed. `LOAD DATA` is the complement of `SELECT ... INTO OUTFILE`. (See Section 13.2.9.1, “SELECT ... INTO Statement”.) To write data from a table to a file, use `SELECT ... INTO OUTFILE`. To read the file back into a table, use `LOAD DATA`. The syntax of the `FIELDS` and `LINES` clauses is the same for both statements.

You can also load data files by using the `mysqlimport` utility; see Section 4.5.5, “mysqlimport — A Data Import Program”. `mysqlimport` operates by sending a `LOAD DATA` statement to the server.

For more information about the efficiency of `INSERT` versus `LOAD DATA` and speeding up `LOAD DATA`, see Section 8.2.4.1, “Optimizing INSERT Statements”.

- Partitioned Table Support
- Input File Name, Location, and Content Interpretation
- Concurrency Considerations
- Duplicate-Key Handling
- Index Handling
- Field and Line Handling
- Column List Specification
- Input Preprocessing
- Statement Result Information
- Miscellaneous Topics

**Partitioned Table Support**

For partitioned tables using storage engines that employ table locks, such as `MyISAM`, any locks caused by `LOAD DATA` perform locks on all partitions of the table. This does not apply to tables using storage engines which employ row-level locking, such as `InnoDB`. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

**Input File Name, Location, and Content Interpretation**

The file name must be given as a literal string. On Windows, specify backslashes in path names as forward slashes or doubled backslashes. The `character_set_filesystem` system variable controls the interpretation of the file name character set.
LOAD DATA Statement

The server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. `SET NAMES` and the setting of `character_set_client` do not affect interpretation of input. If the contents of the input file use a character set that differs from the default, it is usually preferable to specify the character set of the file by using the `CHARACTER SET` clause. A character set of `binary` specifies “no conversion.”

`LOAD DATA` interprets all fields in the file as having the same character set, regardless of the data types of the columns into which field values are loaded. For proper interpretation of file contents, you must ensure that it was written with the correct character set. For example, if you write a data file with `mysqldump -T` or by issuing a `SELECT ... INTO OUTFILE` statement in `mysql`, be sure to use a `--default-character-set` option so that output is written in the character set to be used when the file is loaded with `LOAD DATA`.

**Note**

It is not possible to load data files that use the `ucs2`, `utf16`, or `utf32` character set.

**Concurrency Considerations**

If you use the `LOW_PRIORITY` modifier, execution of the `LOAD DATA` statement is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

If you specify the `CONCURRENT` modifier with a `MyISAM` table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other threads can retrieve data from the table while `LOAD DATA` is executing. This modifier affects the performance of `LOAD DATA` a bit, even if no other thread is using the table at the same time.

For information about `LOAD DATA` in relation to replication, see Section 17.4.1.17, “Replication and LOAD DATA”.

The `LOCAL` modifier affects expected location of the file and error handling, as described later. `LOCAL` works only if your server and your client both have been configured to permit it. For example, if `mysqld` was started with the `local_infile` system variable disabled, `LOCAL` does not work. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

The `LOCAL` modifier affects where the file is expected to be found:

- If `LOCAL` is specified, the file is read by the client program on the client host and sent to the server. The file can be given as a full path name to specify its exact location. If given as a relative path name, the name is interpreted relative to the directory in which the client program was started.

  When using `LOCAL` with `LOAD DATA`, a copy of the file is created in the directory where the MySQL server stores temporary files. See Section B.4.3.5, “Where MySQL Stores Temporary Files”. Lack of sufficient space for the copy in this directory can cause the `LOAD DATA LOCAL` statement to fail.

- If `LOCAL` is not specified, the file must be located on the server host and is read directly by the server. The server uses the following rules to locate the file:

  - If the file name is an absolute path name, the server uses it as given.
  - If the file name is a relative path name with one or more leading components, the server searches for the file relative to the server’s data directory.
  - If a file name with no leading components is given, the server looks for the file in the database directory of the default database.
LOAD DATA Statement

In the non-LOCAL case, these rules mean that a file named as .myfile.txt is read from the server's data directory, whereas the file named as myfile.txt is read from the database directory of the default database. For example, if db1 is the default database, the following LOAD DATA statement reads the file data.txt from the database directory for db1, even though the statement explicitly loads the file into a table in the db2 database:

LOAD DATA INFILE 'data.txt' INTO TABLE db2.my_table;

Non-LOCAL load operations read text files located on the server. For security reasons, such operations require that you have the FILE privilege. See Section 6.2.2, "Privileges Provided by MySQL". Also, non-LOCAL load operations are subject to the secure_file_priv system variable setting. If the variable value is a nonempty directory name, the file to be loaded must be located in that directory. If the variable value is empty (which is insecure), the file need only be readable by the server.

Using LOCAL is a bit slower than letting the server access the files directly, because the file contents must be sent over the connection by the client to the server. On the other hand, you do not need the FILE privilege to load local files.

LOCAL also affects error handling:

• With LOAD DATA, data-interpretation and duplicate-key errors terminate the operation.

• With LOAD DATA LOCAL, data-interpretation and duplicate-key errors become warnings and the operation continues because the server has no way to stop transmission of the file in the middle of the operation. For duplicate-key errors, this is the same as if IGNORE is specified. IGNORE is explained further later in this section.

Duplicate-Key Handling

The REPLACE and IGNORE modifiers control handling of input rows that duplicate existing rows on unique key values:

• If you specify REPLACE, input rows replace existing rows. In other words, rows that have the same value for a primary key or unique index as an existing row. See Section 13.2.8, "REPLACE Statement".

• If you specify IGNORE, rows that duplicate an existing row on a unique key value are discarded.

• If you do not specify either modifier, the behavior depends on whether the LOCAL modifier is specified. Without LOCAL, an error occurs when a duplicate key value is found, and the rest of the text file is ignored. With LOCAL, the default behavior is the same as if IGNORE is specified; this is because the server has no way to stop transmission of the file in the middle of the operation.

Index Handling

To ignore foreign key constraints during the load operation, execute a SET foreign_key_checks = 0 statement before executing LOAD DATA.

If you use LOAD DATA on an empty MyISAM table, all nonunique indexes are created in a separate batch (as for REPAIR TABLE). Normally, this makes LOAD DATA much faster when you have many indexes. In some extreme cases, you can create the indexes even faster by turning them off with ALTER TABLE ... DISABLE KEYS before loading the file into the table and using ALTER TABLE ... ENABLE KEYS to re-create the indexes after loading the file. See Section 8.2.4.1, "Optimizing INSERT Statements".

Field and Line Handling

For both the LOAD DATA and SELECT ... INTO OUTFILE statements, the syntax of the FIELDS and LINES clauses is the same. Both clauses are optional, but FIELDS must precede LINES if both are specified.
LOAD DATA Statement

If you specify a FIELDS clause, each of its subclauses (TERMINATED BY, [OPTIONALLY] ENCLOSED BY, and ESCAPED BY) is also optional, except that you must specify at least one of them. Arguments to these clauses are permitted to contain only ASCII characters.

If you specify no FIELDS or LINES clause, the defaults are the same as if you had written this:

```
FIELDS TERMINATED BY '\t' ENCLOSED BY '' ESCAPED BY '"'
LINES TERMINATED BY '\n' STARTING BY ''
```

Backslash is the MySQL escape character within strings in SQL statements. Thus, to specify a literal backslash, you must specify two backslashes for the value to be interpreted as a single backslash. The escape sequences '\t' and '\n' specify tab and newline characters, respectively.

In other words, the defaults cause LOAD DATA to act as follows when reading input:

- Look for line boundaries at newlines.
- Do not skip any line prefix.
- Break lines into fields at tabs.
- Do not expect fields to be enclosed within any quoting characters.
- Interpret characters preceded by the escape character \ as escape sequences. For example, \t, \n, and \\ signify tab, newline, and backslash, respectively. See the discussion of FIELDS ESCAPED BY later for the full list of escape sequences.

Conversely, the defaults cause SELECT ... INTO OUTFILE to act as follows when writing output:

- Write tabs between fields.
- Do not enclose fields within any quoting characters.
- Use \ to escape instances of tab, newline, or \ that occur within field values.
- Write newlines at the ends of lines.

Note

For a text file generated on a Windows system, proper file reading might require LINES TERMINATED BY '\r\n' because Windows programs typically use two characters as a line terminator. Some programs, such as WordPad, might use \r as a line terminator when writing files. To read such files, use LINES TERMINATED BY '\r'.

If all the input lines have a common prefix that you want to ignore, you can use LINES STARTING BY 'prefix_string' to skip the prefix and anything before it. If a line does not include the prefix, the entire line is skipped. Suppose that you issue the following statement:

```
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test
  FIELDS TERMINATED BY ','  LINES STARTING BY 'xxx';
```

If the data file looks like this:

```
xxx"abc",1
something xxx"def",2
"ghi",3
```

The resulting rows will be ('abc',1) and ('def',2). The third row in the file is skipped because it does not contain the prefix.
The `IGNORE number LINES` option can be used to ignore lines at the start of the file. For example, you can use `IGNORE 1 LINES` to skip an initial header line containing column names:

```sql
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test IGNORE 1 LINES;
```

When you use `SELECT ... INTO OUTFILE` in tandem with `LOAD DATA` to write data from a database into a file and then read the file back into the database later, the field- and line-handling options for both statements must match. Otherwise, `LOAD DATA` will not interpret the contents of the file properly. Suppose that you use `SELECT ... INTO OUTFILE` to write a file with fields delimited by commas:

```sql
SELECT * INTO OUTFILE 'data.txt'
FIELDS TERMINATED BY ','
FROM table2;
```

To read the comma-delimited file, the correct statement would be:

```sql
LOAD DATA INFILE 'data.txt' INTO TABLE table2
FIELDS TERMINATED BY ',';
```

If instead you tried to read the file with the statement shown following, it wouldn't work because it instructs `LOAD DATA` to look for tabs between fields:

```sql
LOAD DATA INFILE 'data.txt' INTO TABLE table2
FIELDS TERMINATED BY '\t';
```

The likely result is that each input line would be interpreted as a single field.

`LOAD DATA` can be used to read files obtained from external sources. For example, many programs can export data in comma-separated values (CSV) format, such that lines have fields separated by commas and enclosed within double quotation marks, with an initial line of column names. If the lines in such a file are terminated by carriage return/newline pairs, the statement shown here illustrates the field- and line-handling options you would use to load the file:

```sql
LOAD DATA INFILE 'data.txt' INTO TABLE tbl_name
FIELDS TERMINATED BY ',' ENCLOSED BY '"'
LINES TERMINATED BY '
'
IGNORE 1 LINES;
```

If the input values are not necessarily enclosed within quotation marks, use `OPTIONALLY` before the `ENCLOSED BY` option.

Any of the field- or line-handling options can specify an empty string (`''`). If not empty, the `FIELDS [OPTIONALLY] ENCLOSED BY` and `FIELDS ESCAPED BY` values must be a single character. The `FIELDS TERMINATED BY`, `LINES STARTING BY`, and `LINES TERMINATED BY` values can be more than one character. For example, to write lines that are terminated by carriage return/linefeed pairs, or to read a file containing such lines, specify a `LINES TERMINATED BY '\r\n'` clause.

To read a file containing jokes that are separated by lines consisting of `%%`, you can do this

```sql
CREATE TABLE jokes
(a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
 joke TEXT NOT NULL);
LOAD DATA INFILE '/tmp/jokes.txt' INTO TABLE jokes
FIELDS TERMINATED BY ''
LINES TERMINED BY '\n%%\n' (joke);
```

`FIELDS [OPTIONALLY] ENCLOSED BY` controls quoting of fields. For output (`SELECT ... INTO OUTFILE`), if you omit the word `OPTIONALLY`, all fields are enclosed by the `ENCLOSED BY` character. An example of such output (using a comma as the field delimiter) is shown here:
If you specify **OPTIONALLY**, the **ENCLOSED BY** character is used only to enclose values from columns that have a string data type (such as **CHAR**, **BINARY**, **TEXT**, or **ENUM**):

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a " quote",102.20
4,"a string containing a ", quote and comma",102.20
```

Occurrences of the **ENCLOSED BY** character within a field value are escaped by prefixing them with the **ESCAPED BY** character. Also, if you specify an empty **ESCAPED BY** value, it is possible to inadvertently generate output that cannot be read properly by **LOAD DATA**. For example, the preceding output just shown would appear as follows if the escape character is empty. Observe that the second field in the fourth line contains a comma following the quote, which (erroneously) appears to terminate the field:

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a " quote",102.20
4,"a string containing a ", quote and comma",102.20
```

For input, the **ENCLOSED BY** character, if present, is stripped from the ends of field values. (This is true regardless of whether **OPTIONALLY** is specified; **OPTIONALLY** has no effect on input interpretation.) Occurrences of the **ENCLOSED BY** character preceded by the **ESCAPED BY** character are interpreted as part of the current field value.

If the field begins with the **ENCLOSED BY** character, instances of that character are recognized as terminating a field value only if followed by the field or line **TERMINATED BY** sequence. To avoid ambiguity, occurrences of the **ENCLOSED BY** character within a field value can be doubled and are interpreted as a single instance of the character. For example, if **ENCLOSED BY ' '** is specified, quotation marks are handled as shown here:

```
"The "BIG" boss"  -> The "BIG" boss
The "BIG" boss    -> The "BIG" boss
The "BIG" boss    -> The "BIG" boss
```

**FIELDS ESCAPED BY** controls how to read or write special characters:

- For input, if the **FIELDS ESCAPED BY** character is not empty, occurrences of that character are stripped and the following character is taken literally as part of a field value. Some two-character sequences that are exceptions, where the first character is the escape character. These sequences are shown in the following table (using \ for the escape character). The rules for **NULL** handling are described later in this section.

<table>
<thead>
<tr>
<th>Character</th>
<th>Escape Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>\0</td>
<td>An ASCII NUL (X'00') character</td>
</tr>
<tr>
<td>\b</td>
<td>A backspace character</td>
</tr>
<tr>
<td>\n</td>
<td>A newline (linefeed) character</td>
</tr>
<tr>
<td>\r</td>
<td>A carriage return character</td>
</tr>
<tr>
<td>\t</td>
<td>A tab character.</td>
</tr>
<tr>
<td>\Z</td>
<td>ASCII 26 (Control+Z)</td>
</tr>
<tr>
<td>\N</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For more information about \-escape syntax, see Section 9.1.1, “String Literals”.

If the FIELDS ESCAPED BY character is empty, escape-sequence interpretation does not occur.

- For output, if the FIELDS ESCAPED BY character is not empty, it is used to prefix the following characters on output:
  - The FIELDS ESCAPED BY character.
  - The FIELDS [OPTIONALLY] ENCLOSED BY character.
  - The first character of the FIELDS TERMINATED BY and LINES TERMINATED BY values, if the ENCLOSED BY character is empty or unspecified.
  - ASCII 0 (what is actually written following the escape character is ASCII 0, not a zero-valued byte).

If the FIELDS ESCAPED BY character is empty, no characters are escaped and NULL is output as NULL, not \N. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

In certain cases, field- and line-handling options interact:

- If LINES TERMINATED BY is an empty string and FIELDS TERMINATED BY is nonempty, lines are also terminated with FIELDS TERMINATED BY.

- If the FIELDS TERMINATED BY and FIELDS ENCLOSED BY values are both empty (" "), a fixed-row (nondelimited) format is used. With fixed-row format, no delimiters are used between fields (but you can still have a line terminator). Instead, column values are read and written using a field width wide enough to hold all values in the field. For TINYINT, SMALLINT, MEDIUMINT, INT, and BIGINT, the field widths are 4, 6, 8, 11, and 20, respectively, no matter what the declared display width is.

   LINES TERMINATED BY is still used to separate lines. If a line does not contain all fields, the rest of the columns are set to their default values. If you do not have a line terminator, you should set this to " ". In this case, the text file must contain all fields for each row.

Fixed-row format also affects handling of NULL values, as described later.

\begin{note}
Fixed-size format does not work if you are using a multibyte character set.
\end{note}

Handling of NULL values varies according to the FIELDS and LINES options in use:

- For the default FIELDS and LINES values, NULL is written as a field value of \N for output, and a field value of \N is read as NULL for input (assuming that the ESCAPED BY character is \).

- If FIELDS ENCLOSED BY is not empty, a field containing the literal word NULL as its value is read as a NULL value. This differs from the word NULL enclosed within FIELDS ENCLOSED BY characters, which is read as the string 'NULL'.

- If FIELDS ESCAPED BY is empty, NULL is written as the word NULL.

- With fixed-row format (which is used when FIELDS TERMINATED BY and FIELDS ENCLOSED BY are both empty), NULL is written as an empty string. This causes both NULL values and empty strings in the table to be indistinguishable when written to the file because both are written as empty strings. If you need to be able to tell the two apart when reading the file back in, you should not use fixed-row format.
An attempt to load NULL into a NOT NULL column causes assignment of the implicit default value for the column's data type and a warning, or an error in strict SQL mode. Implicit default values are discussed in Section 11.5, “Data Type Default Values”.

Some cases are not supported by LOAD DATA:

- Fixed-size rows (FIELDS TERMINATED BY and FIELDS ENCLOSED BY both empty) and BLOB or TEXT columns.

- If you specify one separator that is the same as or a prefix of another, LOAD DATA cannot interpret the input properly. For example, the following FIELDS clause would cause problems:

```
FIELDS TERMINATED BY '' ENCLOSED BY ''
```

- If FIELDS ESCAPED BY is empty, a field value that contains an occurrence of FIELDS ENCLOSED BY or LINES TERMINATED BY followed by the FIELDS TERMINATED BY value causes LOAD DATA to stop reading a field or line too early. This happens because LOAD DATA cannot properly determine where the field or line value ends.

**Column List Specification**

The following example loads all columns of the persondata table:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata;
```

By default, when no column list is provided at the end of the LOAD DATA statement, input lines are expected to contain a field for each table column. If you want to load only some of a table's columns, specify a column list:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata
(col_name_or_user_var [, col_name_or_user_var] ...);
```

You must also specify a column list if the order of the fields in the input file differs from the order of the columns in the table. Otherwise, MySQL cannot tell how to match input fields with table columns.

**Input Preprocessing**

Each col_name_or_user_var value is either a column name or a user variable. With user variables, the SET clause enables you to perform preprocessing transformations on their values before assigning the result to columns.

User variables in the SET clause can be used in several ways. The following example uses the first input column directly for the value of t1.column1, and assigns the second input column to a user variable that is subjected to a division operation before being used for the value of t1.column2:

```
LOAD DATA INFILE 'file.txt'
INTO TABLE t1
(column1, @var1)
SET column2 = @var1/100;
```

The SET clause can be used to supply values not derived from the input file. The following statement sets column3 to the current date and time:

```
LOAD DATA INFILE 'file.txt'
INTO TABLE t1
(column1, column2)
SET column3 = CURRENT_TIMESTAMP;
```

You can also discard an input value by assigning it to a user variable and not assigning the variable to a table column:
LOAD DATA Statement

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
   (column1, @dummy, column2, @dummy, column3);
```

Use of the column/variable list and SET clause is subject to the following restrictions:

- Assignments in the SET clause should have only column names on the left hand side of assignment operators.

- You can use subqueries in the right hand side of SET assignments. A subquery that returns a value to be assigned to a column may be a scalar subquery only. Also, you cannot use a subquery to select from the table that is being loaded.

- Lines ignored by an IGNORE clause are not processed for the column/variable list or SET clause.

- User variables cannot be used when loading data with fixed-row format because user variables do not have a display width.

When processing an input line, LOAD DATA splits it into fields and uses the values according to the column/variable list and the SET clause, if they are present. Then the resulting row is inserted into the table. If there are BEFORE INSERT or AFTER INSERT triggers for the table, they are activated before or after inserting the row, respectively.

If an input line has too many fields, the extra fields are ignored and the number of warnings is incremented.

If an input line has too few fields, the table columns for which input fields are missing are set to their default values. Default value assignment is described in Section 11.5, “Data Type Default Values”.

An empty field value is interpreted different from a missing field:

- For string types, the column is set to the empty string.

- For numeric types, the column is set to 0.

- For date and time types, the column is set to the appropriate “zero” value for the type. See Section 11.2, “Date and Time Data Types”.

These are the same values that result if you assign an empty string explicitly to a string, numeric, or date or time type explicitly in an INSERT or UPDATE statement.

Treatment of empty or incorrect field values differs from that just described if the SQL mode is set to a restrictive value. For example, if sql_mode is set to TRADITIONAL, conversion of an empty value or a value such as 'x' for a numeric column results in an error, not conversion to 0. (With LOCAL or IGNORE, warnings occur rather than errors, even with a restrictive sql_mode value, and the row is inserted using the same closest-value behavior used for nonrestrictive SQL modes. This occurs because the server has no way to stop transmission of the file in the middle of the operation.)

TIMESTAMP columns are set to the current date and time only if there is a NULL value for the column (that is, \N) and the column is not declared to permit NULL values, or if the TIMESTAMP column's default value is the current timestamp and it is omitted from the field list when a field list is specified.

LOAD DATA regards all input as strings, so you cannot use numeric values for ENUM or SET columns the way you can with INSERT statements. All ENUM and SET values must be specified as strings.

BIT values cannot be loaded directly using binary notation (for example, b’011010’). To work around this, use the SET clause to strip off the leading b' and trailing ' and perform a base-2 to base-10 conversion so that MySQL loads the values into the BIT column properly:
### 13.2.7 LOAD XML Statement

```
LOAD XML
  [LOW_PRIORITY | CONCURRENT] [LOCAL]
  INFILE 'file_name'
  [REPLACE | IGNORE]
```
LOAD XML Statement

The LOAD XML statement reads data from an XML file into a table. The file_name must be given as a literal string. The tagname in the optional ROWS IDENTIFIED BY clause must also be given as a literal string, and must be surrounded by angle brackets (< and >).

LOAD XML acts as the complement of running the mysql client in XML output mode (that is, starting the client with the --xml option). To write data from a table to an XML file, you can invoke the mysql client with the --xml and -e options from the system shell, as shown here:

shell> mysql --xml -e 'SELECT * FROM mydb.mytable' > file.xml

To read the file back into a table, use LOAD XML. By default, the <row> element is considered to be the equivalent of a database table row; this can be changed using the ROWS IDENTIFIED BY clause.

This statement supports three different XML formats:

• Column names as attributes and column values as attribute values:

```xml
<row column1="value1" column2="value2" .../>
```

• Column names as tags and column values as the content of these tags:

```xml
<row>
  <column1>value1</column1>
  <column2>value2</column2>
</row>
```

• Column names are the name attributes of <field> tags, and values are the contents of these tags:

```xml
<row>
  <field name='column1'>value1</field>
  <field name='column2'>value2</field>
</row>
```

This is the format used by other MySQL tools, such as mysqldump.

All three formats can be used in the same XML file; the import routine automatically detects the format for each row and interprets it correctly. Tags are matched based on the tag or attribute name and the column name.

Prior to MySQL 5.5.46, LOAD XML did not handle empty XML elements in the form <element/> correctly. (Bug #67542, Bug #16171518)

The following clauses work essentially the same way for LOAD XML as they do for LOAD DATA:

• LOW_PRIORITY or CONCURRENT

• LOCAL

• REPLACE or IGNORE

• CHARACTER_SET
LOAD XML Statement

- SET

See Section 13.2.6, "LOAD DATA Statement", for more information about these clauses.

(field_name_or_user_var, ...) is a list of one or more comma-separated XML fields or user variables. The name of a user variable used for this purpose must match the name of a field from the XML file, prefixed with @. You can use field names to select only desired fields. User variables can be employed to store the corresponding field values for subsequent re-use.

The IGNORE number LINES or IGNORE number ROWS clause causes the first number rows in the XML file to be skipped. It is analogous to the LOAD DATA statement's IGNORE ... LINES clause.

Suppose that we have a table named person, created as shown here:

```
USE test;
CREATE TABLE person (
    person_id INT NOT NULL PRIMARY KEY,
    fname VARCHAR(40) NULL,
    lname VARCHAR(40) NULL,
    created TIMESTAMP
);
```

Suppose further that this table is initially empty.

Now suppose that we have a simple XML file person.xml, whose contents are as shown here:

```
<list>
    <person person_id="1" fname="Kapek" lname="Sainnouine"/>
    <person person_id="2" fname="Sajon" lname="Rondela"/>
    <person person_id="3"><fname>Likame</fname><lname>Örrtmons</lname></person>
    <person person_id="4"><fname>Slar</fname><lname>Manlanth</lname></person>
    <person><field name="person_id">5</field><field name="fname">Stoma</field><field name="lname">Milu</field></person>
    <person><field name="person_id">6</field><field name="fname">Nirtam</field><field name="lname">Sklöd</field></person>
    <person person_id="7"><fname>Sungam</fname><lname>Dulbåd</lname></person>
    <person person_id="8" fname="Sraref" lname="Encmelt"/>
</list>
```

Each of the permissible XML formats discussed previously is represented in this example file.

To import the data in person.xml into the person table, you can use this statement:

```
mysql> LOAD XML LOCAL INFILE 'person.xml'
    -> INTO TABLE person
    -> ROWS IDENTIFIED BY '<person>';
Query OK, 8 rows affected (0.00 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0
```

Here, we assume that person.xml is located in the MySQL data directory. If the file cannot be found, the following error results:

```
ERROR 2 (HY000): File '/person.xml' not found (Errcode: 2)
```

The ROWS IDENTIFIED BY '<person>' clause means that each <person> element in the XML file is considered equivalent to a row in the table into which the data is to be imported. In this case, this is the person table in the test database.

As can be seen by the response from the server, 8 rows were imported into the test.person table. This can be verified by a simple SELECT statement:
This shows, as stated earlier in this section, that any or all of the 3 permitted XML formats may appear in a single file and be read using `LOAD XML`.

The inverse of the import operation just shown—that is, dumping MySQL table data into an XML file—can be accomplished using the `mysql` client from the system shell, as shown here:

```
shell> mysql --xml -e "SELECT * FROM test.person" > person-dump.xml
shell> cat person-dump.xml
<?xml version="1.0"?>
<resultset statement="SELECT * FROM test.person" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <row>
    <field name="person_id">1</field>
    <field name="fname">Kapek</field>
    <field name="lname">Sainnouine</field>
  </row>
  <row>
    <field name="person_id">2</field>
    <field name="fname">Sajon</field>
    <field name="lname">Rondela</field>
  </row>
  <row>
    <field name="person_id">3</field>
    <field name="fname">Likame</field>
    <field name="lname">Örrtmons</field>
  </row>
  <row>
    <field name="person_id">4</field>
    <field name="fname">Slar</field>
    <field name="lname">Manlanth</field>
  </row>
  <row>
    <field name="person_id">5</field>
    <field name="fname">Stoma</field>
    <field name="lname">Nilu</field>
  </row>
  <row>
    <field name="person_id">6</field>
    <field name="fname">Nirtam</field>
    <field name="lname">Sklöd</field>
  </row>
  <row>
    <field name="person_id">7</field>
    <field name="fname">Sungam</field>
    <field name="lname">Dulbåd</field>
  </row>
  <row>
    <field name="person_id">8</field>
    <field name="fname">Sreraf</field>
    <field name="lname">Encmelt</field>
  </row>
</resultset>
```
Note

The --xml option causes the mysql client to use XML formatting for its output; the -e option causes the client to execute the SQL statement immediately following the option. See Section 4.5.1, “mysql — The MySQL Command-Line Client”.

You can verify that the dump is valid by creating a copy of the person table and importing the dump file into the new table, like this:

```
mysql> USE test;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE person2 LIKE person;
Query OK, 0 rows affected (0.00 sec)

mysql> LOAD XML LOCAL INFILE 'person-dump.xml' INTO TABLE person2;
Query OK, 8 rows affected (0.01 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT * FROM person2;
+-----------+--------+------------+---------------------+
| person_id | fname  | lname      | created             |
|-----------+--------+------------+---------------------|
|         1 | Kapek  | Sainnouine | 2007-07-13 16:18:47 |
|         2 | Sajon  | Rondela    | 2007-07-13 16:18:47 |
|         3 | Likema | Örrtmons   | 2007-07-13 16:18:47 |
|         4 | Slar   | Manlanth   | 2007-07-13 16:18:47 |
|         5 | Stoma  | Nilu       | 2007-07-13 16:18:47 |
|         6 | Nirtam | Sklöd      | 2007-07-13 16:18:47 |
|         7 | Sungam | Dulbåd     | 2007-07-13 16:18:47 |
|         8 | Sreraf | Encmelt    | 2007-07-13 16:18:47 |
+-----------+--------+------------+---------------------+
8 rows in set (0.00 sec)
```

There is no requirement that every field in the XML file be matched with a column in the corresponding table. Fields which have no corresponding columns are skipped. You can see this by first emptying the person2 table and dropping the created column, then using the same LOAD XML statement we just employed previously, like this:

```
mysql> TRUNCATE person2;
Query OK, 8 rows affected (0.26 sec)

mysql> ALTER TABLE person2 DROP COLUMN created;
Query OK, 0 rows affected (0.52 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW CREATE TABLE person2\G
*************************** 1. row ***************************
Table: person2
Create Table: CREATE TABLE `person2` ( `person_id` int(11) NOT NULL, `fname` varchar(40) DEFAULT NULL, `lname` varchar(40) DEFAULT NULL, PRIMARY KEY (`person_id`) ) ENGINE=InnoDB DEFAULT CHARSET=utf8
1 row in set (0.00 sec)
```
mysql> LOAD XML LOCAL INFILE 'person-dump.xml' -> INTO TABLE person2;
Query OK, 8 rows affected (0.01 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT * FROM person2;
+-----------+--------+------------+
| person_id | fname  | lname      |
+-----------+--------+------------+
|         1 | Kapek  | Sainnouine |
|         2 | Sajon  | Rondela    |
|         3 | Likema | Örrtmons   |
|         4 | Slar   | Manlanth   |
|         5 | Stoma  | Nilu       |
|         6 | Nirtam | Sklöd      |
|         7 | Sungam | Dulbåd     |
|         8 | Sreraf | Encmelt    |
+-----------+--------+------------+
8 rows in set (0.00 sec)

The order in which the fields are given within each row of the XML file does not affect the operation of LOAD XML; the field order can vary from row to row, and is not required to be in the same order as the corresponding columns in the table.

As mentioned previously, you can use a \texttt{(field name or user var, \ldots)} list of one or more XML fields (to select desired fields only) or user variables (to store the corresponding field values for later use). User variables can be especially useful when you want to insert data from an XML file into table columns whose names do not match those of the XML fields. To see how this works, we first create a table named \texttt{individual} whose structure matches that of the \texttt{person} table, but whose columns are named differently:

mysql> CREATE TABLE individual (-> individual_id INT NOT NULL PRIMARY KEY, -> name1 VARCHAR(40) NULL, -> name2 VARCHAR(40) NULL, -> made TIMESTAMP -> );
Query OK, 0 rows affected (0.42 sec)

In this case, you cannot simply load the XML file directly into the table, because the field and column names do not match:

mysql> LOAD XML INFILE '../bin/person-dump.xml' INTO TABLE test.individual;
ERROR 1263 (22004): Column set to default value; NULL supplied to NOT NULL column 'individual_id' at row 1

This happens because the MySQL server looks for field names matching the column names of the target table. You can work around this problem by selecting the field values into user variables, then setting the target table's columns equal to the values of those variables using \texttt{SET}. You can perform both of these operations in a single statement, as shown here:

mysql> LOAD XML INFILE '../bin/person-dump.xml' -> INTO TABLE test.individual (@person_id, @fname, @lname, @made) -> SET individual_id=@person_id, name1=@fname, name2=@lname, made=@made;
Query OK, 8 rows affected (0.05 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT * FROM individual;
+---------------+--------+------------+---------------------+
| individual_id | name1  | name2      | made                |
+---------------+--------+------------+---------------------+
|             1 | Kapek  | Sainnouine | 2007-07-13 16:18:47 |
|             2 | Sajon  | Rondela    | 2007-07-13 16:18:47 |
|             3 | Likema | Örrtmons   | 2007-07-13 16:18:47 |
|             4 | Slar   | Manlanth   | 2007-07-13 16:18:47 |
+---------------+--------+------------+---------------------+
The names of the user variables *must* match those of the corresponding fields from the XML file, with the addition of the required `@` prefix to indicate that they are variables. The user variables need not be listed or assigned in the same order as the corresponding fields.

Using a `ROWS IDENTIFIED BY '<tagname>'` clause, it is possible to import data from the same XML file into database tables with different definitions. For this example, suppose that you have a file named `address.xml` which contains the following XML:

```xml
<?xml version="1.0"?>
<list>
  <person person_id="1">
    <fname>Robert</fname>
    <lname>Jones</lname>
    <address address_id="1" street="Mill Creek Road" zip="45365" city="Sidney"/>
    <address address_id="2" street="Main Street" zip="28681" city="Taylorsville"/>
  </person>
  <person person_id="2">
    <fname>Mary</fname>
    <lname>Smith</lname>
    <address address_id="3" street="River Road" zip="80239" city="Denver"/>
    <!-- <address address_id="4" street="North Street" zip="37920" city="Knoxville"/> -->
  </person>
</list>
```

You can again use the `test.person` table as defined previously in this section, after clearing all the existing records from the table and then showing its structure as shown here:

```sql
TRUNCATE person;
Query OK, 0 rows affected (0.04 sec)
SHOW CREATE TABLE person\G
```

```sql
Table: person
Create Table: CREATE TABLE `person` ( `person_id` int(11) NOT NULL, `fname` varchar(40) DEFAULT NULL, `lname` varchar(40) DEFAULT NULL, `created` timestamp NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP, PRIMARY KEY (`person_id`) ) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

Now create an `address` table in the `test` database using the following `CREATE TABLE` statement:

```sql
CREATE TABLE address (  address_id INT NOT NULL PRIMARY KEY,  person_id INT NULL,  street VARCHAR(40) NULL,  zip INT NULL,  city VARCHAR(40) NULL,  created TIMESTAMP );
```

To import the data from the XML file into the `person` table, execute the following `LOAD XML` statement, which specifies that rows are to be specified by the `<person>` element, as shown here:
LOAD XML Statement

mysql> LOAD XML LOCAL INFILE 'address.xml'
    -> INTO TABLE person
    -> ROWS IDENTIFIED BY '<person>';
Query OK, 2 rows affected (0.00 sec)
Records: 2  Deleted: 0  Skipped: 0  Warnings: 0

You can verify that the records were imported using a `SELECT` statement:

mysql> SELECT * FROM person;

+-----------+--------+-------+---------------------+
<table>
<thead>
<tr>
<th>person_id</th>
<th>fname</th>
<th>lname</th>
<th>created</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Robert</td>
<td>Jones</td>
<td>2007-07-24 17:37:06</td>
</tr>
<tr>
<td>2</td>
<td>Mary</td>
<td>Smith</td>
<td>2007-07-24 17:37:06</td>
</tr>
</tbody>
</table>
+-----------+--------+-------+---------------------+

2 rows in set (0.00 sec)

Since the `<address>` elements in the XML file have no corresponding columns in the `person` table, they are skipped.

To import the data from the `<address>` elements into the `address` table, use the `LOAD XML` statement shown here:

mysql> LOAD XML LOCAL INFILE 'address.xml'
    -> INTO TABLE address
    -> ROWS IDENTIFIED BY '<address>':
Query OK, 3 rows affected (0.00 sec)
Records: 3  Deleted: 0  Skipped: 0  Warnings: 0

You can see that the data was imported using a `SELECT` statement such as this one:

mysql> SELECT * FROM address;

+------------+-----------+-----------------+-------+--------------+---------------------+
<table>
<thead>
<tr>
<th>address_id</th>
<th>person_id</th>
<th>street</th>
<th>zip</th>
<th>city</th>
<th>created</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Mill Creek Road</td>
<td>45365</td>
<td>Sidney</td>
<td>2007-07-24 17:37:37</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Main Street</td>
<td>28681</td>
<td>Taylorsville</td>
<td>2007-07-24 17:37:37</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>River Road</td>
<td>80239</td>
<td>Denver</td>
<td>2007-07-24 17:37:37</td>
</tr>
</tbody>
</table>
+------------+-----------+-----------------+-------+--------------+---------------------+

3 rows in set (0.00 sec)

The data from the `<address>` element that is enclosed in XML comments is not imported. However, since there is a `person_id` column in the `address` table, the value of the `person_id` attribute from the parent `<person>` element for each `<address>` is imported into the `address` table.

Security Considerations. As with the `LOAD DATA` statement, the transfer of the XML file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server's choosing rather than the file named by the client in the `LOAD XML` statement. Such a server could access any file on the client host to which the client user has read access.

In a Web environment, clients usually connect to MySQL from a Web server. A user that can run any command against the MySQL server can use `LOAD XML LOCAL` to read any files to which the Web server process has read access. In this environment, the client with respect to the MySQL server is actually the Web server, not the remote program being run by the user who connects to the Web server.

You can disable loading of XML files from clients by starting the server with `--local-infile=0` or `--local-infile=OFF`. This option can also be used when starting the `mysql` client to disable `LOAD XML` for the duration of the client session.

To prevent a client from loading XML files from the server, do not grant the `FILE` privilege to the corresponding MySQL user account, or revoke this privilege if the client user account already has it.
**Important**

Revoking the FILE privilege (or not granting it in the first place) keeps the user only from executing the LOAD XML statement (as well as the LOAD_FILE() function; it does not prevent the user from executing LOAD XML LOCAL. To disallow this statement, you must start the server or the client with `--local-infile=OFF`.

In other words, the FILE privilege affects only whether the client can read files on the server; it has no bearing on whether the client can read files on the local file system.

For partitioned tables using storage engines that employ table locks, such as MyISAM, any locks caused by LOAD XML perform locks on all partitions of the table. This does not apply to tables using storage engines which employ row-level locking, such as InnoDB. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

### 13.2.8 REPLACE Statement

```sql
REPLACE [LOW_PRIORITY | DELAYED]
INTO tbl_name
[(col_name [, col_name] ...)]
VALUES | VALUE (value_list) [, (value_list)] ...
```

```sql
REPLACE [LOW_PRIORITY | DELAYED]
INTO tbl_name
SET assignment_list
```

```sql
REPLACE [LOW_PRIORITY | DELAYED]
INTO tbl_name
[(col_name [, col_name] ...)]
SELECT ...
```

- **value:**
  - `expr` | DEFAULT

- **value_list:**
  - `value [, value]`

- **assignment:**
  - `col_name = value`

- **assignment_list:**
  - `assignment [, assignment]`

**REPLACE** works exactly like **INSERT**, except that if an old row in the table has the same value as a new row for a PRIMARY KEY or a UNIQUE index, the old row is deleted before the new row is inserted. See Section 13.2.5, “INSERT Statement”.

**REPLACE** is a MySQL extension to the SQL standard. It either inserts, or deletes and inserts. For another MySQL extension to standard SQL—that either inserts or updates—see Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”.

**Note**

**REPLACE** makes sense only if a table has a PRIMARY KEY or UNIQUE index. Otherwise, it becomes equivalent to **INSERT**, because there is no index to be used to determine whether a new row duplicates another.

Values for all columns are taken from the values specified in the **REPLACE** statement. Any missing columns are set to their default values, just as happens for **INSERT**. You cannot refer to values from the current
row and use them in the new row. If you use an assignment such as `SET col_name = col_name + 1`, the reference to the column name on the right hand side is treated as `DEFAULT(col_name)`, so the assignment is equivalent to `SET col_name = DEFAULT(col_name) + 1`.

To use `REPLACE`, you must have both the `INSERT` and `DELETE` privileges for the table.

The `REPLACE` statement returns a count to indicate the number of rows affected. This is the sum of the rows deleted and inserted. If the count is 1 for a single-row `REPLACE`, a row was inserted and no rows were deleted. If the count is greater than 1, one or more old rows were deleted before the new row was inserted. It is possible for a single row to replace more than one old row if the table contains multiple unique indexes and the new row duplicates values for different old rows in different unique indexes.

The affected-rows count makes it easy to determine whether `REPLACE` only added a row or whether it also replaced any rows: Check whether the count is 1 (added) or greater (replaced).

If you are using the C API, the affected-rows count can be obtained using the `mysql_affected_rows()` function.

You cannot replace into a table and select from the same table in a subquery.

MySQL uses the following algorithm for `REPLACE` (and `LOAD DATA ... REPLACE`):

1. Try to insert the new row into the table
2. While the insertion fails because a duplicate-key error occurs for a primary key or unique index:
   a. Delete from the table the conflicting row that has the duplicate key value
   b. Try again to insert the new row into the table

It is possible that in the case of a duplicate-key error, a storage engine may perform the `REPLACE` as an update rather than a delete plus insert, but the semantics are the same. There are no user-visible effects other than a possible difference in how the storage engine increments `Handler_xxx` status variables.

Because the results of `REPLACE ... SELECT` statements depend on the ordering of rows from the `SELECT` and this order cannot always be guaranteed, it is possible when logging these statements for the master and the slave to diverge. For this reason, in MySQL 5.5.18 and later, `REPLACE ... SELECT` statements are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode, and are written to the binary log using the row-based format when using `MIXED` mode. See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

When modifying an existing table that is not partitioned to accommodate partitioning, or, when modifying the partitioning of an already partitioned table, you may consider altering the table’s primary key (see Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”). You should be aware that, if you do this, the results of `REPLACE` statements may be affected, just as they would be if you modified the primary key of a nonpartitioned table. Consider the table created by the following `CREATE TABLE` statement:

```
CREATE TABLE test (  
id INT UNSIGNED NOT NULL AUTO_INCREMENT,
data VARCHAR(64) DEFAULT NULL,
ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
PRIMARY KEY (id)
);
```

When we create this table and run the statements shown in the mysql client, the result is as follows:

```
mysql> REPLACE INTO test VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.04 sec)
```
SELECT Statement

mysql> REPLACE INTO test VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 2 rows affected (0.04 sec)

mysql> SELECT * FROM test;
+----+------+---------------------+
<table>
<thead>
<tr>
<th>id</th>
<th>data</th>
<th>ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New</td>
<td>2014-08-20 18:47:42</td>
</tr>
</tbody>
</table>
+----+------+---------------------+
1 row in set (0.00 sec)

Now we create a second table almost identical to the first, except that the primary key now covers 2 columns, as shown here (emphasized text):

```
CREATE TABLE test2 (
    id INT UNSIGNED NOT NULL AUTO_INCREMENT,
    data VARCHAR(64) DEFAULT NULL,
    ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    PRIMARY KEY (id, ts)
);
```

When we run on `test2` the same two REPLACE statements as we did on the original `test` table, we obtain a different result:

```
mysql> REPLACE INTO test2 VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.05 sec)

mysql> REPLACE INTO test2 VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 1 row affected (0.06 sec)

mysql> SELECT * FROM test2;
+----+------+---------------------+
<table>
<thead>
<tr>
<th>id</th>
<th>data</th>
<th>ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Old</td>
<td>2014-08-20 18:47:00</td>
</tr>
<tr>
<td>1</td>
<td>New</td>
<td>2014-08-20 18:47:42</td>
</tr>
</tbody>
</table>
+----+------+---------------------+
2 rows in set (0.00 sec)
```

This is due to the fact that, when run on `test2`, both the `id` and `ts` column values must match those of an existing row for the row to be replaced; otherwise, a row is inserted.

A REPLACE statement affecting a partitioned table using a storage engine such as MyISAM that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.9 SELECT Statement

```sql
SELECT
    [ALL | DISTINCT | DISTINCTROW]
    [HIGH_PRIORITY]
    [STRAIGHT_JOIN]
    [SQL_SMALL_RESULT] [SQL_BIG_RESULT] [SQL_BUFFER_RESULT]
    [SQL_CACHE | SQL_NO_CACHE] [SQL_CALC_FOUND_ROWS]
    select_expr [ , select_expr ] ...
    [into_option]
    [FROM table_references]
    [WHERE where_condition]
    [GROUP BY {col_name | expr | position}]
    [ASC | DESC], ... [WITH ROLLUP]
    [HAVING where_condition]
    [ORDER BY {col_name | expr | position}]
```
**SELECT Statement**

```sql
[ASC | DESC], ...]
[LIMIT {[offset,] row_count | row_count OFFSET offset]}
[PROCEDURE procedure_name(argument_list)]
[into_option]
[FOR UPDATE | LOCK IN SHARE MODE]
```

**into_option:**

- INTO OUTFILE 'file_name'
- [CHARACTER SET charset_name]
- export_options
- INTO DUMPFILE 'file_name'
- INTO var_name [, var_name] ...  

The `SELECT` statement is used to retrieve rows selected from one or more tables, and can include `UNION` statements and subqueries. See Section 13.2.9.3, “UNION Clause”, and Section 13.2.10, “Subqueries”.

The most commonly used clauses of `SELECT` statements are these:

- Each `select_expr` indicates a column that you want to retrieve. There must be at least one `select_expr`.
- `table_references` indicates the table or tables from which to retrieve rows. Its syntax is described in Section 13.2.9.2, “JOIN Clause”.
- The `WHERE` clause, if given, indicates the condition or conditions that rows must satisfy to be selected. `where_condition` is an expression that evaluates to true for each row to be selected. The statement selects all rows if there is no `WHERE` clause.

In the `WHERE` expression, you can use any of the functions and operators that MySQL supports, except for aggregate (summary) functions. See Section 9.5, “Expressions”, and Chapter 12, Functions and Operators.

`SELECT` can also be used to retrieve rows computed without reference to any table.

For example:

```sql
mysql> SELECT 1 + 1;
-> 2
```

You are permitted to specify `DUAL` as a dummy table name in situations where no tables are referenced:

```sql
mysql> SELECT 1 + 1 FROM DUAL;
-> 2
```

`DUAL` is purely for the convenience of people who require that all `SELECT` statements should have `FROM` and possibly other clauses. MySQL may ignore the clauses. MySQL does not require `FROM DUAL` if no tables are referenced.

In general, clauses used must be given in exactly the order shown in the syntax description. For example, a `HAVING` clause must come after any `GROUP BY` clause and before any `ORDER BY` clause. The `INTO` clause, if present, can appear in any position indicated by the syntax description, but within a given statement can appear only once, not in multiple positions. For more information about `INTO`, see Section 13.2.9.1, “SELECT ... INTO Statement”.

The list of `select_expr` terms comprises the select list that indicates which columns to retrieve. Terms specify a column or expression or can use `*`-shorthand:

- A select list consisting only of a single unqualified `*` can be used as shorthand to select all columns from all tables:
SELECT Statement

- `tbl_name.*` can be used as a qualified shorthand to select all columns from the named table:

  ```sql
  SELECT t1.*, t2.* FROM t1 INNER JOIN t2 ...
  ```

- Use of an unqualified `*` with other items in the select list may produce a parse error. To avoid this problem, use a qualified `tbl_name.*` reference:

  ```sql
  SELECT AVG(score), t1.* FROM t1 ...
  ```

The following list provides additional information about other SELECT clauses:

- A `select_expr` can be given an alias using `AS alias_name`. The alias is used as the expression's column name and can be used in `GROUP BY`, `ORDER BY`, or `HAVING` clauses. For example:

  ```sql
  SELECT CONCAT(last_name,', ',first_name) AS full_name
  FROM mytable ORDER BY full_name;
  ```

  The `AS` keyword is optional when aliasing a `select_expr` with an identifier. The preceding example could have been written like this:

  ```sql
  SELECT CONCAT(last_name,', ',first_name) full_name
  FROM mytable ORDER BY full_name;
  ```

  However, because the `AS` is optional, a subtle problem can occur if you forget the comma between two `select_expr` expressions: MySQL interprets the second as an alias name. For example, in the following statement, `columnb` is treated as an alias name:

  ```sql
  SELECT columna columnb FROM mytable;
  ```

  For this reason, it is good practice to be in the habit of using `AS` explicitly when specifying column aliases.

  It is not permissible to refer to a column alias in a `WHERE` clause, because the column value might not yet be determined when the `WHERE` clause is executed. See Section B.4.4.4, “Problems with Column Aliases”.

- The `FROM table_references` clause indicates the table or tables from which to retrieve rows. If you name more than one table, you are performing a join. For information on join syntax, see Section 13.2.9.2, “JOIN Clause”. For each table specified, you can optionally specify an alias:

  ```sql
  tbl_name [(AS] alias [index_hint]]
  ```

  The use of index hints provides the optimizer with information about how to choose indexes during query processing. For a description of the syntax for specifying these hints, see Section 8.9.3, “Index Hints”.

  You can use `SET max_seeks_for_key=value` as an alternative way to force MySQL to prefer key scans instead of table scans. See Section 5.1.7, “Server System Variables”.

  You can refer to a table within the default database as `tbl_name`, or as `db_name.tbl_name` to specify a database explicitly. You can refer to a column as `col_name, tbl_name.col_name`, or `db_name.tbl_name.col_name`. You need not specify a `tbl_name` or `db_name.tbl_name` prefix for a column reference unless the reference would be ambiguous. See Section 9.2.2, “Identifier Qualifiers”, for examples of ambiguity that require the more explicit column reference forms.

  A table reference can be aliased using `tbl_name AS alias_name` or `tbl_name alias_name`. These statements are equivalent:
SELECT Statement

SELECT t1.name, t2.salary FROM employee AS t1, info AS t2
WHERE t1.name = t2.name;

SELECT t1.name, t2.salary FROM employee t1, info t2
WHERE t1.name = t2.name;

- Columns selected for output can be referred to in ORDER BY and GROUP BY clauses using column names, column aliases, or column positions. Column positions are integers and begin with 1:

SELECT college, region, seed FROM tournament
ORDER BY region, seed;

SELECT college, region AS r, seed AS s FROM tournament
ORDER BY r, s;

SELECT college, region, seed FROM tournament
ORDER BY 2, 3;

To sort in reverse order, add the DESC (descending) keyword to the name of the column in the ORDER BY clause that you are sorting by. The default is ascending order; this can be specified explicitly using the ASC keyword.

If ORDER BY occurs within a subquery and also is applied in the outer query, the outermost ORDER BY takes precedence. For example, results for the following statement are sorted in descending order, not ascending order:

(SELECT ... ORDER BY a) ORDER BY a DESC;

Use of column positions is deprecated because the syntax has been removed from the SQL standard.

- MySQL extends the GROUP BY clause so that you can also specify ASC and DESC after columns named in the clause:

SELECT a, COUNT(b) FROM test_table GROUP BY a DESC;

- If you use GROUP BY, output rows are sorted according to the GROUP BY columns as if you had an ORDER BY for the same columns. To avoid the overhead of sorting that GROUP BY produces, add ORDER BY NULL:

SELECT a, COUNT(b) FROM test_table GROUP BY a ORDER BY NULL;

Relying on implicit GROUP BY sorting (that is, sorting in the absence of ASC or DESC designators) is deprecated. To produce a given sort order, use explicit ASC or DESC designators for GROUP BY columns or provide an ORDER BY clause.

- When you use ORDER BY or GROUP BY to sort a column in a SELECT, the server sorts values using only the initial number of bytes indicated by the max_sort_length system variable.

- MySQL extends the use of GROUP BY to permit selecting fields that are not mentioned in the GROUP BY clause. If you are not getting the results that you expect from your query, please read the description of GROUP BY found in Section 12.17, “Aggregate (GROUP BY) Functions”.

- GROUP BY permits a WITH ROLLUP modifier. See Section 12.17.2, “GROUP BY Modifiers”.

- The HAVING clause is applied nearly last, just before items are sent to the client, with no optimization. (LIMIT is applied after HAVING.)

The SQL standard requires that HAVING must reference only columns in the GROUP BY clause or columns used in aggregate functions. However, MySQL supports an extension to this behavior, and permits HAVING to refer to columns in the SELECT list and columns in outer subqueries as well.
If the **HAVING** clause refers to a column that is ambiguous, a warning occurs. In the following statement, `col2` is ambiguous because it is used as both an alias and a column name:

```sql
SELECT COUNT(col1) AS col2 FROM t GROUP BY col2 HAVING col2 = 2;
```

Preference is given to standard SQL behavior, so if a **HAVING** column name is used both in **GROUP BY** and as an aliased column in the output column list, preference is given to the column in the **GROUP BY** column.

- Do not use **HAVING** for items that should be in the **WHERE** clause. For example, do not write the following:

  ```sql
  SELECT col_name FROM tbl_name HAVING col_name > 0;
  ```

  Write this instead:

  ```sql
  SELECT col_name FROM tbl_name WHERE col_name > 0;
  ```

- The **HAVING** clause can refer to aggregate functions, which the **WHERE** clause cannot:

  ```sql
  SELECT user, MAX(salary) FROM users
  GROUP BY user HAVING MAX(salary) > 10;
  ```

  (This did not work in some older versions of MySQL.)

- MySQL permits duplicate column names. That is, there can be more than one `select_expr` with the same name. This is an extension to standard SQL. Because MySQL also permits **GROUP BY** and **HAVING** to refer to `select_expr` values, this can result in an ambiguity:

  ```sql
  SELECT 12 AS a, a FROM t GROUP BY a;
  ```

  In that statement, both columns have the name `a`. To ensure that the correct column is used for grouping, use different names for each `select_expr`.

- MySQL resolves unqualified column or alias references in **ORDER BY** clauses by searching in the `select_expr` values, then in the columns of the tables in the **FROM** clause. For **GROUP BY** or **HAVING** clauses, it searches the **FROM** clause before searching in the `select_expr` values. (For **GROUP BY** and **HAVING**, this differs from the pre-MySQL 5.0 behavior that used the same rules as for **ORDER BY**.)

- The **LIMIT** clause can be used to constrain the number of rows returned by the **SELECT** statement. **LIMIT** takes one or two numeric arguments, which must both be nonnegative integer constants, with these exceptions:

  - Within prepared statements, **LIMIT** parameters can be specified using `?` placeholder markers.
  - Within stored programs, **LIMIT** parameters can be specified using integer-valued routine parameters or local variables.

  With two arguments, the first argument specifies the offset of the first row to return, and the second specifies the maximum number of rows to return. The offset of the initial row is 0 (not 1):  

  ```sql
  SELECT * FROM tbl LIMIT 5,10;  # Retrieve rows 6-15
  ```

  To retrieve all rows from a certain offset up to the end of the result set, you can use some large number for the second parameter. This statement retrieves all rows from the 96th row to the last:

  ```sql
  SELECT * FROM tbl LIMIT 95,18446744073709551615;
  ```

  With one argument, the value specifies the number of rows to return from the beginning of the result set:
SELECT Statement

```sql
SELECT * FROM tbl LIMIT 5;  # Retrieve first 5 rows
```

In other words, `LIMIT row_count` is equivalent to `LIMIT 0, row_count`.

For prepared statements, you can use placeholders. The following statements will return one row from the `tbl` table:

```sql
SET @a=1;
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?';
EXECUTE STMT USING @a;
```

The following statements will return the second to sixth row from the `tbl` table:

```sql
SET @skip=1; SET @numrows=5;
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?, ?';
EXECUTE STMT USING @skip, @numrows;
```

For compatibility with PostgreSQL, MySQL also supports the `LIMIT row_count OFFSET offset` syntax.

If `LIMIT` occurs within a subquery and also is applied in the outer query, the outermost `LIMIT` takes precedence. For example, the following statement produces two rows, not one:

```sql
(SELECT ... LIMIT 1) LIMIT 2;
```

- **A PROCEDURE clause** names a procedure that should process the data in the result set. For an example, see Section 8.4.2.4, “Using PROCEDURE ANALYSE”, which describes `ANALYSE`, a procedure that can be used to obtain suggestions for optimal column data types that may help reduce table sizes.

  A PROCEDURE clause is not permitted in a `UNION` statement.

- **The `SELECT ... INTO` form of SELECT** enables the query result to be written to a file or stored in variables. For more information, see Section 13.2.9.1, “SELECT ... INTO Statement”.

- If you use `FOR UPDATE` with a storage engine that uses page or row locks, rows examined by the query are write-locked until the end of the current transaction. Using `LOCK IN SHARE MODE` sets a shared lock that permits other transactions to read the examined rows but not to update or delete them. See Section 14.10.2.4, “Locking Reads”.

Following the `SELECT` keyword, you can use a number of modifiers that affect the operation of the statement. `HIGH_PRIORITY`, `STRAIGHT_JOIN`, and modifiers beginning with `SQL_` are MySQL extensions to standard SQL.

- **The ALL and DISTINCT modifiers** specify whether duplicate rows should be returned. `ALL` (the default) specifies that all matching rows should be returned, including duplicates. `DISTINCT` specifies removal of duplicate rows from the result set. It is an error to specify both modifiers. `DISTINCTROW` is a synonym for `DISTINCT`.

- **HIGH_PRIORITY** gives the `SELECT` higher priority than a statement that updates a table. You should use this only for queries that are very fast and must be done at once. A `SELECT HIGH_PRIORITY` query that is issued while the table is locked for reading runs even if there is an update statement waiting for the table to be free. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

  `HIGH_PRIORITY` cannot be used with `SELECT` statements that are part of a `UNION`.

- **STRAIGHT_JOIN** forces the optimizer to join the tables in the order in which they are listed in the `FROM` clause. You can use this to speed up a query if the optimizer joins the tables in nonoptimal order.
STRAIGHT_JOIN also can be used in the table_references list. See Section 13.2.9.2, “JOIN Clause”.

STRAIGHT_JOIN does not apply to any table that the optimizer treats as a const or system table. Such a table produces a single row, is read during the optimization phase of query execution, and references to its columns are replaced with the appropriate column values before query execution proceeds. These tables will appear first in the query plan displayed by EXPLAIN. See Section 8.8.1, “Optimizing Queries with EXPLAIN”. This exception may not apply to const or system tables that are used on the NULL-complemented side of an outer join (that is, the right-side table of a LEFT JOIN or the left-side table of a RIGHT JOIN).

• SQL_BIG_RESULT or SQL_SMALL_RESULT can be used with GROUP BY or DISTINCT to tell the optimizer that the result set has many rows or is small, respectively. For SQL_BIG_RESULT, MySQL directly uses disk-based temporary tables if they are created, and prefers sorting to using a temporary table with a key on the GROUP BY elements. For SQL_SMALL_RESULT, MySQL uses in-memory temporary tables to store the resulting table instead of using sorting. This should not normally be needed.

• SQL_BUFFER_RESULT forces the result to be put into a temporary table. This helps MySQL free the table locks early and helps in cases where it takes a long time to send the result set to the client. This modifier can be used only for top-level SELECT statements, not for subqueries or following UNION.

• SQL_CALC_FOUND_ROWS tells MySQL to calculate how many rows there would be in the result set, disregarding any LIMIT clause. The number of rows can then be retrieved with SELECT FOUND_ROWS(). See Section 12.15, “Information Functions”.

• The SQL_CACHE and SQL_NO_CACHE modifiers affect caching of query results in the query cache (see Section 8.10.3, “The MySQL Query Cache”). SQL_CACHE tells MySQL to store the result in the query cache if it is cacheable and the value of the query_cache_type system variable is 2 or DEMAND. With SQL_NO_CACHE, the server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the SQL_NO_CACHE keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

These two modifiers are mutually exclusive and an error occurs if they are both specified. Also, these modifiers are not permitted in subqueries (including subqueries in the FROM clause), and SELECT statements in unions other than the first SELECT.

For views, SQL_NO_CACHE applies if it appears in any SELECT in the query. For a cacheable query, SQL_CACHE applies if it appears in the first SELECT of a view referred to by the query.

A SELECT from a partitioned table using a storage engine such as MyISAM that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.9.1 SELECT ... INTO Statement

The SELECT ... INTO form of SELECT enables a query result to be stored in variables or written to a file:

• SELECT ... INTO var_list selects column values and stores them into variables.

• SELECT ... INTO OUTFILE writes the selected rows to a file. Column and line terminators can be specified to produce a specific output format.

• SELECT ... INTO DUMPFILE writes a single row to a file without any formatting.
A given `SELECT` statement can contain at most one `INTO` clause, although as shown by the `SELECT` syntax description (see Section 13.2.9, “SELECT Statement”), the `INTO` can appear in different positions:

- **Before `FROM`.** Example:
  ```sql
  SELECT * INTO @myvar FROM t1;
  ```

- **Before a trailing locking clause.** Example:
  ```sql
  SELECT * FROM t1 INTO @myvar FOR UPDATE;
  ```

An `INTO` clause should not be used in a nested `SELECT` because such a `SELECT` must return its result to the outer context. There are also constraints on the use of `INTO` within `UNION` statements; see Section 13.2.9.3, “UNION Clause”.

For the `INTO var_list` variant:

- `var_list` names a list of one or more variables, each of which can be a user-defined variable, stored procedure or function parameter, or stored program local variable. (Within a prepared `SELECT ... INTO var_list` statement, only user-defined variables are permitted; see Section 13.6.4.2, “Local Variable Scope and Resolution”.)

- The selected values are assigned to the variables. The number of variables must match the number of columns. The query should return a single row. If the query returns no rows, a warning with error code 1329 occurs (No data), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (Result consisted of more than one row). If it is possible that the statement may retrieve multiple rows, you can use `LIMIT 1` to limit the result set to a single row.

  ```sql
  SELECT id, data INTO @x, @y FROM test.t1 LIMIT 1;
  ```

User variable names are not case-sensitive. See Section 9.4, “User-Defined Variables”.

The `SELECT ... INTO OUTFILE 'file_name'` form of `SELECT` writes the selected rows to a file. The file is created on the server host, so you must have the `FILE` privilege to use this syntax. `file_name` cannot be an existing file, which among other things prevents files such as `/etc/passwd` and database tables from being modified. The `character_set_filesystem` system variable controls the interpretation of the file name.

The `SELECT ... INTO OUTFILE` statement is intended to enable dumping a table to a text file on the server host. To create the resulting file on some other host, `SELECT ... INTO OUTFILE` normally is unsuitable because there is no way to write a path to the file relative to the server host file system, unless the location of the file on the remote host can be accessed using a network-mapped path on the server host file system.

Alternatively, if the MySQL client software is installed on the remote host, you can use a client command such as `mysql -e "SELECT ..." > file_name` to generate the file on that host.

`SELECT ... INTO OUTFILE` is the complement of `LOAD DATA`. Column values are written converted to the character set specified in the `CHARACTER SET` clause. If no such clause is present, values are dumped using the `binary` character set. In effect, there is no character set conversion. If a result set contains columns in several character sets, so will the output data file and it may not be possible to reload the file correctly.

The syntax for the `export_options` part of the statement consists of the same `FIELDS` and `LINES` clauses that are used with the `LOAD DATA` statement. For information about the `FIELDS` and `LINES` clauses, including their default values and permissible values, see Section 13.2.6, “LOAD DATA Statement”.

1521
SELECT Statement

**FIELDS ESCAPED BY** controls how to write special characters. If the **FIELDS ESCAPED BY** character is not empty, it is used when necessary to avoid ambiguity as a prefix that precedes following characters on output:

- The **FIELDS ESCAPED BY** character
- The **FIELDS [OPTIONALLY] ENCLOSED BY** character
- The first character of the **FIELDS TERMINATED BY** and **LINES TERMINATED BY** values
- ASCII NUL (the zero-valued byte; what is actually written following the escape character is ASCII 0, not a zero-valued byte)

The **FIELDS TERMINATED BY**, **ENCLOSED BY**, **ESCAPED BY**, or **LINES TERMINATED BY** characters must be escaped so that you can read the file back in reliably. ASCII NUL is escaped to make it easier to view with some pagers.

The resulting file need not conform to SQL syntax, so nothing else need be escaped.

If the **FIELDS ESCAPED BY** character is empty, no characters are escaped and **NULL** is output as **NULL**, not \N. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

Here is an example that produces a file in the comma-separated values (CSV) format used by many programs:

```sql
SELECT a,b,a+b INTO OUTFILE '/tmp/result.txt'
  FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"'
  LINES TERMINATED BY '
'
FROM test_table;
```

If you use **INTO DUMPFILE** instead of **INTO OUTFILE**, MySQL writes only one row into the file, without any column or line termination and without performing any escape processing. This is useful for selecting a **BLOB** value and storing it in a file.

**Note**

Any file created by **INTO OUTFILE** or **INTO DUMPFILE** is writable by all users on the server host. The reason for this is that the MySQL server cannot create a file that is owned by anyone other than the user under whose account it is running. (You should never run mysqld as root for this and other reasons.) The file thus must be world-writable so that you can manipulate its contents.

If the **secure_file_priv** system variable is set to a nonempty directory name, the file to be written must be located in that directory.

In the context of **SELECT ... INTO** statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For additional information, see Section 20.4.5, “Event Scheduler Status”.

### 13.2.9.2 JOIN Clause

MySQL supports the following **JOIN** syntax for the **table_references** part of **SELECT** statements and multiple-table **DELETE** and **UPDATE** statements:

```sql
table_references:
  escaped_table_reference [, escaped_table_reference] ...
```
A table reference is also known as a join expression.

The syntax of `table_factor` is extended in MySQL in comparison with standard SQL. The standard accepts only `table_reference`, not a list of them inside a pair of parentheses.

This is a conservative extension if each comma in a list of `table_reference` items is considered as equivalent to an inner join. For example:

```sql
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
ON (t2.a = t1.a AND t3.b = t1.b AND t4.c = t1.c)
```

is equivalent to:

```sql
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3) CROSS JOIN t4
ON (t2.a = t1.a AND t3.b = t1.b AND t4.c = t1.c)
```

In MySQL, `JOIN`, `CROSS JOIN`, and `INNER JOIN` are syntactic equivalents (they can replace each other). In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause, `CROSS JOIN` is used otherwise.

In general, parentheses can be ignored in join expressions containing only inner join operations. MySQL also supports nested joins. See Section 8.2.1.6, “Nested Join Optimization”.

Index hints can be specified to affect how the MySQL optimizer makes use of indexes. For more information, see Section 8.9.3, “Index Hints”. The `optimizer_switch` system variable is another way to influence optimizer use of indexes. See Section 8.9.2, “Switchable Optimizations”.

1523
The following list describes general factors to take into account when writing joins:

- A table reference can be aliased using `tbl_name AS alias_name` or `tbl_name alias_name`:

```sql
SELECT t1.name, t2.salary
FROM employee AS t1 INNER JOIN info AS t2 ON t1.name = t2.name;
```

```sql
SELECT t1.name, t2.salary
FROM employee t1 INNER JOIN info t2 ON t1.name = t2.name;
```

- A `table_subquery` is also known as a derived table or subquery in the `FROM` clause. See Section 13.2.10.8, “Derived Tables.” Such subqueries must include an alias to give the subquery result a table name. A trivial example follows:

```sql
SELECT * FROM (SELECT 1, 2, 3) AS t1;
```

- The maximum number of tables that can be referenced in a single join is 61.

- `INNER JOIN` and `,` (comma) are semantically equivalent in the absence of a join condition: both produce a Cartesian product between the specified tables (that is, each and every row in the first table is joined to each and every row in the second table).

However, the precedence of the comma operator is less than that of `INNER JOIN, CROSS JOIN, LEFT JOIN`, and so on. If you mix comma joins with the other join types when there is a join condition, an error of the form `Unknown column 'col_name' in 'on clause'` may occur. Information about dealing with this problem is given later in this section.

- The `search_condition` used with `ON` is any conditional expression of the form that can be used in a `WHERE` clause. Generally, the `ON` clause serves for conditions that specify how to join tables, and the `WHERE` clause restricts which rows to include in the result set.

- If there is no matching row for the right table in the `ON` or `USING` part in a `LEFT JOIN`, a row with all columns set to `NULL` is used for the right table. You can use this fact to find rows in a table that have no counterpart in another table:

```sql
SELECT left_tbl.*
FROM left_tbl LEFT JOIN right_tbl ON left_tbl.id = right_tbl.id
WHERE right_tbl.id IS NULL;
```

This example finds all rows in `left_tbl` with an `id` value that is not present in `right_tbl` (that is, all rows in `left_tbl` with no corresponding row in `right_tbl`). See Section 8.2.1.7, “Outer Join Optimization”.

- The `USING(join_column_list)` clause names a list of columns that must exist in both tables. If tables `a` and `b` both contain columns `c1, c2,` and `c3`, the following join compares corresponding columns from the two tables:

```sql
a LEFT JOIN b USING (c1, c2, c3)
```

- The `NATURAL [LEFT] JOIN` of two tables is defined to be semantically equivalent to an `INNER JOIN` or a `LEFT JOIN` with a `USING` clause that names all columns that exist in both tables.

- `RIGHT JOIN` works analogously to `LEFT JOIN`. To keep code portable across databases, it is recommended that you use `LEFT JOIN` instead of `RIGHT JOIN`.

- The `{ OJ ... }` syntax shown in the join syntax description exists only for compatibility with ODBC. The curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

```sql
SELECT left_tbl.*
```

```sql
FROM left_tbl
```
SELECT Statement

```sql
FROM { OJ left_tbl LEFT OUTER JOIN right_tbl
    ON left_tbl.id = right_tbl.id }
WHERE right_tbl.id IS NULL;
```

You can use other types of joins within `{ OJ ... }`, such as INNER JOIN or RIGHT OUTER JOIN. This helps with compatibility with some third-party applications, but is not official ODBC syntax.

The parser does not permit nested `{ OJ ... }` constructs (which are not legal ODBC syntax, anyway). Queries that use such constructs should be rewritten.

- **STRAIGHT_JOIN** is similar to JOIN, except that the left table is always read before the right table. This can be used for those (few) cases for which the join optimizer processes the tables in a suboptimal order.

Some join examples:

```sql
SELECT * FROM table1, table2;
SELECT * FROM table1 INNER JOIN table2 ON table1.id = table2.id;
SELECT * FROM table1 LEFT JOIN table2 ON table1.id = table2.id;
SELECT * FROM table1 LEFT JOIN table2 USING (id);
SELECT * FROM table1 LEFT JOIN table2 ON table1.id = table2.id
    LEFT JOIN table3 ON table2.id = table3.id;
```

Natural joins and joins with USING, including outer join variants, are processed according to the SQL:2003 standard:

- Redundant columns of a NATURAL join do not appear. Consider this set of statements:

```sql
CREATE TABLE t1 (i INT, j INT);
CREATE TABLE t2 (k INT, j INT);
INSERT INTO t1 VALUES(1, 1);
INSERT INTO t2 VALUES(1, 1);
SELECT * FROM t1 NATURAL JOIN t2;
SELECT * FROM t1 JOIN t2 USING (j);
```

In the first `SELECT` statement, column `j` appears in both tables and thus becomes a join column, so, according to standard SQL, it should appear only once in the output, not twice. Similarly, in the second `SELECT` statement, column `j` is named in the USING clause and should appear only once in the output, not twice.

Thus, the statements produce this output:

```
+-------+---+---+
| j     | i | k |
+-------+---+---+
| 1     | 1 | 1 |
```

Redundant column elimination and column ordering occurs according to standard SQL, producing this display order:

- First, coalesced common columns of the two joined tables, in the order in which they occur in the first table.
SELECT Statement

• Second, columns unique to the first table, in order in which they occur in that table
• Third, columns unique to the second table, in order in which they occur in that table

The single result column that replaces two common columns is defined using the coalesce operation. That is, for two \( t_1.a \) and \( t_2.a \) the resulting single join column \( a \) is defined as \( a = \text{COALESCE}(t_1.a, t_2.a) \), where:

\[
\text{COALESCE}(x, y) = (\text{CASE WHEN } x \text{ IS NOT NULL THEN } x \text{ ELSE } y \text{ END})
\]

If the join operation is any other join, the result columns of the join consist of the concatenation of all columns of the joined tables.

A consequence of the definition of coalesced columns is that, for outer joins, the coalesced column contains the value of the non-
NULL column if one of the two columns is always \text{NULL}. If neither or both columns are \text{NULL}, both common columns have the same value, so it doesn't matter which one is chosen as the value of the coalesced column. A simple way to interpret this is to consider that a coalesced column of an outer join is represented by the common column of the inner table of a JOIN.

Suppose that the tables \( t_1(a, b) \) and \( t_2(a, c) \) have the following contents:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>t2</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>1 x</td>
<td>2 z</td>
<td></td>
</tr>
<tr>
<td>2 y</td>
<td>3 w</td>
<td></td>
</tr>
</tbody>
</table>

Then, for this join, column \( a \) contains the values of \( t_1.a \):

```
mysql> SELECT * FROM t1 NATURAL LEFT JOIN t2;
+------+------+------+
| a    | b    | c    |
+------+------+------+
|    1 | x    | NULL |
|    2 | y    | z    |
+------+------+------+
```

By contrast, for this join, column \( a \) contains the values of \( t_2.a \).

```
mysql> SELECT * FROM t1 NATURAL RIGHT JOIN t2;
+------+------+------+
| a    | c    | b    |
+------+------+------+
|    2 | z    | y    |
|    3 | w    | NULL |
+------+------+------+
```

Compare those results to the otherwise equivalent queries with JOIN ... ON:

```
mysql> SELECT * FROM t1 LEFT JOIN t2 ON (t1.a = t2.a);
+------+------+-----+
<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x</td>
<td>1</td>
<td>NULL</td>
</tr>
<tr>
<td>2 y</td>
<td>2</td>
<td>z</td>
</tr>
</tbody>
</table>
+------+------+-----+
```

```
mysql> SELECT * FROM t1 RIGHT JOIN t2 ON (t1.a = t2.a);
+------+------+-----+
<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>NULL</td>
<td>2 z</td>
</tr>
<tr>
<td>2 y</td>
<td>2</td>
<td>z</td>
</tr>
</tbody>
</table>
+------+------+-----+
```
**SELECT Statement**

- **A **USING clause can be rewritten as an **ON** clause that compares corresponding columns. However, although USING and ON are similar, they are not quite the same. Consider the following two queries:

```
  a LEFT JOIN b USING (c1, c2, c3)
  a LEFT JOIN b ON a.c1 = b.c1 AND a.c2 = b.c2 AND a.c3 = b.c3
```

With respect to determining which rows satisfy the join condition, both joins are semantically identical.

With respect to determining which columns to display for **SELECT** * expansion, the two joins are not semantically identical. The USING join selects the coalesced value of corresponding columns, whereas the ON join selects all columns from all tables. For the USING join, **SELECT** * selects these values:

```
COALESCE(a.c1, b.c1), COALESCE(a.c2, b.c2), COALESCE(a.c3, b.c3)
```

For the ON join, **SELECT** * selects these values:

```
a.c1, a.c2, a.c3, b.c1, b.c2, b.c3
```

With an inner join, **COALESCE(a.c1, b.c1)** is the same as either **a.c1** or **b.c1** because both columns will have the same value. With an outer join (such as **LEFT JOIN**), one of the two columns can be **NULL**. That column is omitted from the result.

- **An **ON clause can refer only to its operands.

  Example:

  ```sql
  CREATE TABLE t1 (i1 INT);
  CREATE TABLE t2 (i2 INT);
  CREATE TABLE t3 (i3 INT);
  SELECT * FROM t1 JOIN t2 ON (i1 = i3) JOIN t3;
  ```

  The statement fails with an **Unknown column 'i3' in 'on clause'** error because **i3** is a column in **t3**, which is not an operand of the **ON clause**. To enable the join to be processed, rewrite the statement as follows:

  ```sql
  SELECT * FROM t1 JOIN t2 JOIN t3 ON (i1 = i3);
  ```

  - **JOIN** has higher precedence than the comma operator (,), so the join expression **t1, t2 JOIN t3** is interpreted as **(t1, (t2 JOIN t3))**, not as **((t1, t2) JOIN t3)**. This affects statements that use an **ON clause** because that clause can refer only to columns in the operands of the join, and the precedence affects interpretation of what those operands are.

  Example:

  ```sql
  CREATE TABLE t1 (i1 INT, j1 INT);
  CREATE TABLE t2 (i2 INT, j2 INT);
  CREATE TABLE t3 (i3 INT, j3 INT);
  INSERT INTO t1 VALUES(1, 1);
  INSERT INTO t2 VALUES(1, 1);
  INSERT INTO t3 VALUES(1, 1);
  ```
SELECT * FROM t1, t2 JOIN t3 ON (t1.i1 = t3.i3);

The JOIN takes precedence over the comma operator, so the operands for the ON clause are t2 and t3. Because t1.i1 is not a column in either of the operands, the result is an Unknown column 't1.i1' in 'on clause' error.

To enable the join to be processed, use either of these strategies:

- Group the first two tables explicitly with parentheses so that the operands for the ON clause are (t1, t2) and t3:
  ```sql
  SELECT * FROM (t1, t2) JOIN t3 ON (t1.i1 = t3.i3);
  ```

- Avoid the use of the comma operator and use JOIN instead:
  ```sql
  SELECT * FROM t1 JOIN t2 JOIN t3 ON (t1.i1 = t3.i3);
  ```

The same precedence interpretation also applies to statements that mix the comma operator with INNER JOIN, CROSS JOIN, LEFT JOIN, and RIGHT JOIN, all of which have higher precedence than the comma operator.

- A MySQL extension compared to the SQL:2003 standard is that MySQL permits you to qualify the common (coalesced) columns of NATURAL or USING joins, whereas the standard disallows that.

### 13.2.9.3 UNION Clause

```sql
SELECT ... UNION [ALL | DISTINCT] SELECT ... [UNION [ALL | DISTINCT] SELECT ...]
```

UNION combines the result from multiple SELECT statements into a single result set. The result set column names are taken from the column names of the first SELECT statement.

Selected columns listed in corresponding positions of each SELECT statement should have the same data type. (For example, the first column selected by the first statement should have the same type as the first column selected by the other statements.) If the data types of corresponding SELECT columns do not match, the types and lengths of the columns in the UNION result take into account the values retrieved by all of the SELECT statements. For example, consider the following:

```sql
mysql> SELECT REPEAT('a',1) UNION SELECT REPEAT('b',10);
+---------------+
| REPEAT('a',1) |
| bbbbbbbbbbbb |
+---------------+
```

The SELECT statements are normal select statements, but with the following restrictions:

- HIGH_PRIORITY cannot be used with SELECT statements that are part of a UNION. If you specify it for the first SELECT, it has no effect. If you specify it for any subsequent SELECT statements, a syntax error results.

- Only the last SELECT statement can use an INTO clause. However, the entire UNION result is written to the INTO output destination.

By default, duplicate rows are removed from UNION results. The optional DISTINCT keyword has the same effect but makes it explicit. With the optional ALL keyword, duplicate-row removal does not occur and the result includes all matching rows from all the SELECT statements.
You can mix `UNION ALL` and `UNION DISTINCT` in the same query. Mixed `UNION` types are treated such that a `DISTINCT` union overrides any `ALL` union to its left. A `DISTINCT` union can be produced explicitly by using `UNION DISTINCT` or implicitly by using `UNION` with no following `DISTINCT` or `ALL` keyword.

To apply `ORDER BY` or `LIMIT` to an individual `SELECT`, place the clause inside the parentheses that enclose the `SELECT`:

```
(SELECT a FROM t1 WHERE a=10 AND B=1 ORDER BY a LIMIT 10)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2 ORDER BY a LIMIT 10);
```

Use of `ORDER BY` for individual `SELECT` statements implies nothing about the order in which the rows appear in the final result because `UNION` by default produces an unordered set of rows. Therefore, `ORDER BY` in this context typically is used in conjunction with `LIMIT`, to determine the subset of the selected rows to retrieve for the `SELECT`, even though it does not necessarily affect the order of those rows in the final `UNION` result. If `ORDER BY` appears without `LIMIT` in a `SELECT`, it is optimized away because it will have no effect, anyway.

To use an `ORDER BY` or `LIMIT` clause to sort or limit the entire `UNION` result, parenthesize the individual `SELECT` statements and place the `ORDER BY` or `LIMIT` after the last one. The following example uses both clauses:

```
(SELECT a FROM t1 WHERE a=10 AND B=1)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2)
ORDER BY a LIMIT 10;
```

A statement without parentheses is equivalent to one parenthesized as just shown.

This kind of `ORDER BY` cannot use column references that include a table name (that is, names in `tbl_name.col_name` format). Instead, provide a column alias in the first `SELECT` statement and refer to the alias in the `ORDER BY`. (Alternatively, refer to the column in the `ORDER BY` using its column position. However, use of column positions is deprecated.)

Also, if a column to be sorted is aliased, the `ORDER BY` clause must refer to the alias, not the column name. The first of the following statements is permitted, but the second fails with an `Unknown column 'a' in 'order clause'` error:

```
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY b;
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY a;
```

To cause rows in a `UNION` result to consist of the sets of rows retrieved by each `SELECT` one after the other, select an additional column in each `SELECT` to use as a sort column and add an `ORDER BY` following the last `SELECT`:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col;
```

To additionally maintain sort order within individual `SELECT` results, add a secondary column to the `ORDER BY` clause:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col, col1a;
```

Use of an additional column also enables you to determine which `SELECT` each row comes from. Extra columns can provide other identifying information as well, such as a string that indicates a table name.

## 13.2.10 Subqueries
A subquery is a `SELECT` statement within another statement.

All subquery forms and operations that the SQL standard requires are supported, as well as a few features that are MySQL-specific.

Here is an example of a subquery:

```sql
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

In this example, `SELECT * FROM t1` ... is the outer query (or outer statement), and `(SELECT column1 FROM t2)` is the subquery. We say that the subquery is nested within the outer query, and in fact it is possible to nest subqueries within other subqueries, to a considerable depth. A subquery must always appear within parentheses.

The main advantages of subqueries are:

- They allow queries that are structured so that it is possible to isolate each part of a statement.
- They provide alternative ways to perform operations that would otherwise require complex joins and unions.
- Many people find subqueries more readable than complex joins or unions. Indeed, it was the innovation of subqueries that gave people the original idea of calling the early SQL “Structured Query Language.”

Here is an example statement that shows the major points about subquery syntax as specified by the SQL standard and supported in MySQL:

```sql
DELETE FROM t1
WHERE s11 > ANY
  (SELECT COUNT(*) /* no hint */ FROM t2
   WHERE NOT EXISTS
   (SELECT * FROM t3
    WHERE ROW(5*t2.s1,77)=
      (SELECT 50,11*s1 FROM t4 UNION SELECT 50,77 FROM
       (SELECT * FROM t5) AS t5)));
```

A subquery can return a scalar (a single value), a single row, a single column, or a table (one or more rows of one or more columns). These are called scalar, column, row, and table subqueries. Subqueries that return a particular kind of result often can be used only in certain contexts, as described in the following sections.

There are few restrictions on the type of statements in which subqueries can be used. A subquery can contain many of the keywords or clauses that an ordinary `SELECT` can contain: `DISTINCT`, `GROUP BY`, `ORDER BY`, `LIMIT`, joins, index hints, `UNION` constructs, comments, functions, and so on.

A subquery's outer statement can be any one of: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `SET`, or `DO`.

In MySQL, you cannot modify a table and select from the same table in a subquery. This applies to statements such as `DELETE`, `INSERT`, `REPLACE`, `UPDATE`, and (because subqueries can be used in the `SET` clause) `LOAD DATA`.

For information about how the optimizer handles subqueries, see Section 8.2.2, “Subquery Optimization”. For a discussion of restrictions on subquery use, including performance issues for certain forms of subquery syntax, see Section 13.2.10.12, “Restrictions on Subqueries”.

### 13.2.10.1 The Subquery as Scalar Operand

In its simplest form, a subquery is a scalar subquery that returns a single value. A scalar subquery is a simple operand, and you can use it almost anywhere a single column value or literal is legal, and you can...
Subqueries

expect it to have those characteristics that all operands have: a data type, a length, an indication that it can be NULL, and so on. For example:

```sql
CREATE TABLE t1 (s1 INT, s2 CHAR(5) NOT NULL);
INSERT INTO t1 VALUES(100, 'abcde');
SELECT (SELECT s2 FROM t1);
```

The subquery in this `SELECT` returns a single value ("abcde") that has a data type of CHAR, a length of 5, a character set and collation equal to the defaults in effect at CREATE TABLE time, and an indication that the value in the column can be NULL. Nullability of the value selected by a scalar subquery is not copied because if the subquery result is empty, the result is NULL. For the subquery just shown, if `t1` were empty, the result would be NULL even though `s2` is NOT NULL.

There are a few contexts in which a scalar subquery cannot be used. If a statement permits only a literal value, you cannot use a subquery. For example, LIMIT requires literal integer arguments, and LOAD DATA requires a literal string file name. You cannot use subqueries to supply these values.

When you see examples in the following sections that contain the rather spartan construct `(SELECT column1 FROM t1)`, imagine that your own code contains much more diverse and complex constructions.

Suppose that we make two tables:

```sql
CREATE TABLE t1 (s1 INT);
INSERT INTO t1 VALUES (1);
CREATE TABLE t2 (s1 INT);
INSERT INTO t2 VALUES (2);
```

Then perform a `SELECT`:

```sql
SELECT (SELECT s1 FROM t2) FROM t1;
```

The result is 2 because there is a row in `t2` containing a column `s1` that has a value of 2.

A scalar subquery can be part of an expression, but remember the parentheses, even if the subquery is an operand that provides an argument for a function. For example:

```sql
SELECT UPPER((SELECT s1 FROM t1)) FROM t2;
```

### 13.2.10.2 Comparisons Using Subqueries

The most common use of a subquery is in the form:

```
non_subquery_operand comparison_operator (subquery)
```

Where `comparison_operator` is one of these operators:

- `=` `>` `<` `>=` `<=` `<>` `!=` `<>`

For example:

```sql
... WHERE 'a' = (SELECT column1 FROM t1)
```

MySQL also permits this construct:

```
non_subquery_operand LIKE (subquery)
```

At one time the only legal place for a subquery was on the right side of a comparison, and you might still find some old DBMSs that insist on this.
Here is an example of a common-form subquery comparison that you cannot do with a join. It finds all the rows in table \texttt{t1} for which the \texttt{column1} value is equal to a maximum value in table \texttt{t2}:

\begin{verbatim}
SELECT * FROM t1
  WHERE column1 = (SELECT MAX(column2) FROM t2);
\end{verbatim}

Here is another example, which again is impossible with a join because it involves aggregating for one of the tables. It finds all rows in table \texttt{t1} containing a value that occurs twice in a given column:

\begin{verbatim}
SELECT * FROM t1 AS t
  WHERE 2 = (SELECT COUNT(*) FROM t1 WHERE t1.id = t.id);
\end{verbatim}

For a comparison of the subquery to a scalar, the subquery must return a scalar. For a comparison of the subquery to a row constructor, the subquery must be a row subquery that returns a row with the same number of values as the row constructor. See Section 13.2.10.5, “Row Subqueries”.

### 13.2.10.3 Subqueries with ANY, IN, or SOME

**Syntax:**

\begin{verbatim}
operand comparison_operator ANY (subquery)
operand IN (subquery)
operand comparison_operator SOME (subquery)
\end{verbatim}

Where \texttt{comparison_operator} is one of these operators:

>=  >  <  <=  >=  <=  !=  <>

The \texttt{ANY} keyword, which must follow a comparison operator, means “return \texttt{TRUE} if the comparison is \texttt{TRUE} for \texttt{ANY} of the values in the column that the subquery returns.” For example:

\begin{verbatim}
SELECT s1 FROM t1 WHERE s1 > ANY (SELECT s1 FROM t2);
\end{verbatim}

Suppose that there is a row in table \texttt{t1} containing \texttt{(10)}. The expression is \texttt{TRUE} if table \texttt{t2} contains \texttt{(21,14,7)} because there is a value \texttt{7} in \texttt{t2} that is less than \texttt{10}. The expression is \texttt{FALSE} if table \texttt{t2} contains \texttt{(20,10)}, or if table \texttt{t2} is empty. The expression is \texttt{unknown} (that is, \texttt{NULL}) if table \texttt{t2} contains \texttt{(NULL,NULL,NULL)}.

When used with a subquery, the word \texttt{IN} is an alias for \texttt{= ANY}. Thus, these two statements are the same:

\begin{verbatim}
SELECT s1 FROM t1 WHERE s1 > ANY (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 IN (SELECT s1 FROM t2);
\end{verbatim}

\texttt{IN} and \texttt{= ANY} are not synonyms when used with an expression list. \texttt{IN} can take an expression list, but \texttt{= ANY} cannot. See Section 12.3.2, “Comparison Functions and Operators”.

\texttt{NOT IN} is not an alias for \texttt{<> ANY}, but for \texttt{<> ALL}. See Section 13.2.10.4, “Subqueries with ALL”.

The word \texttt{SOME} is an alias for \texttt{ANY}. Thus, these two statements are the same:

\begin{verbatim}
SELECT s1 FROM t1 WHERE s1 <> ANY (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 IN (SELECT s1 FROM t2);
\end{verbatim}

Use of the word \texttt{SOME} is rare, but this example shows why it might be useful. To most people, the English phrase “\texttt{a} is not equal to \texttt{any b}” means “there is no \texttt{b} which is equal to \texttt{a},” but that is not what is meant by the SQL syntax. The syntax means “there is some \texttt{b} to which \texttt{a} is not equal.” Using \texttt{<> SOME} instead helps ensure that everyone understands the true meaning of the query.

### 13.2.10.4 Subqueries with ALL

**Syntax:**
Subqueries

The word `ALL`, which must follow a comparison operator, means “return `TRUE` if the comparison is `TRUE` for `ALL` of the values in the column that the subquery returns.” For example:

```sql
SELECT s1 FROM t1 WHERE s1 > ALL (SELECT s1 FROM t2);
```

Suppose that there is a row in table `t1` containing `(10)`. The expression is `TRUE` if table `t2` contains `(-5,0,+5)` because `10` is greater than all three values in `t2`. The expression is `FALSE` if table `t2` contains `(12,6,NULL,-100)` because there is a single value `12` in table `t2` that is greater than `10`. The expression is `unknown` (that is, `NULL`) if table `t2` contains `(0,NULL,1)`.

Finally, the expression is `TRUE` if table `t2` is empty. So, the following expression is `TRUE` when table `t2` is empty:

```sql
SELECT * FROM t1 WHERE 1 > ALL (SELECT s1 FROM t2);
```

But this expression is `NULL` when table `t2` is empty:

```sql
SELECT * FROM t1 WHERE 1 > (SELECT s1 FROM t2);
```

In addition, the following expression is `NULL` when table `t2` is empty:

```sql
SELECT * FROM t1 WHERE 1 > ALL (SELECT MAX(s1) FROM t2);
```

In general, *tables containing `NULL` values and empty tables* are “edge cases.” When writing subqueries, always consider whether you have taken those two possibilities into account.

`NOT IN` is an alias for `<> ALL`. Thus, these two statements are the same:

```sql
SELECT s1 FROM t1 WHERE s1 <> ALL (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 NOT IN (SELECT s1 FROM t2);
```

### 13.2.10.5 Row Subqueries

Scalar or column subqueries return a single value or a column of values. A *row subquery* is a subquery variant that returns a single row and can thus return more than one column value. Legal operators for row subquery comparisons are:

- `=`  
- `>`  
- `<`  
- `>=`  
- `<=`  
- `<>`  
- `!=`  
- `<=>`

Here are two examples:

```sql
SELECT * FROM t1
WHERE (col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
SELECT * FROM t1
WHERE ROW(col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
```

For both queries, if the table `t2` contains a single row with `id = 10`, the subquery returns a single row. If this row has `col3` and `col4` values equal to the `col1` and `col2` values of any rows in `t1`, the WHERE expression is `TRUE` and each query returns those `t1` rows. If the `t2` row `col3` and `col4` values are not equal the `col1` and `col2` values of any `t1` row, the expression is `FALSE` and the query returns an empty result set. The expression is `unknown` (that is, `NULL`) if the subquery produces no rows. An error occurs if the subquery produces multiple rows because a row subquery can return at most one row.

For information about how each operator works for row comparisons, see Section 12.3.2, “Comparison Functions and Operators”.

The expressions `(1,2)` and `ROW(1,2)` are sometimes called *row constructors*. The two are equivalent. The row constructor and the row returned by the subquery must contain the same number of values.
A row constructor is used for comparisons with subqueries that return two or more columns. When a subquery returns a single column, this is regarded as a scalar value and not as a row, so a row constructor cannot be used with a subquery that does not return at least two columns. Thus, the following query fails with a syntax error:

```sql
SELECT * FROM t1 WHERE ROW(1) = (SELECT column1 FROM t2)
```

Row constructors are legal in other contexts. For example, the following two statements are semantically equivalent (and are handled in the same way by the optimizer):

```sql
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

The following query answers the request, “find all rows in table t1 that also exist in table t2”:

```sql
SELECT column1,column2,column3
FROM t1
WHERE (column1,column2,column3) IN
  (SELECT column1,column2,column3 FROM t2);
```

For more information about the optimizer and row constructors, see Section 8.2.1.15, “Row Constructor Expression Optimization”

### 13.2.10.6 Subqueries with EXISTS or NOT EXISTS

If a subquery returns any rows at all, EXISTS subquery is TRUE, and NOT EXISTS subquery is FALSE. For example:

```sql
SELECT column1 FROM t1 WHERE EXISTS (SELECT * FROM t2);
```

Traditionally, an EXISTS subquery starts with SELECT *, but it could begin with SELECT 5 or SELECT column1 or anything at all. MySQL ignores the SELECT list in such a subquery, so it makes no difference.

For the preceding example, if t2 contains any rows, even rows with nothing but NULL values, the EXISTS condition is TRUE. This is actually an unlikely example because a [NOT] EXISTS subquery almost always contains correlations. Here are some more realistic examples:

- What kind of store is present in one or more cities?

  ```sql
  SELECT DISTINCT store_type FROM stores
  WHERE EXISTS (SELECT * FROM cities_stores
    WHERE cities_stores.store_type = stores.store_type);
  ```

- What kind of store is present in no cities?

  ```sql
  SELECT DISTINCT store_type FROM stores
  WHERE NOT EXISTS (SELECT * FROM cities_stores
    WHERE cities_stores.store_type = stores.store_type);
  ```

- What kind of store is present in all cities?

  ```sql
  SELECT DISTINCT store_type FROM stores s1
  WHERE NOT EXISTS (SELECT * FROM cities WHERE NOT EXISTS (SELECT * FROM cities_stores
    WHERE cities_stores.store_type = stores.store_type;
  ```

  The last example is a double-nested NOT EXISTS query. That is, it has a NOT EXISTS clause within a NOT EXISTS clause. Formally, it answers the question “does a city exist with a store that is not in Stores”? But it is easier to say that a nested NOT EXISTS answers the question “is x TRUE for all y?”
13.2.10.7 Correlated Subqueries

A **correlated subquery** is a subquery that contains a reference to a table that also appears in the outer query. For example:

```sql
SELECT * FROM t1
  WHERE column1 = ANY (SELECT column1 FROM t2
                          WHERE t2.column2 = t1.column2);
```

Notice that the subquery contains a reference to a column of `t1`, even though the subquery's `FROM` clause does not mention a table `t1`. So, MySQL looks outside the subquery, and finds `t1` in the outer query.

Suppose that table `t1` contains a row where `column1 = 5` and `column2 = 6`; meanwhile, table `t2` contains a row where `column1 = 5` and `column2 = 7`. The simple expression `... WHERE column1 = ANY (SELECT column1 FROM t2)` would be **TRUE**, but in this example, the `WHERE` clause within the subquery is **FALSE** (because `(5,6)` is not equal to `(5,7)`), so the expression as a whole is **FALSE**.

**Scoping rule:** MySQL evaluates from inside to outside. For example:

```sql
SELECT column1 FROM t1 AS x
  WHERE x.column1 = (SELECT column1 FROM t2 AS x
                        WHERE x.column1 = (SELECT column1 FROM t3
                                                WHERE x.column2 = t3.column1));
```

In this statement, `x.column2` must be a column in table `t2` because `SELECT column1 FROM t2 AS x ...` renames `t2`. It is not a column in table `t1` because `SELECT column1 FROM t1 ...` is an outer query that is **farther out**.

For subqueries in `HAVING` or `ORDER BY` clauses, MySQL also looks for column names in the outer select list.

For certain cases, a correlated subquery is optimized. For example:

```sql
val IN (SELECT key_val FROM tbl_name WHERE correlated_condition)
```

Otherwise, they are inefficient and likely to be slow. Rewriting the query as a join might improve performance.

Aggregate functions in correlated subqueries may contain outer references, provided the function contains nothing but outer references, and provided the function is not contained in another function or expression.

13.2.10.8 Derived Tables

A derived table is an expression that generates a table within the scope of a query `FROM` clause. For example, a subquery in a `SELECT` statement `FROM` clause is a derived table:

```sql
SELECT ... FROM (subquery) [AS] tbl_name ...
```

The `[AS] tbl_name` clause is mandatory because every table in a `FROM` clause must have a name. Any columns in the derived table must have unique names.

For the sake of illustration, assume that you have this table:

```sql
CREATE TABLE t1 (s1 INT, s2 CHAR(5), s3 FLOAT);
```

Here is how to use a subquery in the `FROM` clause, using the example table:

```sql
INSERT INTO t1 VALUES (1,'1',1.0);
INSERT INTO t1 VALUES (2,'2',2.0);
```
Subqueries

```sql
SELECT sb1, sb2, sb3
FROM (SELECT s1 AS sb1, s2 AS sb2, s3*2 AS sb3 FROM t1) AS sb
WHERE sb1 > 1;
```

Result:

```
+------+------+------+
<table>
<thead>
<tr>
<th>sb1</th>
<th>sb2</th>
<th>sb3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
+------+------+------+
```

Here is another example: Suppose that you want to know the average of a set of sums for a grouped table. This does not work:

```sql
SELECT AVG(SUM(column1)) FROM t1 GROUP BY column1;
```

However, this query provides the desired information:

```sql
SELECT AVG(sum_column1)
FROM (SELECT SUM(column1) AS sum_column1
FROM t1 GROUP BY column1) AS t1;
```

Notice that the column name used within the subquery (sum_column1) is recognized in the outer query.

A derived table can return a scalar, column, row, or table.

Derived tables are subject to these restrictions:

- A derived table cannot be a correlated subquery.
- A derived table cannot contain references to other tables of the same `SELECT`.
- A derived table cannot contain outer references. This is a MySQL restriction, not a restriction of the SQL standard.

Subqueries in the `FROM` clause are executed even for the `EXPLAIN` statement (that is, derived temporary tables are materialized). This occurs because upper-level queries need information about all tables during the optimization phase, and the table represented by a subquery in the `FROM` clause is unavailable unless the subquery is executed.

It is possible under certain circumstances that using `EXPLAIN SELECT` will modify table data. This can occur if the outer query accesses any tables and an inner query invokes a stored function that changes one or more rows of a table. Suppose that there are two tables `t1` and `t2` in database `d1`, and a stored function `f1` that modifies `t2`, created as shown here:

```sql
CREATE DATABASE d1;
USE d1;
CREATE TABLE t1 (c1 INT);
CREATE TABLE t2 (c1 INT);
CREATE FUNCTION f1(p1 INT) RETURNS INT
BEGIN
    INSERT INTO t2 VALUES (p1);
    RETURN p1;
END;
```

Referencing the function directly in an `EXPLAIN SELECT` has no effect on `t2`, as shown here:

```
mysql> SELECT * FROM t2;
Empty set (0.02 sec)
```
Subqueries

mysql> EXPLAIN SELECT f1(5)\G
+-----------------------------+---------+------------------------------------------+
| id  | select_type | table | type | possible_keys | key | key_len | ref | rows | filtered | Extra                              |
+-----+-------------+-------+------+--------------+-----+---------+-----+------+----------+-------------------------------------+
|    1| SIMPLE      | NULL  | NULL | NULL         | NULL| NULL    | NULL| NULL | NULL     | No tables used                      |
+-----+-------------+-------+------+--------------+-----+---------+-----+------+----------+-------------------------------------+
1 row in set (0.01 sec)

This is because the `SELECT` statement did not reference any tables, as can be seen in the `table` and `Extra` columns of the output. This is also true of the following nested `SELECT`:

mysql> EXPLAIN SELECT NOW() AS a1, (SELECT f1(5)) AS a2\G
+-----------------------------+-------------+------------------------------------------+
| id  | select_type | table | type         | possible_keys | key | key_len | ref | rows | filtered | Extra                              |
+-----+-------------+-------+-------------+--------------+-----+---------+-----+------+----------+-------------------------------------+
|    1| PRIMARY     | NULL  | NULL        | NULL         | NULL| NULL    | NULL| NULL | NULL     | No tables used                      |
+-----+-------------+-------+-------------+--------------+-----+---------+-----+------+----------+-------------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+------------------------------------------+
| Level | Code | Message                                  |
+-------+------+------------------------------------------+
| Note  | 1249 | Select 2 was reduced during optimization |
+-------+------+------------------------------------------+
1 row in set (0.00 sec)

However, if the outer `SELECT` references any tables, the optimizer executes the statement in the subquery as well, with the result that `t2` is modified:

mysql> EXPLAIN SELECT * FROM t1 AS a1, (SELECT f1(5)) AS a2\G
+-----------------------------+-------------+------------------------------------------+
| id  | select_type | table | type | possible_keys | key | key_len | ref | rows | filtered | Extra                              |
+-----+-------------+-------+------|--------------+-----+---------+-----+------+----------+-------------------------------------+
|    2| PRIMARY     | a1    | ALL  | NULL         | NULL| NULL    | NULL| 1    | NULL     |                                    |
+-----+-------------+-------+------|--------------+-----+---------+-----+------+----------+-------------------------------------+
1 row in set (0.01 sec)

1537
This also means that an `EXPLAIN SELECT` statement such as the one shown here may take a long time to execute because the `BENCHMARK()` function is executed once for each row in `t1`:

```
EXPLAIN SELECT * FROM t1 AS a1, (SELECT BENCHMARK(1000000, MD5(NOW())));
```

### 13.2.10.9 Subquery Errors

There are some errors that apply only to subqueries. This section describes them.

- **Unsupported subquery syntax:**

  ```
  ERROR 1235 (ER_NOT_SUPPORTED_YET)
  SQLSTATE = 42000
  Message = "This version of MySQL doesn't yet support 'LIMIT & IN/ALL/ANY/SOME subquery'"
  ```

  This means that MySQL does not support statements of the following form:

  ```
  SELECT * FROM t1 WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1)
  ```

- **Incorrect number of columns from subquery:**

  ```
  ERROR 1241 (ER_OPERAND_COL)
  SQLSTATE = 21000
  Message = "Operand should contain 1 column(s)"
  ```

  This error occurs in cases like this:

  ```
  SELECT (SELECT column1, column2 FROM t2) FROM t1;
  ```

  You may use a subquery that returns multiple columns, if the purpose is row comparison. In other contexts, the subquery must be a scalar operand. See Section 13.2.10.5, “Row Subqueries”.

- **Incorrect number of rows from subquery:**

  ```
  ERROR 1242 (ER_SUBSELECT_NO_1_ROW)
  SQLSTATE = 21000
  ```
Subqueries

Message = "Subquery returns more than 1 row"

This error occurs for statements where the subquery must return at most one row but returns multiple rows. Consider the following example:

```sql
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

If `SELECT column1 FROM t2` returns just one row, the previous query will work. If the subquery returns more than one row, error 1242 will occur. In that case, the query should be rewritten as:

```sql
SELECT * FROM t1 WHERE column1 = ANY (SELECT column1 FROM t2);
```

- Incorrectly used table in subquery:

```
<table>
<thead>
<tr>
<th>Error 1093 (ER_UPDATE_TABLE_USED)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQLSTATE = HY000</td>
</tr>
<tr>
<td>Message = &quot;You can't specify target table 'x' for update in FROM clause&quot;</td>
</tr>
</tbody>
</table>
```

This error occurs in cases such as the following, which attempts to modify a table and select from the same table in the subquery:

```sql
UPDATE t1 SET column2 = (SELECT MAX(column1) FROM t1);
```

You can use a subquery for assignment within an `UPDATE` statement because subqueries are legal in `UPDATE` and `DELETE` statements as well as in `SELECT` statements. However, you cannot use the same table (in this case, table `t1`) for both the subquery `FROM` clause and the update target.

For transactional storage engines, the failure of a subquery causes the entire statement to fail. For nontransactional storage engines, data modifications made before the error was encountered are preserved.

### 13.2.10.10 Optimizing Subqueries

Development is ongoing, so no optimization tip is reliable for the long term. The following list provides some interesting tricks that you might want to play with. See also Section 8.2.2, “Subquery Optimization”.

- Use subquery clauses that affect the number or order of the rows in the subquery. For example:

```sql
SELECT * FROM t1 WHERE t1.column1 IN
(SELECT column1 FROM t2 ORDER BY column1);
SELECT * FROM t1 WHERE t1.column1 IN
(SELECT DISTINCT column1 FROM t2);
SELECT * FROM t1 WHERE EXISTS
(SELECT * FROM t2 LIMIT 1);
```

- Replace a join with a subquery. For example, try this:

```sql
SELECT DISTINCT column1 FROM t1 WHERE t1.column1 IN {
    SELECT column1 FROM t2);
```

Instead of this:

```sql
SELECT DISTINCT t1.column1 FROM t1, t2
WHERE t1.column1 = t2.column1;
```

- Some subqueries can be transformed to joins for compatibility with older versions of MySQL that do not support subqueries. However, in some cases, converting a subquery to a join may improve performance. See Section 13.2.10.11, “Rewriting Subqueries as Joins”.

- Move clauses from outside to inside the subquery. For example, use this query:
Subqueries

SELECT * FROM t1
WHERE s1 IN (SELECT s1 FROM t1 UNION ALL SELECT s1 FROM t2);

Instead of this query:

SELECT * FROM t1
WHERE s1 IN (SELECT s1 FROM t1) OR s1 IN (SELECT s1 FROM t2);

For another example, use this query:

SELECT (SELECT column1 + 5 FROM t1) FROM t2;

Instead of this query:

SELECT (SELECT column1 FROM t1) + 5 FROM t2;

• Use a row subquery instead of a correlated subquery. For example, use this query:

SELECT * FROM t1
WHERE (column1,column2) IN (SELECT column1,column2 FROM t2);

Instead of this query:

SELECT * FROM t1
WHERE EXISTS (SELECT * FROM t2 WHERE t2.column1=t1.column1
AND t2.column2=t1.column2);

• Use NOT (a = ANY (...)) rather than a <> ALL (...).

• Use x = ANY (table containing (1,2)) rather than x=1 OR x=2.

• Use = ANY rather than EXISTS.

• For uncorrelated subqueries that always return one row, IN is always slower than =. For example, use this query:

SELECT * FROM t1
WHERE t1.col_name = (SELECT a FROM t2 WHERE b = some_const);

Instead of this query:

SELECT * FROM t1
WHERE t1.col_name IN (SELECT a FROM t2 WHERE b = some_const);

These tricks might cause programs to go faster or slower. Using MySQL facilities like the BENCHMARK() function, you can get an idea about what helps in your own situation. See Section 12.15, “Information Functions”.

Some optimizations that MySQL itself makes are:

• MySQL executes uncorrelated subqueries only once. Use EXPLAIN to make sure that a given subquery really is uncorrelated.

• MySQL rewrites IN, ALL, ANY, and SOME subqueries in an attempt to take advantage of the possibility that the select-list columns in the subquery are indexed.

• MySQL replaces subqueries of the following form with an index-lookup function, which EXPLAIN describes as a special join type (unique_subquery or index_subquery):

    ... IN (SELECT indexed_column FROM single_table ...)

• MySQL enhances expressions of the following form with an expression involving \texttt{MIN()} or \texttt{MAX()}, unless \texttt{NULL} values or empty sets are involved:

\begin{verbatim}
value \{ALL|ANY|SOME\} \{> | < | >= | <=\} (uncorrelated subquery)
\end{verbatim}

For example, this \texttt{WHERE} clause:

\begin{verbatim}
WHERE 5 > ALL (SELECT x FROM t)
\end{verbatim}

might be treated by the optimizer like this:

\begin{verbatim}
WHERE 5 > (SELECT MAX(x) FROM t)
\end{verbatim}

See also MySQL Internals: How MySQL Transforms Subqueries.

13.2.10.11 Rewriting Subqueries as Joins

Sometimes there are other ways to test membership in a set of values than by using a subquery. Also, on some occasions, it is not only possible to rewrite a query without a subquery, but it can be more efficient to make use of some of these techniques rather than to use subqueries. One of these is the \texttt{IN()} construct:

For example, this query:

\begin{verbatim}
SELECT * FROM t1 WHERE id IN (SELECT id FROM t2);
\end{verbatim}

Can be rewritten as:

\begin{verbatim}
SELECT DISTINCT t1.* FROM t1, t2 WHERE t1.id=t2.id;
\end{verbatim}

The queries:

\begin{verbatim}
SELECT * FROM t1 WHERE id NOT IN (SELECT id FROM t2);
SELECT * FROM t1 WHERE NOT EXISTS (SELECT id FROM t2 WHERE t1.id=t2.id);
\end{verbatim}

Can be rewritten as:

\begin{verbatim}
SELECT table1.*
FROM table1 LEFT JOIN table2 ON table1.id=table2.id
WHERE table2.id IS NULL;
\end{verbatim}

A \texttt{LEFT [OUTER] JOIN} can be faster than an equivalent subquery because the server might be able to optimize it better—a fact that is not specific to MySQL Server alone. Prior to SQL-92, outer joins did not exist, so subqueries were the only way to do certain things. Today, MySQL Server and many other modern database systems offer a wide range of outer join types.

MySQL Server supports multiple-table \texttt{DELETE} statements that can be used to efficiently delete rows based on information from one table or even from many tables at the same time. Multiple-table \texttt{UPDATE} statements are also supported. See Section 13.2.2, “DELETE Statement”, and Section 13.2.11, “UPDATE Statement”.

13.2.10.12 Restrictions on Subqueries

• Subquery optimization for \texttt{IN} is not as effective as for the \texttt{=} operator or for the \texttt{IN(value_list)} operator.

A typical case for poor \texttt{IN} subquery performance is when the subquery returns a small number of rows but the outer query returns a large number of rows to be compared to the subquery result.
Subqueries

The problem is that, for a statement that uses an `IN` subquery, the optimizer rewrites it as a correlated subquery. Consider the following statement that uses an uncorrelated subquery:

```sql
SELECT ... FROM t1 WHERE t1.a IN (SELECT b FROM t2);
```

The optimizer rewrites the statement to a correlated subquery:

```sql
SELECT ... FROM t1 WHERE EXISTS (SELECT 1 FROM t2 WHERE t2.b = t1.a);
```

If the inner and outer queries return $M$ and $N$ rows, respectively, the execution time becomes on the order of $O(M \times N)$, rather than $O(M + N)$ as it would be for an uncorrelated subquery.

An implication is that an `IN` subquery can be much slower than a query written using an `IN(value_list)` operator that lists the same values that the subquery would return.

- In general, you cannot modify a table and select from the same table in a subquery. For example, this limitation applies to statements of the following forms:

  ```sql
  DELETE FROM t WHERE ... (SELECT ... FROM t ...);
  UPDATE t ... WHERE col = (SELECT ... FROM t ...);
  {INSERT|REPLACE} INTO t (SELECT ... FROM t ...);
  ```

  Exception: The preceding prohibition does not apply if for the modified table you are using a derived table and that derived table is materialized rather than merged into the outer query. Example:

  ```sql
  UPDATE t ... WHERE col = (SELECT * FROM (SELECT ... FROM t...) AS _t ...);
  ```

  Here the result from the derived table is materialized as a temporary table, so the relevant rows in $t$ have already been selected by the time the update to $t$ takes place.

- Row comparison operations are only partially supported:

  - For `expr [NOT] IN subquery`, `expr` can be an $n$-tuple (specified using row constructor syntax) and the subquery can return rows of $n$-tuples. The permitted syntax is therefore more specifically expressed as `row_constructor [NOT] IN table_subquery`

  - For `expr op {ALL|ANY|SOME} subquery`, `expr` must be a scalar value and the subquery must be a column subquery; it cannot return multiple-column rows.

In other words, for a subquery that returns rows of $n$-tuples, this is supported:

```sql
(expr_1, ..., expr_n) [NOT] IN table_subquery
```

But this is not supported:

```sql
(expr_1, ..., expr_n) op {ALL|ANY|SOME} subquery
```

The reason for supporting row comparisons for `IN` but not for the others is that `IN` is implemented by rewriting it as a sequence of `=` comparisons and `AND` operations. This approach cannot be used for `ALL`, `ANY`, or `SOME`.

- Subqueries in the `FROM` clause cannot be correlated subqueries. They are materialized in whole (evaluated to produce a result set) before evaluating the outer query, so they cannot be evaluated per row of the outer query.

- MySQL does not support `LIMIT` in subqueries for certain subquery operators:
UPDATE Statement

ERROR 1235 (42000): This version of MySQL doesn't yet support 'LIMIT & IN/ALL/ANY/SOME subquery'

• The optimizer is more mature for joins than for subqueries, so in many cases a statement that uses a subquery can be executed more efficiently if you rewrite it as a join.

An exception occurs for the case where an IN subquery can be rewritten as a SELECT DISTINCT join. Example:

```sql
SELECT col FROM t1 WHERE id_col IN (SELECT id_col2 FROM t2 WHERE condition);
```

That statement can be rewritten as follows:

```sql
SELECT DISTINCT col FROM t1, t2 WHERE t1.id_col = t2.id_col AND condition;
```

But in this case, the join requires an extra DISTINCT operation and is not more efficient than the subquery.

• MySQL permits a subquery to refer to a stored function that has data-modifying side effects such as inserting rows into a table. For example, if \( f() \) inserts rows, the following query can modify data:

```sql
SELECT ... WHERE x IN (SELECT f() ...);
```

This behavior is an extension to the SQL standard. In MySQL, it can produce nondeterministic results because \( f() \) might be executed a different number of times for different executions of a given query depending on how the optimizer chooses to handle it.

For statement-based or mixed-format replication, one implication of this indeterminism is that such a query can produce different results on the master and its slaves.

13.2.11 UPDATE Statement

UPDATE is a DML statement that modifies rows in a table.

Single-table syntax:

```sql
UPDATE [LOW_PRIORITY] [IGNORE] table_reference
    SET assignment_list
    [WHERE where_condition]
    [ORDER BY ...]
    [LIMIT row_count]
```

value:
```sql
{expr | DEFAULT}
```

assignment:
```sql
col_name = value
```

assignment_list:
```sql
    assignment [, assignment] ...
```

Multiple-table syntax:

```sql
UPDATE [LOW_PRIORITY] [IGNORE] table_references
    SET assignment_list
    [WHERE where_condition]
```

For the single-table syntax, the UPDATE statement updates columns of existing rows in the named table with new values. The SET clause indicates which columns to modify and the values they should be given. Each value can be given as an expression, or the keyword DEFAULT to set a column explicitly to its default value. The WHERE clause, if given, specifies the conditions that identify which rows to update. With no
**UPDATE Statement**

*WHERE* clause, all rows are updated. If the *ORDER BY* clause is specified, the rows are updated in the order that is specified. The *LIMIT* clause places a limit on the number of rows that can be updated.

For the multiple-table syntax, *UPDATE* updates rows in each table named in *table_references* that satisfy the conditions. Each matching row is updated once, even if it matches the conditions multiple times. For multiple-table syntax, *ORDER BY* and *LIMIT* cannot be used.

*where_condition* is an expression that evaluates to true for each row to be updated. For expression syntax, see Section 9.5, “Expressions”.

*table_references* and *where_condition* are specified as described in Section 13.2.9, “SELECT Statement”.

You need the *UPDATE* privilege only for columns referenced in an *UPDATE* that are actually updated. You need only the *SELECT* privilege for any columns that are read but not modified.

The *UPDATE* statement supports the following modifiers:

- With the *LOW_PRIORITY* modifier, execution of the *UPDATE* is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as *MyISAM*, *MEMORY*, and *MERGE*).

- With the *IGNORE* modifier, the update statement does not abort even if errors occur during the update. Rows for which duplicate-key conflicts occur on a unique key value are not updated. Rows updated to values that would cause data conversion errors are updated to the closest valid values instead.

In MySQL 5.5.18 and later, *UPDATE IGNORE* statements, including those having an *ORDER BY* clause, are flagged as unsafe for statement-based replication. (This is because the order in which the rows are updated determines which rows are ignored.) Such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using *MIXED* mode. (Bug #11758262, Bug #50439) See Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”, for more information.

If you access a column from the table to be updated in an expression, *UPDATE* uses the current value of the column. For example, the following statement sets *col1* to one more than its current value:

```
UPDATE t1 SET col1 = col1 + 1;
```

The second assignment in the following statement sets *col2* to the current (updated) *col1* value, not the original *col1* value. The result is that *col1* and *col2* have the same value. This behavior differs from standard SQL.

```
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

Single-table *UPDATE* assignments are generally evaluated from left to right. For multiple-table updates, there is no guarantee that assignments are carried out in any particular order.

If you set a column to the value it currently has, MySQL notices this and does not update it.

If you update a column that has been declared *NOT NULL* by setting to *NULL*, an error occurs if strict SQL mode is enabled; otherwise, the column is set to the implicit default value for the column data type and the warning count is incremented. The implicit default value is 0 for numeric types, the empty string ("") for string types, and the “zero” value for date and time types. See Section 11.5, “Data Type Default Values”.

*UPDATE* returns the number of rows that were actually changed. The *mysql_info()* C API function returns the number of rows that were matched and updated and the number of warnings that occurred during the *UPDATE*. 
You can use `LIMIT row_count` to restrict the scope of the `UPDATE`. A `LIMIT` clause is a rows-matched restriction. The statement stops as soon as it has found `row_count` rows that satisfy the `WHERE` clause, whether or not they actually were changed.

If an `UPDATE` statement includes an `ORDER BY` clause, the rows are updated in the order specified by the clause. This can be useful in certain situations that might otherwise result in an error. Suppose that a table `t` contains a column `id` that has a unique index. The following statement could fail with a duplicate-key error, depending on the order in which rows are updated:

```
UPDATE t SET id = id + 1;
```

For example, if the table contains 1 and 2 in the `id` column and 1 is updated to 2 before 2 is updated to 3, an error occurs. To avoid this problem, add an `ORDER BY id` clause to cause the rows with larger `id` values to be updated before those with smaller values:

```
UPDATE t SET id = id + 1 ORDER BY id DESC;
```

You can also perform `UPDATE` operations covering multiple tables. However, you cannot use `ORDER BY` or `LIMIT` with a multiple-table `UPDATE`. The `table_references` clause lists the tables involved in the join. Its syntax is described in Section 13.2.9.2, “JOIN Clause”. Here is an example:

```
UPDATE items,month SET items.price=month.price
WHERE items.id=month.id;
```

The preceding example shows an inner join that uses the comma operator, but multiple-table `UPDATE` statements can use any type of join permitted in `SELECT` statements, such as `LEFT JOIN`.

If you use a multiple-table `UPDATE` statement involving InnoDB tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, update a single table and rely on the `ON UPDATE` capabilities that InnoDB provides to cause the other tables to be modified accordingly. See Section 13.1.17.6, “FOREIGN KEY Constraints”.

You cannot update a table and select from the same table in a subquery.

An `UPDATE` on a partitioned table using a storage engine such as MyISAM that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

### 13.3 Transactional and Locking Statements

MySQL supports local transactions (within a given client session) through statements such as `SET autocommit`, `START TRANSACTION`, `COMMIT`, and `ROLLBACK`. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”. XA transaction support enables MySQL to participate in distributed transactions as well. See Section 13.3.7, “XA Transactions”.

#### 13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Statements

```
START TRANSACTION [WITH CONSISTENT SNAPSHOT]
BEGIN [WORK]
COMMIT [WORK] [AND [NO] CHAIN] [AND [NO] RELEASE]
ROLLBACK [WORK] [AND [NO] CHAIN] [AND [NO] RELEASE]
SET autocommit = {0 | 1}
```

These statements provide control over use of transactions:

- `START TRANSACTION` or `BEGIN` start a new transaction.
START TRANSACTION, COMMIT, and ROLLBACK Statements

- **COMMIT** commits the current transaction, making its changes permanent.
- **ROLLBACK** rolls back the current transaction, canceling its changes.
- **SET autocommit** disables or enables the default autocommit mode for the current session.

By default, MySQL runs with autocommit mode enabled. This means that, when not otherwise inside a transaction, each statement is atomic, as if it were surrounded by `START TRANSACTION` and `COMMIT`. You cannot use `ROLLBACK` to undo the effect; however, if an error occurs during statement execution, the statement is rolled back.

To disable autocommit mode implicitly for a single series of statements, use the `START TRANSACTION` statement:

```
START TRANSACTION;
SELECT @A:=SUM(salary) FROM table1 WHERE type=1;
UPDATE table2 SET summary=@A WHERE type=1;
COMMIT;
```

With `START TRANSACTION`, autocommit remains disabled until you end the transaction with `COMMIT` or `ROLLBACK`. The autocommit mode then reverts to its previous state.

You can also begin a transaction like this:

```
START TRANSACTION WITH CONSISTENT SNAPSHOT;
```

The `WITH CONSISTENT SNAPSHOT` option starts a consistent read for storage engines that are capable of it. This applies only to InnoDB. The effect is the same as issuing a `START TRANSACTION` followed by a `SELECT` from any InnoDB table. See Section 14.10.2.3, “Consistent Nonlocking Reads”. The `WITH CONSISTENT SNAPSHOT` option does not change the current transaction isolation level, so it provides a consistent snapshot only if the current isolation level is one that permits a consistent read. The only isolation level that permits a consistent read is REPEATABLE READ. For all other isolation levels, the `WITH CONSISTENT SNAPSHOT` clause is ignored. As of MySQL 5.5.34, a warning is generated when the `WITH CONSISTENT SNAPSHOT` is ignored.

Important

Many APIs used for writing MySQL client applications (such as JDBC) provide their own methods for starting transactions that can (and sometimes should) be used instead of sending a `START TRANSACTION` statement from the client. See Chapter 23, Connectors and APIs, or the documentation for your API, for more information.

To disable autocommit mode explicitly, use the following statement:

```
SET autocommit=0;
```

After disabling autocommit mode by setting the autocommit variable to zero, changes to transaction-safe tables (such as those for InnoDB or NDBCLUSTER) are not made permanent immediately. You must use `COMMIT` to store your changes to disk or `ROLLBACK` to ignore the changes.

`autocommit` is a session variable and must be set for each session. To disable autocommit mode for each new connection, see the description of the `autocommit` system variable at Section 5.1.7, “Server System Variables”.

`BEGIN` and `BEGIN WORK` are supported as aliases of `START TRANSACTION` for initiating a transaction. `START TRANSACTION` is standard SQL syntax and is the recommended way to start an ad-hoc transaction.
The `BEGIN` statement differs from the use of the `BEGIN ... END` compound statement. The latter does not begin a transaction. See Section 13.6.1, “BEGIN ... END Compound Statement”.

![Note]

Within all stored programs (stored procedures and functions, triggers, and events), the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. Begin a transaction in this context with `START TRANSACTION` instead.

The optional `WORK` keyword is supported for `COMMIT` and `ROLLBACK`, as are the `CHAIN` and `RELEASE` clauses. `CHAIN` and `RELEASE` can be used for additional control over transaction completion. The value of the `completion_type` system variable determines the default completion behavior. See Section 5.1.7, “Server System Variables”.

The `AND CHAIN` clause causes a new transaction to begin as soon as the current one ends, and the new transaction has the same isolation level as the just-terminated transaction. The new transaction also uses the same access mode (`READ WRITE` or `READ ONLY`) as the just-terminated transaction. The `RELEASE` clause causes the server to disconnect the current client session after terminating the current transaction. Including the `NO` keyword suppresses `CHAIN` or `RELEASE` completion, which can be useful if the `completion_type` system variable is set to cause chaining or release completion by default.

Beginning a transaction causes any pending transaction to be committed. See Section 13.3.3, “Statements That Cause an Implicit Commit”, for more information.

Beginning a transaction also causes table locks acquired with `LOCK TABLES` to be released, as though you had executed `UNLOCK TABLES`. Beginning a transaction does not release a global read lock acquired with `FLUSH TABLES WITH READ LOCK`.

For best results, transactions should be performed using only tables managed by a single transaction-safe storage engine. Otherwise, the following problems can occur:

- If you use tables from more than one transaction-safe storage engine (such as InnoDB), and the transaction isolation level is not `SERIALIZABLE`, it is possible that when one transaction commits, another ongoing transaction that uses the same tables will see only some of the changes made by the first transaction. That is, the atomicity of transactions is not guaranteed with mixed engines and inconsistencies can result. (If mixed-engine transactions are infrequent, you can use `SET TRANSACTION ISOLATION LEVEL` to set the isolation level to `SERIALIZABLE` on a per-transaction basis as necessary.)

- If you use tables that are not transaction-safe within a transaction, changes to those tables are stored at once, regardless of the status of autocommit mode.

- If you issue a `ROLLBACK` statement after updating a nontransactional table within a transaction, an `ER_WARNING_NOT_COMPLETE_ROLLBACK` warning occurs. Changes to transaction-safe tables are rolled back, but not changes to nontransactional table.

Each transaction is stored in the binary log in one chunk, upon `COMMIT`. Transactions that are rolled back are not logged. (Exception: Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a `ROLLBACK` statement at the end to ensure that modifications to the nontransactional tables are replicated.) See Section 5.4.4, “The Binary Log”.

You can change the isolation level for transactions with the `SET TRANSACTION` statement. See Section 13.3.6, “SET TRANSACTION Statement”. 

1547
Rolling back can be a slow operation that may occur implicitly without the user having explicitly asked for it (for example, when an error occurs). Because of this, `SHOW PROCESSLIST` displays `Rolling back` in the State column for the session, not only for explicit rollbacks performed with the `ROLLBACK` statement but also for implicit rollbacks.

Note

In MySQL 5.5, `BEGIN`, `COMMIT`, and `ROLLBACK` are not affected by `--replicate-do-db` or `--replicate-ignore-db` rules.

13.3.2 Statements That Cannot Be Rolled Back

Some statements cannot be rolled back. In general, these include data definition language (DDL) statements, such as those that create or drop databases, those that create, drop, or alter tables or stored routines.

You should design your transactions not to include such statements. If you issue a statement early in a transaction that cannot be rolled back, and then another statement later fails, the full effect of the transaction cannot be rolled back in such cases by issuing a `ROLLBACK` statement.

13.3.3 Statements That Cause an Implicit Commit

The statements listed in this section (and any synonyms for them) implicitly end any transaction active in the current session, as if you had done a `COMMIT` before executing the statement.

Most of these statements also cause an implicit commit after executing. The intent is to handle each such statement in its own special transaction because it cannot be rolled back anyway. Transaction-control and locking statements are exceptions: If an implicit commit occurs before execution, another does not occur after.

- **Data definition language (DDL) statements that define or modify database objects.** `ALTER DATABASE ... UPGRADE DATA DIRECTORY NAME, ALTER EVENT, ALTER PROCEDURE, ALTER SERVER, ALTER TABLE, ALTER VIEW, CREATE DATABASE, CREATE EVENT, CREATE INDEX, CREATE PROCEDURE, CREATE SERVER, CREATE TABLE, CREATE TRIGGER, CREATE VIEW, DROP DATABASE, DROP EVENT, DROP INDEX, DROP PROCEDURE, DROP SERVER, DROP TABLE, DROP TRIGGER, DROP VIEW, RENAME TABLE, TRUNCATE TABLE.`

  `ALTER FUNCTION, CREATE FUNCTION` and `DROP FUNCTION` also cause an implicit commit when used with stored functions, but not with user-defined functions. (`ALTER FUNCTION` can only be used with stored functions.)

  `CREATE TABLE` and `DROP TABLE` statements do not commit a transaction if the `TEMPORARY` keyword is used. (This does not apply to other operations on temporary tables such as `ALTER TABLE` and `CREATE INDEX`, which do cause a commit.) However, although no implicit commit occurs, neither can the statement be rolled back, which means that the use of such statements causes transactional atomicity to be violated. For example, if you use `CREATE TEMPORARY TABLE` and then roll back the transaction, the table remains in existence.

The `CREATE TABLE` statement in InnoDB is processed as a single transaction. This means that a `ROLLBACK` from the user does not undo `CREATE TABLE` statements the user made during that transaction.

`CREATE TABLE ... SELECT` causes an implicit commit before and after the statement is executed when you are creating nontemporary tables. (No commit occurs for `CREATE TEMPORARY TABLE ... SELECT`.)
SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements

- **Statements that implicitly use or modify tables in the `mysql` database.** `CREATE USER`, `DROP USER`, `GRANT`, `RENAME USER`, `REVOKE`, `SET PASSWORD`.

- **Transaction-control and locking statements.** `BEGIN`, `LOCK TABLES`, `SET autocommit = 1` (if the value is not already 1), `START TRANSACTION`, `UNLOCK TABLES`.

  `UNLOCK TABLES` commits a transaction only if any tables currently have been locked with `LOCK TABLES` to acquire nontransactional table locks. A commit does not occur for `UNLOCK TABLES` following `FLUSH TABLES WITH READ LOCK` because the latter statement does not acquire table-level locks.

Transactions cannot be nested. This is a consequence of the implicit commit performed for any current transaction when you issue a `START TRANSACTION` statement or one of its synonyms.

  Statements that cause an implicit commit cannot be used in an XA transaction while the transaction is in an **ACTIVE** state.

  The `BEGIN` statement differs from the use of the `BEGIN` keyword that starts a `BEGIN ... END` compound statement. The latter does not cause an implicit commit. See Section 13.6.1, "BEGIN ... END Compound Statement”.

- **Data loading statements.** `LOAD DATA`. `LOAD DATA` causes an implicit commit only for tables using the `NDB` storage engine.

- **Administrative statements.** `ANALYZE TABLE`, `CACHE INDEX`, `CHECK TABLE`, `LOAD INDEX INTO CACHE`, `OPTIMIZE TABLE`, `REPAIR TABLE`.

13.3.4 SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements

<table>
<thead>
<tr>
<th>SQL Statement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>SAVEPOINT identifier</code></td>
<td>Sets a named transaction savepoint with a name of <code>identifier</code>. If the current transaction has a savepoint with the same name, the old savepoint is deleted and a new one is set.</td>
</tr>
<tr>
<td><code>ROLLBACK [WORK] TO [SAVEPOINT] identifier</code></td>
<td>Rolls back a transaction to the named savepoint without terminating the transaction. Modifications that the current transaction made to rows after the savepoint was set are undone in the rollback, but <code>InnoDB</code> does not release the row locks that were stored in memory after the savepoint. (For a new inserted row, the lock information is carried by the transaction ID stored in the row; the lock is not separately stored in memory. In this case, the row lock is released in the undo.) Savepoints that were set at a later time than the named savepoint are deleted.</td>
</tr>
<tr>
<td><code>RELEASE SAVEPOINT identifier</code></td>
<td>Removes the named savepoint from the set of savepoints of the current transaction. No commit or rollback occurs. It is an error if the savepoint does not exist.</td>
</tr>
</tbody>
</table>

If the `ROLLBACK TO SAVEPOINT` statement returns the following error, it means that no savepoint with the specified name exists:

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERROR 1305 (42000): <code>SAVEPOINT identifier</code> does not exist</td>
<td></td>
</tr>
</tbody>
</table>

The `RELEASE SAVEPOINT` statement removes the named savepoint from the set of savepoints of the current transaction. No commit or rollback occurs. It is an error if the savepoint does not exist.

All savepoints of the current transaction are deleted if you execute a `COMMIT`, or a `ROLLBACK` that does not name a savepoint.
A new savepoint level is created when a stored function is invoked or a trigger is activated. The savepoints on previous levels become unavailable and thus do not conflict with savepoints on the new level. When the function or trigger terminates, any savepoints it created are released and the previous savepoint level is restored.

13.3.5 LOCK TABLES and UNLOCK TABLES Statements

LOCK TABLES
   tbl_name [[AS] alias] lock_type
   [, tbl_name [[AS] alias] lock_type] ...

lock_type: {
   READ [LOCAL]
   | [LOW_PRIORITY] WRITE
}

UNLOCK TABLES

MySQL enables client sessions to acquire table locks explicitly for the purpose of cooperating with other sessions for access to tables, or to prevent other sessions from modifying tables during periods when a session requires exclusive access to them. A session can acquire or release locks only for itself. One session cannot acquire locks for another session or release locks held by another session.

Locks may be used to emulate transactions or to get more speed when updating tables. This is explained in more detail in Table-Locking Restrictions and Conditions.

LOCK TABLES explicitly acquires table locks for the current client session. Table locks can be acquired for base tables or views. You must have the LOCK TABLES privilege, and the SELECT privilege for each object to be locked.

For view locking, LOCK TABLES adds all base tables used in the view to the set of tables to be locked and locks them automatically. If you lock a table explicitly with LOCK TABLES, any tables used in triggers are also locked implicitly, as described in LOCK TABLES and Triggers.

UNLOCK TABLES explicitly releases any table locks held by the current session. LOCK TABLES implicitly releases any table locks held by the current session before acquiring new locks.

Another use for UNLOCK TABLES is to release the global read lock acquired with the FLUSH TABLES WITH READ LOCK statement, which enables you to lock all tables in all databases. See Section 13.7.6.3, “FLUSH Statement”. (This is a very convenient way to get backups if you have a file system such as Veritas that can take snapshots in time.)

A table lock protects only against inappropriate reads or writes by other sessions. A session holding a WRITE lock can perform table-level operations such as DROP TABLE or TRUNCATE TABLE. For sessions holding a READ lock, DROP TABLE and TRUNCATE TABLE operations are not permitted.

The following discussion applies only to non-TEMPORARY tables. LOCK TABLES is permitted (but ignored) for a TEMPORARY table. The table can be accessed freely by the session within which it was created, regardless of what other locking may be in effect. No lock is necessary because no other session can see the table.

- Table Lock Acquisition
- Table Lock Release
- Interaction of Table Locking and Transactions
- LOCK TABLES and Triggers
- Table-Locking Restrictions and Conditions
Table Lock Acquisition

To acquire table locks within the current session, use the LOCK TABLES statement, which acquires metadata locks (see Section 8.11.4, “Metadata Locking”).

The following lock types are available:

**READ [LOCAL] lock:**
- The session that holds the lock can read the table (but not write it).
- Multiple sessions can acquire a READ lock for the table at the same time.
- Other sessions can read the table without explicitly acquiring a READ lock.
- The LOCAL modifier enables nonconflicting INSERT statements (concurrent inserts) by other sessions to execute while the lock is held. (See Section 8.11.3, “Concurrent Inserts”.) However, READ LOCAL cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock. For InnoDB tables, READ LOCAL is the same as READ.

**[LOW_PRIORITY] WRITE lock:**
- The session that holds the lock can read and write the table.
- Only the session that holds the lock can access the table. No other session can access it until the lock is released.
- Lock requests for the table by other sessions block while the WRITE lock is held.
- The LOW_PRIORITY modifier has no effect. In previous versions of MySQL, it affected locking behavior, but this is no longer true. It is now deprecated and its use produces a warning. Use WRITE without LOW_PRIORITY instead.

WRITE locks normally have higher priority than READ locks to ensure that updates are processed as soon as possible. This means that if one session obtains a READ lock and then another session requests a WRITE lock, subsequent READ lock requests wait until the session that requested the WRITE lock has obtained the lock and released it. (An exception to this policy can occur for small values of the max_write_lock_count system variable; see Section 8.11.4, “Metadata Locking”.)

If the LOCK TABLES statement must wait due to locks held by other sessions on any of the tables, it blocks until all locks can be acquired.

A session that requires locks must acquire all the locks that it needs in a single LOCK TABLES statement. While the locks thus obtained are held, the session can access only the locked tables. For example, in the following sequence of statements, an error occurs for the attempt to access t2 because it was not locked in the LOCK TABLES statement:

```sql
mysql> LOCK TABLES t1 READ;
mysql> SELECT COUNT(*) FROM t1;
+----------+
| COUNT(*) |
+----------+
|        3 |
+----------+

mysql> SELECT COUNT(*) FROM t2;
ERROR 1100 (HY000): Table 't2' was not locked with LOCK TABLES
```

Tables in the INFORMATION_SCHEMA database are an exception. They can be accessed without being locked explicitly even while a session holds table locks obtained with LOCK TABLES.
LOCK TABLES and UNLOCK TABLES Statements

You cannot refer to a locked table multiple times in a single query using the same name. Use aliases instead, and obtain a separate lock for the table and each alias:

```sql
mysql> LOCK TABLE t WRITE, t AS t1 READ;
mysql> INSERT INTO t SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> INSERT INTO t SELECT * FROM t AS t1;
```

The error occurs for the first `INSERT` because there are two references to the same name for a locked table. The second `INSERT` succeeds because the references to the table use different names.

If your statements refer to a table by means of an alias, you must lock the table using that same alias. It does not work to lock the table without specifying the alias:

```sql
mysql> LOCK TABLE t READ;
mysql> SELECT * FROM t AS myalias;
ERROR 1100: Table 'myalias' was not locked with LOCK TABLES
```

Conversely, if you lock a table using an alias, you must refer to it in your statements using that alias:

```sql
mysql> LOCK TABLE t AS myalias READ;
mysql> SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> SELECT * FROM t AS myalias;
```

**Note**

LOCK TABLES or UNLOCK TABLES, when applied to a partitioned table, always locks or unlocks the entire table. See Section 19.5.4, “Partitioning and Table-Level Locking”.

**Table Lock Release**

When the table locks held by a session are released, they are all released at the same time. A session can release its locks explicitly, or locks may be released implicitly under certain conditions.

- A session can release its locks explicitly with UNLOCK TABLES.
- If a session issues a LOCK TABLES statement to acquire a lock while already holding locks, its existing locks are released implicitly before the new locks are granted.
- If a session begins a transaction (for example, with START TRANSACTION), an implicit UNLOCK TABLES is performed, which causes existing locks to be released. (For additional information about the interaction between table locking and transactions, see Interaction of Table Locking and Transactions.)

If the connection for a client session terminates, whether normally or abnormally, the server implicitly releases all table locks held by the session (transactional and nontransactional). If the client reconnects, the locks will no longer be in effect. In addition, if the client had an active transaction, the server rolls back the transaction upon disconnect, and if reconnect occurs, the new session begins with autocommit enabled. For this reason, clients may wish to disable auto-reconnect. With auto-reconnect enabled, if the connection drops, an error occurs for the next statement issued. The client can detect the error and take appropriate action such as reacquiring the locks or redoing the transaction. See Section 23.7.19, “C API Automatic Reconnection Control”.

**Note**

If you use ALTER TABLE on a locked table, it may become unlocked. For example, if you attempt a second ALTER TABLE operation, the result may be an error Table
Interaction of Table Locking and Transactions

LOCK TABLES and UNLOCK TABLES interact with the use of transactions as follows:

- **LOCK TABLES** is not transaction-safe and implicitly commits any active transaction before attempting to lock the tables.

- **UNLOCK TABLES** implicitly commits any active transaction, but only if **LOCK TABLES** has been used to acquire table locks. For example, in the following set of statements, **UNLOCK TABLES** releases the global read lock but does not commit the transaction because no table locks are in effect:

  ```sql
  FLUSH TABLES WITH READ LOCK;
  START TRANSACTION;
  SELECT ... ;
  UNLOCK TABLES;
  ```

- Beginning a transaction (for example, with **START TRANSACTION**) implicitly commits any current transaction and releases existing table locks.

- **FLUSH TABLES WITH READ LOCK** acquires a global read lock and not table locks, so it is not subject to the same behavior as **LOCK TABLES** and **UNLOCK TABLES** with respect to table locking and implicit commits. For example, **START TRANSACTION** does not release the global read lock. See Section 13.7.6.3, “FLUSH Statement”.

- Other statements that implicitly cause transactions to be committed do not release existing table locks. For a list of such statements, see Section 13.3.3, “Statements That Cause an Implicit Commit”.

- The correct way to use **LOCK TABLES** and **UNLOCK TABLES** with transactional tables, such as InnoDB tables, is to begin a transaction with **SET autocommit = 0** (not **START TRANSACTION**) followed by **LOCK TABLES**, and to not call **UNLOCK TABLES** until you commit the transaction explicitly. For example, if you need to write to table **t1** and read from table **t2**, you can do this:

  ```sql
  SET autocommit=0;
  LOCK TABLES t1 WRITE, t2 READ, ...; ... do something with tables t1 and t2 here ... COMMIT;
  UNLOCK TABLES;
  ```

  When you call **LOCK TABLES**, InnoDB internally takes its own table lock, and MySQL takes its own table lock. InnoDB releases its internal table lock at the next commit, but for MySQL to release its table lock, you have to call **UNLOCK TABLES**. You should not have **autocommit = 1**, because then InnoDB releases its internal table lock immediately after the call of **LOCK TABLES**, and deadlocks can very easily happen. InnoDB does not acquire the internal table lock at all if **autocommit = 1**, to help old applications avoid unnecessary deadlocks.

- **ROLLBACK** does not release table locks.

**LOCK TABLES and Triggers**

If you lock a table explicitly with **LOCK TABLES**, any tables used in triggers are also locked implicitly:

- The locks are taken as the same time as those acquired explicitly with the **LOCK TABLES** statement.

- The lock on a table used in a trigger depends on whether the table is used only for reading. If so, a read lock suffices. Otherwise, a write lock is used.
• If a table is locked explicitly for reading with \texttt{LOCK TABLES}, but needs to be locked for writing because it might be modified within a trigger, a write lock is taken rather than a read lock. (That is, an implicit write lock needed due to the table's appearance within a trigger causes an explicit read lock request for the table to be converted to a write lock request.)

Suppose that you lock two tables, \texttt{t1} and \texttt{t2}, using this statement:

\begin{verbatim}
LOCK TABLES t1 WRITE, t2 READ;
\end{verbatim}

If \texttt{t1} or \texttt{t2} have any triggers, tables used within the triggers will also be locked. Suppose that \texttt{t1} has a trigger defined like this:

\begin{verbatim}
CREATE TRIGGER t1_a_ins AFTER INSERT ON t1 FOR EACH ROW
BEGIN
    UPDATE t4 SET count = count+1
    WHERE id = NEW.id AND EXISTS (SELECT a FROM t3);
    INSERT INTO t2 VALUES(1, 2);
END;
\end{verbatim}

The result of the \texttt{LOCK TABLES} statement is that \texttt{t1} and \texttt{t2} are locked because they appear in the statement, and \texttt{t3} and \texttt{t4} are locked because they are used within the trigger:

• \texttt{t1} is locked for writing per the \texttt{WRITE} lock request.

• \texttt{t2} is locked for writing, even though the request is for a \texttt{READ} lock. This occurs because \texttt{t2} is inserted into within the trigger, so the \texttt{READ} request is converted to a \texttt{WRITE} request.

• \texttt{t3} is locked for reading because it is only read from within the trigger.

• \texttt{t4} is locked for writing because it might be updated within the trigger.

\section*{Table-Locking Restrictions and Conditions}

You can safely use \texttt{KILL} to terminate a session that is waiting for a table lock. See Section 13.7.6.4, "KILL Statement".

Do \textit{not} lock any tables that you are using with \texttt{INSERT DELAYED}. An \texttt{INSERT DELAYED} in this case results in an error because the insert must be handled by a separate thread, not by the session which holds the lock.

\texttt{LOCK TABLES} and \texttt{UNLOCK TABLES} cannot be used within stored programs.

Tables in the \texttt{performance_schema} database cannot be locked with \texttt{LOCK TABLES}, except the \texttt{setup_xxx} tables.

The following statements are prohibited while a \texttt{LOCK TABLES} statement is in effect: \texttt{CREATE TABLE}, \texttt{CREATE TABLE ... LIKE}, \texttt{CREATE VIEW}, \texttt{DROP VIEW}, and DDL statements on stored functions and procedures and events.

For some operations, system tables in the \texttt{mysql} database must be accessed. For example, the \texttt{HELP} statement requires the contents of the server-side help tables, and \texttt{CONVERT_TZ()} might need to read the time zone tables. The server implicitly locks the system tables for reading as necessary so that you need not lock them explicitly. These tables are treated as just described:
If you want to explicitly place a WRITE lock on any of those tables with a LOCK TABLES statement, the table must be the only one locked; no other table can be locked with the same statement.

Normally, you do not need to lock tables, because all single UPDATE statements are atomic; no other session can interfere with any other currently executing SQL statement. However, there are a few cases when locking tables may provide an advantage:

- If you are going to run many operations on a set of MyISAM tables, it is much faster to lock the tables you are going to use. Locking MyISAM tables speeds up inserting, updating, or deleting on them because MySQL does not flush the key cache for the locked tables until UNLOCK TABLES is called. Normally, the key cache is flushed after each SQL statement.

  The downside to locking the tables is that no session can update a READ-locked table (including the one holding the lock) and no session can access a WRITE-locked table other than the one holding the lock.

- If you are using tables for a nontransactional storage engine, you must use LOCK TABLES if you want to ensure that no other session modifies the tables between a SELECT and an UPDATE. The example shown here requires LOCK TABLES to execute safely:

  ```
  LOCK TABLES trans READ, customer WRITE;
  SELECT SUM(value) FROM trans WHERE customer_id=some_id;
  UPDATE customer
      SET total_value=sum_from_previous_statement
      WHERE customer_id=some_id;
  UNLOCK TABLES;
  ```

  Without LOCK TABLES, it is possible that another session might insert a new row in the trans table between execution of the SELECT and UPDATE statements.

You can avoid using LOCK TABLES in many cases by using relative updates (UPDATE customer SET value=value+new_value) or the LAST_INSERT_ID() function.

You can also avoid locking tables in some cases by using the user-level advisory lock functions GET_LOCK() and RELEASE_LOCK(). These locks are saved in a hash table in the server and implemented with pthread_mutex_lock() and pthread_mutex_unlock() for high speed. See Section 12.14, “Locking Functions”.

See Section 8.11.1, “Internal Locking Methods”, for more information on locking policy.

### 13.3.6 SET TRANSACTION Statement

```
SET [GLOBAL | SESSION] TRANSACTION ISOLATION LEVEL level
```

**level**: 
- REPEATABLE READ
- READ COMMITTED
- READ UNCOMMITTED
- SERIALIZABLE

This statement sets the transaction isolation level, used for operations on InnoDB tables.

- Transaction Isolation Levels
- Transaction Isolation Level Scope
Transaction Isolation Levels

To set the transaction isolation level, use an `ISOLATION LEVEL level` clause.

The default isolation level is `REPEATABLE READ`. Other permitted values are `READ COMMITTED`, `READ UNCOMMITTED`, and `SERIALIZABLE`. For information about these isolation levels, see Section 14.10.2.1, “Transaction Isolation Levels”.

Transaction Isolation Level Scope

You can set the isolation level globally, for the current session, or for the next transaction only:

- With the `GLOBAL` keyword:
  - The statement applies globally for all subsequent sessions.
  - Existing sessions are unaffected.
- With the `SESSION` keyword:
  - The statement applies to all subsequent transactions performed within the current session.
  - The statement is permitted within transactions, but does not affect the current ongoing transaction.
  - If executed between transactions, the statement overrides any preceding statement that sets the next-transaction isolation level.
- Without any `SESSION` or `GLOBAL` keyword:
  - The statement applies only to the next single transaction performed within the session.
  - Subsequent transactions revert to using the session isolation level.
  - The statement is not permitted within transactions:

  ```sql
  mysql> START TRANSACTION;
  Query OK, 0 rows affected (0.02 sec)
  mysql> SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
  ERROR 1568 (25001): Transaction isolation level can't be changed while a transaction is in progress
  ```

A change to the global isolation level requires the `SUPER` privilege. Any session is free to change its session isolation level (even in the middle of a transaction), or the isolation level for its next transaction (prior to the start of that transaction).

To set the global isolation level at server startup, use the `--transaction-isolation=level` option on the command line or in an option file. Values of `level` for this option use dashes rather than spaces, so the permissible values are `READ-UNCOMMITTED`, `READ-COMMITTED`, `REPEATABLE-READ`, or `SERIALIZABLE`. For example, to set the isolation level to `REPEATABLE READ`, use these lines in the `[mysqld]` section of an option file:

```ini
[mysqld]
transaction-isolation = REPEATABLE-READ
```

It is possible to set or check the global and session transaction isolation levels at runtime by using the `tx_isolation` system variable:

```sql
SET GLOBAL tx_isolation='REPEATABLE-READ';
```
SET SESSION tx_isolation='SERIALIZABLE';
SELECT @@GLOBAL.tx_isolation, @@SESSION.tx_isolation;

13.3.7 XA Transactions

Support for XA transactions is available for the InnoDB storage engine. The MySQL XA implementation is based on the X/Open CAE document Distributed Transaction Processing: The XA Specification. This document is published by The Open Group and available at http://www.opengroup.org/public/pubs/catalog/c193.htm. Limitations of the current XA implementation are described in Section 13.3.7.3, “Restrictions on XA Transactions”.

On the client side, there are no special requirements. The XA interface to a MySQL server consists of SQL statements that begin with the XA keyword. MySQL client programs must be able to send SQL statements and to understand the semantics of the XA statement interface. They do not need be linked against a recent client library. Older client libraries also will work.

Among the MySQL Connectors, MySQL Connector/J 5.0.0 supports XA directly (by means of a class interface that handles the XA SQL statement interface for you).

XA supports distributed transactions, that is, the ability to permit multiple separate transactional resources to participate in a global transaction. Transactional resources often are RDBMSs but may be other kinds of resources.

A global transaction involves several actions that are transactional in themselves, but that all must either complete successfully as a group, or all be rolled back as a group. In essence, this extends ACID properties “up a level” so that multiple ACID transactions can be executed in concert as components of a global operation that also has ACID properties. (As with nondistributed transactions, SERIALIZABLE may be preferred if your applications are sensitive to read phenomena. REPEATABLE READ may not be sufficient for distributed transactions.)

Some examples of distributed transactions:

- An application may act as an integration tool that combines a messaging service with an RDBMS. The application makes sure that transactions dealing with message sending, retrieval, and processing that also involve a transactional database all happen in a global transaction. You can think of this as “transactional email.”

- An application performs actions that involve different database servers, such as a MySQL server and an Oracle server (or multiple MySQL servers), where actions that involve multiple servers must happen as part of a global transaction, rather than as separate transactions local to each server.

- A bank keeps account information in an RDBMS and distributes and receives money through automated teller machines (ATMs). It is necessary to ensure that ATM actions are correctly reflected in the accounts, but this cannot be done with the RDBMS alone. A global transaction manager integrates the ATM and database resources to ensure overall consistency of financial transactions.

Applications that use global transactions involve one or more Resource Managers and a Transaction Manager:

- A Resource Manager (RM) provides access to transactional resources. A database server is one kind of resource manager. It must be possible to either commit or roll back transactions managed by the RM.

- A Transaction Manager (TM) coordinates the transactions that are part of a global transaction. It communicates with the RMs that handle each of these transactions. The individual transactions within a global transaction are “branches” of the global transaction. Global transactions and their branches are identified by a naming scheme described later.
XA Transactions

The MySQL implementation of XA enables a MySQL server to act as a Resource Manager that handles XA transactions within a global transaction. A client program that connects to the MySQL server acts as the Transaction Manager.

To carry out a global transaction, it is necessary to know which components are involved, and bring each component to a point when it can be committed or rolled back. Depending on what each component reports about its ability to succeed, they must all commit or roll back as an atomic group. That is, either all components must commit, or all components must roll back. To manage a global transaction, it is necessary to take into account that any component or the connecting network might fail.

The process for executing a global transaction uses two-phase commit (2PC). This takes place after the actions performed by the branches of the global transaction have been executed.

1. In the first phase, all branches are prepared. That is, they are told by the TM to get ready to commit. Typically, this means each RM that manages a branch records the actions for the branch in stable storage. The branches indicate whether they are able to do this, and these results are used for the second phase.

2. In the second phase, the TM tells the RMs whether to commit or roll back. If all branches indicated when they were prepared that they will be able to commit, all branches are told to commit. If any branch indicated when it was prepared that it will not be able to commit, all branches are told to roll back.

In some cases, a global transaction might use one-phase commit (1PC). For example, when a Transaction Manager finds that a global transaction consists of only one transactional resource (that is, a single branch), that resource can be told to prepare and commit at the same time.

### 13.3.7.1 XA Transaction SQL Statements

To perform XA transactions in MySQL, use the following statements:

```sql
XA {START|BEGIN} xid [JOIN|RESUME]
XA END xid [SUSPEND [FOR MIGRATE]]
XA PREPARE xid
XA COMMIT xid [ONE PHASE]
XA ROLLBACK xid
XA RECOVER
```

For **XA START**, the **JOIN** and **RESUME** clauses are recognized but have no effect.

For **XA END** the **SUSPEND [FOR MIGRATE]** clause is recognized but has no effect.

Each XA statement begins with the **XA** keyword, and most of them require an **xid** value. An **xid** is an XA transaction identifier. It indicates which transaction the statement applies to. **xid** values are supplied by the client, or generated by the MySQL server. An **xid** value has from one to three parts:

```sql
xid: gtrid [, bqual [, formatID ]]
```

**gtrid** is a global transaction identifier, **bqual** is a branch qualifier, and **formatID** is a number that identifies the format used by the **gtrid** and **bqual** values. As indicated by the syntax, **bqual** and **formatID** are optional. The default **bqual** value is `'` if not given. The default **formatID** value is 1 if not given.

**gtrid** and **bqual** must be string literals, each up to 64 bytes (not characters) long. **gtrid** and **bqual** can be specified in several ways. You can use a quoted string (`'ab'`), hex string (`X'6162'`, `0x6162`), or bit value (`b'nnnn'`).
**formatID** is an unsigned integer.

The **gtrid** and **bqual** values are interpreted in bytes by the MySQL server's underlying XA support routines. However, while an SQL statement containing an XA statement is being parsed, the server works with some specific character set. To be safe, write **gtrid** and **bqual** as hex strings.

**xid** values typically are generated by the Transaction Manager. Values generated by one TM must be different from values generated by other TMs. A given TM must be able to recognize its own **xid** values in a list of values returned by the XA **RECOVER** statement.

**XA START xid** starts an XA transaction with the given **xid** value. Each XA transaction must have a unique **xid** value, so the value must not currently be used by another XA transaction. Uniqueness is assessed using the **gtrid** and **bqual** values. All following XA statements for the XA transaction must be specified using the same **xid** value as that given in the XA **START** statement. If you use any of those statements but specify an **xid** value that does not correspond to some existing XA transaction, an error occurs.

One or more XA transactions can be part of the same global transaction. All XA transactions within a given global transaction must use the same **gtrid** value in the **xid** value. For this reason, **gtrid** values must be globally unique so that there is no ambiguity about which global transaction a given XA transaction is part of. The **bqual** part of the **xid** value must be different for each XA transaction within a global transaction. (The requirement that **bqual** values be different is a limitation of the current MySQL XA implementation. It is not part of the XA specification.)

The XA **RECOVER** statement returns information for those XA transactions on the MySQL server that are in the PREPARED state. (See Section 13.3.7.2, “XA Transaction States”.) The output includes a row for each such XA transaction on the server, regardless of which client started it.

**XA RECOVER** output rows look like this (for an example **xid** value consisting of the parts 'abc', 'def', and 7):

```sql
mysql> XA RECOVER;
+----------+--------------+--------------+--------+
| formatID | gtrid_length | bqual_length | data   |
+----------+--------------+--------------+--------+
|        7 |            3 |            3 | abcdef |
+----------+--------------+--------------+--------+
```

The output columns have the following meanings:

- **formatID** is the **formatID** part of the transaction **xid**
- **gtrid_length** is the length in bytes of the **gtrid** part of the **xid**
- **bqual_length** is the length in bytes of the **bqual** part of the **xid**
- **data** is the concatenation of the **gtrid** and **bqual** parts of the **xid**

### 13.3.7.2 XA Transaction States

An XA transaction progresses through the following states:

1. Use **XA START** to start an XA transaction and put it in the **ACTIVE** state.
2. For an **ACTIVE** XA transaction, issue the SQL statements that make up the transaction, and then issue an **XA END** statement. **XA END** puts the transaction in the **IDLE** state.
3. For an **IDLE** XA transaction, you can issue either an **XA PREPARE** statement or an **XA COMMIT ... ONE PHASE** statement:
XA Transactions

• **XA PREPARE** puts the transaction in the **PREPARED** state. An **XA RECOVER** statement at this point will include the transaction's *xid* value in its output, because **XA RECOVER** lists all XA transactions that are in the **PREPARED** state.

• **XA COMMIT ... ONE PHASE** prepares and commits the transaction. The *xid* value will not be listed by **XA RECOVER** because the transaction terminates.

4. For a **PREPARED** XA transaction, you can issue an **XA COMMIT** statement to commit and terminate the transaction, or **XA ROLLBACK** to roll back and terminate the transaction.

Here is a simple XA transaction that inserts a row into a table as part of a global transaction:

```sql
mysql> XA START 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO mytable (i) VALUES(10);
Query OK, 1 row affected (0.04 sec)

mysql> XA END 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> XA PREPARE 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> XA COMMIT 'xatest';
Query OK, 0 rows affected (0.00 sec)
```

Within the context of a given client connection, XA transactions and local (non-XA) transactions are mutually exclusive. For example, if **XA START** has been issued to begin an XA transaction, a local transaction cannot be started until the XA transaction has been committed or rolled back. Conversely, if a local transaction has been started with **START TRANSACTION**, no XA statements can be used until the transaction has been committed or rolled back.

If an XA transaction is in the **ACTIVE** state, you cannot issue any statements that cause an implicit commit. That would violate the XA contract because you could not roll back the XA transaction. You will receive the following error if you try to execute such a statement:

```
ERROR 1399 (XAE07): XAER_RMFAIL: The command cannot be executed when global transaction is in the ACTIVE state
```

Statements to which the preceding remark applies are listed at **Section 13.3.3, “Statements That Cause an Implicit Commit”**.

### 13.3.7.3 Restrictions on XA Transactions

XA transaction support is limited to the **InnoDB** storage engine.

For “external XA,” a MySQL server acts as a Resource Manager and client programs act as Transaction Managers. For “Internal XA,” storage engines within a MySQL server act as RMs, and the server itself acts as a TM. Internal XA support is limited by the capabilities of individual storage engines. Internal XA is required for handling XA transactions that involve more than one storage engine. The implementation of internal XA requires that a storage engine support two-phase commit at the table handler level, and currently this is true only for **InnoDB**.

For **XA START**, the **JOIN** and **RESUME** clauses are recognized but have no effect.

For **XA END** the **SUSPEND [FOR MIGRATE]** clause is recognized but has no effect.

The requirement that the *bqual* part of the *xid* value be different for each XA transaction within a global transaction is a limitation of the current MySQL XA implementation. It is not part of the XA specification.
If an XA transaction has reached the **PREPARED** state and the MySQL server is killed (for example, with `kill -9` on Unix) or shuts down abnormally, the transaction can be continued after the server restarts. However, if the client reconnects and commits the transaction, the transaction will be absent from the binary log even though it has been committed. This means the data and the binary log have gone out of synchrony. An implication is that XA cannot be used safely together with replication.

It is possible that the server will roll back a pending XA transaction, even one that has reached the **PREPARED** state. This happens if a client connection terminates and the server continues to run, or if clients are connected and the server shuts down gracefully. (In the latter case, the server marks each connection to be terminated, and then rolls back the **PREPARED** XA transaction associated with it.) It should be possible to commit or roll back a **PREPARED** XA transaction, but this cannot be done without changes to the binary logging mechanism.

**FLUSH TABLES WITH READ LOCK** is not compatible with XA transactions.

### 13.4 Replication Statements

Replication can be controlled through the SQL interface using the statements described in this section. One group of statements controls master servers, the other controls slave servers.

#### 13.4.1 SQL Statements for Controlling Master Servers

This section discusses statements for managing master replication servers. Section 13.4.2, “SQL Statements for Controlling Slave Servers”, discusses statements for managing slave servers.

In addition to the statements described here, the following **SHOW** statements are used with master servers in replication. For information about these statements, see Section 13.7.5, “SHOW Statements”.

- **SHOW BINARY LOGS**
- **SHOW BINLOG EVENTS**
- **SHOW MASTER STATUS**
- **SHOW SLAVE HOSTS**

#### 13.4.1.1 PURGE BINARY LOGS Statement

```
PURGE { BINARY | MASTER } LOGS {
  TO 'log_name'
  | BEFORE datetime_expr
}
```

The binary log is a set of files that contain information about data modifications made by the MySQL server. The log consists of a set of binary log files, plus an index file (see Section 5.4.4, “The Binary Log”).

The **PURGE BINARY LOGS** statement deletes all the binary log files listed in the log index file prior to the specified log file name or date. **BINARY** and **MASTER** are synonyms. Deleted log files also are removed from the list recorded in the index file, so that the given log file becomes the first in the list.

This statement has no effect if the server was not started with the **--log-bin** option to enable binary logging.

Examples:

```
PURGE BINARY LOGS TO 'mysql-bin.010';
PURGE BINARY LOGS BEFORE '2019-04-02 22:46:26';
```
The **BEFORE** variant’s `datetime_expr` argument should evaluate to a `DATETIME` value (a value in 'YYYY-MM-DD hh:mm:ss' format).

This statement is safe to run while slaves are replicating. You need not stop them. If you have an active slave that currently is reading one of the log files you are trying to delete, this statement does nothing and fails with an error. However, if a slave is not connected and you happen to purge one of the log files it has yet to read, the slave will be unable to replicate after it reconnects.

To safely purge binary log files, follow this procedure:

1. On each slave server, use `SHOW SLAVE STATUS` to check which log file it is reading.
2. Obtain a listing of the binary log files on the master server with `SHOW BINARY LOGS`.
3. Determine the earliest log file among all the slaves. This is the target file. If all the slaves are up to date, this is the last log file on the list.
4. Make a backup of all the log files you are about to delete. (This step is optional, but always advisable.)
5. Purge all log files up to but not including the target file.

You can also set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.7, “Server System Variables”). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master.

**PURGE BINARY LOGS TO** and **PURGE BINARY LOGS BEFORE** both fail with an error when binary log files listed in the `.index` file had been removed from the system by some other means (such as using `rm` on Linux). (Bug #18199, Bug #18453) To handle such errors, edit the `.index` file (which is a simple text file) manually to ensure that it lists only the binary log files that are actually present, then run again the **PURGE BINARY LOGS** statement that failed.

### 13.4.1.2 RESET MASTER Statement

**RESET MASTER**

Deletes all binary log files listed in the index file, resets the binary log index file to be empty, and creates a new binary log file. This statement is intended to be used only when the master is started for the first time.

**Important**

The effects of **RESET MASTER** differ from those of **PURGE BINARY LOGS** in 2 key ways:

1. **RESET MASTER** removes all binary log files that are listed in the index file, leaving only a single, empty binary log file with a numeric suffix of `.000001`, whereas the numbering is not reset by **PURGE BINARY LOGS**.

2. **RESET MASTER** is not intended to be used while any replication slaves are running. The behavior of **RESET MASTER** when used while slaves are running is undefined (and thus unsupported), whereas **PURGE BINARY LOGS** may be safely used while replication slaves are running.

See also **Section 13.4.1.1, “PURGE BINARY LOGS Statement”**.

**RESET MASTER** can prove useful when you first set up the master and the slave, so that you can verify the setup as follows:

1. Start the master and slave, and start replication (see **Section 17.1.1, “How to Set Up Replication”**).
2. Execute a few test queries on the master.
3. Check that the queries were replicated to the slave.
4. When replication is running correctly, issue `STOP SLAVE` followed by `RESET SLAVE` on the slave, then verify that any unwanted data no longer exists on the slave.
5. Issue `RESET MASTER` on the master to clean up the test queries.

After verifying the setup and getting rid of any unwanted and log files generated by testing, you can start the slave and begin replicating.

### 13.4.1.3 SET sql_log_bin Statement

```sql
SET sql_log_bin = {OFF|ON}
```

The `sql_log_bin` variable controls whether logging to the binary log is enabled for the current session (assuming that the binary log itself is enabled). The default value is `ON`. To disable or enable binary logging for the current session, set the session `sql_log_bin` variable to `OFF` or `ON`.

Set this variable to `OFF` for a session to temporarily disable binary logging while making changes to the master you do not want replicated to the slave.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

It is not possible to set the session value of `sql_log_bin` within a transaction or subquery.

As of MySQL 5.5.41, the global `sql_log_bin` variable is read only and cannot be modified. The global scope is deprecated and will be removed in a future MySQL release. Prior to 5.5.41, `sql_log_bin` can be set as a global or session variable. Setting `sql_log_bin` globally is only detected when a new session is started. Any sessions previously running are not impacted when setting `sql_log_bin` globally.

**Warning**

Incorrect use of `sql_log_bin` with a global scope means any changes made in an already running session are still being recorded to the binary log and therefore replicated. Exercise extreme caution using `sql_log_bin` with a global scope as the above situation could cause unexpected results including replication failure.

### 13.4.2 SQL Statements for Controlling Slave Servers

This section discusses statements for managing slave replication servers. Section 13.4.1, “SQL Statements for Controlling Master Servers”, discusses statements for managing master servers.

In addition to the statements described here, `SHOW SLAVE STATUS` and `SHOW RELAYLOG EVENTS` are also used with replication slaves. For information about these statements, see Section 13.7.5.35, “SHOW SLAVE STATUS Statement”, and Section 13.7.5.33, “SHOW RELAYLOG EVENTS Statement”.

#### 13.4.2.1 CHANGE MASTER TO Statement

```sql
CHANGE MASTER TO option [, option] ...
```

**option:**
- `MASTER_BIND = 'interface_name'`
- `MASTER_HOST = 'host_name'`
- `MASTER_USER = 'user_name'`
- `MASTER_PASSWORD = 'password'`
- `MASTER_PORT = port_num`
- `MASTER_CONNECT_RETRY = interval`
SQL Statements for Controlling Slave Servers

```sql
| MASTER_HEARTBEAT_PERIOD  =  interval |
| MASTER_LOG_FILE = 'master_log_name' |
| MASTER_LOG_POS = master_log_pos |
| RELAY_LOG_FILE = 'relay_log_name' |
| RELAY_LOG_POS = relay_log_pos |
| MASTER_SSL = {0|1} |
| MASTER_SSL_CA = 'ca_file_name' |
| MASTER_SSL_CAPATH = 'ca_directory_name' |
| MASTER_SSL_CERT = 'cert_file_name' |
| MASTER_SSL_KEY = 'key_file_name' |
| MASTER_SSL_CIPHER = 'cipher_list' |
| MASTER_SSL_VERIFY_SERVER_CERT = {0|1} |
| IGNORE_SERVER_IDS = (server_id_list) |

server_id_list:
  [server_id [, server_id] ... ]
```

**CHANGE MASTER TO** changes the parameters that the slave server uses for connecting to the master server, for reading the master binary log, and reading the slave relay log. It also updates the contents of the `master.info` and `relay-log.info` files. **CHANGE MASTER TO** requires the `SUPER` privilege.

To use **CHANGE MASTER TO**, the slave replication threads must be stopped (use **STOP SLAVE** if necessary).

Options not specified retain their value, except as indicated in the following discussion. Thus, in most cases, there is no need to specify options that do not change. For example, if the password to connect to your MySQL master has changed, you just need to issue these statements to tell the slave about the new password:

```sql
STOP SLAVE; -- if replication was running
CHANGE MASTER TO MASTER_PASSWORD='new3cret';
START SLAVE; -- if you want to restart replication
```

**MASTER_HOST**, **MASTER_USER**, **MASTER_PASSWORD**, and **MASTER_PORT** provide information to the slave about how to connect to its master:

- **MASTER_HOST** and **MASTER_PORT** are the host name (or IP address) of the master host and its TCP/IP port.

  ![Note]

  Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

If you specify the **MASTER_HOST** or **MASTER_PORT** option, the slave assumes that the master server is different from before (even if the option value is the same as its current value.) In this case, the old values for the master binary log file name and position are considered no longer applicable, so if you do not specify **MASTER_LOG_FILE** and **MASTER_LOG_POS** in the statement, **MASTER_LOG_FILE=''** and **MASTER_LOG_POS=4** are silently appended to it.

Setting **MASTER_HOST=''** (that is, setting its value explicitly to an empty string) is *not* the same as not setting **MASTER_HOST** at all. Beginning with MySQL 5.5, trying to set **MASTER_HOST** to an empty string fails with an error. Previously, setting **MASTER_HOST** to an empty string caused **START SLAVE** subsequently to fail. (Bug #28796)

- **MASTER_USER** and **MASTER_PASSWORD** are the user name and password of the account to use for connecting to the master.

In MySQL 5.5.20 and later, **MASTER_USER** cannot be made empty; setting **MASTER_USER = ''** or leaving it unset when setting a value for **MASTER_PASSWORD** causes an error (Bug #13427949).
The password used for a MySQL Replication slave account in a `CHANGE MASTER TO` statement is limited to 32 characters in length; if the password is longer, the statement succeeds, but any excess characters are silently truncated. This is an issue specific to MySQL Replication, which is fixed in MySQL 5.7. (Bug #11752299, Bug #43439)

The text of a running `CHANGE MASTER TO` statement, including values for `MASTER_USER` and `MASTER_PASSWORD`, can be seen in the output of a concurrent `SHOW PROCESSLIST` statement.

The `MASTER_SSL_rhs` options provide information about using SSL for the connection. They correspond to the `--ssl-rhs` options described in Command Options for Encrypted Connections, and Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”. These options can be changed even on slaves that are compiled without SSL support. They are saved to the `master.info` file, but are ignored if the slave does not have SSL support enabled.

`MASTER_CONNECT_RETRY` specifies how many seconds to wait between connect retries. The default is 60. The number of reconnection attempts is limited by the `--master-retry-count` server option; for more information, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

The `MASTER_BIND` option is available in MySQL NDB Cluster 7.2 and later, but is not supported in mainline MySQL 5.5.

`MASTER_BIND` is for use on replication slaves having multiple network interfaces, and determines which of the slave’s network interfaces is chosen for connecting to the master.

`MASTER_HEARTBEAT_PERIOD` sets the interval in seconds between replication heartbeats. Whenever the master's binary log is updated with an event, the waiting period for the next heartbeat is reset. `interval` is a decimal value having the range 0 to 4294967 seconds and a resolution in milliseconds; the smallest nonzero value is 0.001. Heartbeats are sent by the master only if there are no unsent events in the binary log file for a period longer than `interval`.

Setting `interval` to 0 disables heartbeats altogether. The default value for `interval` is equal to the value of `slave_net_timeout` divided by 2.

Setting `@@GLOBAL slave_net_timeout` to a value less than that of the current heartbeat interval results in a warning being issued. The effect of issuing `RESET SLAVE` on the heartbeat interval is to reset it to the default value.

`MASTER_LOG_FILE` and `MASTER_LOG_POS` are the coordinates at which the slave I/O thread should begin reading from the master the next time the thread starts. `RELAY_LOG_FILE` and `RELAY_LOG_POS` are the coordinates at which the slave SQL thread should begin reading from the relay log the next time the thread starts. If you specify either of `MASTER_LOG_FILE` or `MASTER_LOG_POS`, you cannot specify `RELAY_LOG_FILE` or `RELAY_LOG_POS`. If neither of `MASTER_LOG_FILE` or `MASTER_LOG_POS` is specified, the slave uses the last coordinates of the slave SQL thread before `CHANGE MASTER TO` was issued. This ensures that there is no discontinuity in replication, even if the slave SQL thread was late compared to the slave I/O thread, when you merely want to change, say, the password to use.

`CHANGE MASTER TO` deletes all relay log files and starts a new one, unless you specify `RELAY_LOG_FILE` or `RELAY_LOG_POS`. In that case, relay log files are kept; the `relay_log_purge` global variable is set silently to 0.

Prior to MySQL 5.5, `RELAY_LOG_FILE` required an absolute path. In MySQL 5.5, the path can be relative, in which case the path is assumed to be relative to the slave’s data directory. (Bug #12190)

`IGNORE_SERVER_IDS` was added in MySQL 5.5. This option takes a comma-separated list of 0 or more server IDs. Events originating from the corresponding servers are ignored, with the exception of log rotation and deletion events, which are still recorded in the relay log.
In circular replication, the originating server normally acts as the terminator of its own events, so that they are not applied more than once. Thus, this option is useful in circular replication when one of the servers in the circle is removed. Suppose that you have a circular replication setup with 4 servers, having server IDs 1, 2, 3, and 4, and server 3 fails. When bridging the gap by starting replication from server 2 to server 4, you can include `IGNORE_SERVER_IDS = (3)` in the `CHANGE MASTER TO` statement that you issue on server 4 to tell it to use server 2 as its master instead of server 3. Doing so causes it to ignore and not to propagate any statements that originated with the server that is no longer in use.

When a `CHANGE MASTER TO` statement is issued without any `IGNORE_SERVER_IDS` option, any existing list is preserved. To clear the list of ignored servers, it is necessary to use the option with an empty list:

```
CHANGE MASTER TO IGNORE_SERVER_IDS = ();
```

`RESET SLAVE ALL` has no effect on the server ID list. This issue is fixed in MySQL 5.7. (Bug #18816897)

If `IGNORE_SERVER_IDS` contains the server's own ID and the server was started with the `--replicate-same-server-id` option enabled, an error results.

Also beginning with MySQL 5.5, the `master.info` file and the output of `SHOW SLAVE STATUS` are extended to provide the list of servers that are currently ignored. For more information, see Section 17.2.2.2, “Slave Status Logs”, and Section 13.7.5.35, “SHOW SLAVE STATUS Statement”.

Beginning with MySQL 5.5.5, invoking `CHANGE MASTER TO` causes the previous values for `MASTER_HOST`, `MASTER_PORT`, `MASTER_LOG_FILE`, and `MASTER_LOG_POS` to be written to the error log, along with other information about the slave's state prior to execution.

`CHANGE MASTER TO` is useful for setting up a slave when you have the snapshot of the master and have recorded the master binary log coordinates corresponding to the time of the snapshot. After loading the snapshot into the slave to synchronize it with the master, you can run `CHANGE MASTER TO MASTER_LOG_FILE='log_name', MASTER_LOG_POS=log_pos` on the slave to specify the coordinates at which the slave should begin reading the master binary log.

The following example changes the master server the slave uses and establishes the master binary log coordinates from which the slave begins reading. This is used when you want to set up the slave to replicate the master:

```
CHANGE MASTER TO
  MASTER_HOST='master2.example.com',
  MASTER_USER='replication',
  MASTER_PASSWORD='bigs3cret',
  MASTER_PORT=3306,
  MASTER_LOG_FILE='master2-bin.001',
  MASTER_LOG_POS=4,
  MASTER_CONNECT_RETRY=10;
```

The next example shows an operation that is less frequently employed. It is used when the slave has relay log files that you want it to execute again for some reason. To do this, the master need not be reachable. You need only use `CHANGE MASTER TO` and start the SQL thread (`START SLAVE SQL_THREAD`):

```
CHANGE MASTER TO
  RELAY_LOG_FILE='slave-relay-bin.006',
  RELAY_LOG_POS=4025;
```

The following table shows the maximum permissible length for the string-valued options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Maximum Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASTER_HOST</td>
<td>60</td>
</tr>
<tr>
<td>MASTER_USER</td>
<td>16</td>
</tr>
</tbody>
</table>
SQL Statements for Controlling Slave Servers

<table>
<thead>
<tr>
<th>Option</th>
<th>Maximum Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASTER_PASSWORD</td>
<td>32</td>
</tr>
<tr>
<td>MASTER_LOG_FILE</td>
<td>255</td>
</tr>
<tr>
<td>RELAY_LOG_FILE</td>
<td>255</td>
</tr>
<tr>
<td>MASTER_SSL_CA</td>
<td>255</td>
</tr>
<tr>
<td>MASTER_SSL_CAPATH</td>
<td>255</td>
</tr>
<tr>
<td>MASTER_SSL_CERT</td>
<td>255</td>
</tr>
<tr>
<td>MASTER_SSL_KEY</td>
<td>255</td>
</tr>
<tr>
<td>MASTER_SSL_CIPHER</td>
<td>511</td>
</tr>
</tbody>
</table>

### 13.4.2.2 MASTER_POS_WAIT() Statement

```
SELECT MASTER_POS_WAIT('master_log_file', master_log_pos [, timeout])
```

This is actually a function, not a statement. It is used to ensure that the slave has read and executed events up to a given position in the master's binary log. See Section 12.18, “Miscellaneous Functions”, for a full description.

### 13.4.2.3 RESET SLAVE Statement

**RESET SLAVE [ALL]**

`RESET SLAVE` makes the slave forget its replication position in the master's binary log. This statement is meant to be used for a clean start: It deletes the `master.info` and `relay-log.info` files, all the relay log files, and starts a new relay log file. To use `RESET SLAVE`, the slave replication threads must be stopped (use `STOP SLAVE` if necessary).

**Note**

All relay log files are deleted, even if they have not been completely executed by the slave SQL thread. (This is a condition likely to exist on a replication slave if you have issued a `STOP SLAVE` statement or if the slave is highly loaded.)

In MySQL 5.5 (unlike the case in MySQL 5.1 and earlier), `RESET SLAVE` does not change any replication connection parameters such as master host, master port, master user, or master password, which are retained in memory. This means that `START SLAVE` can be issued without requiring a `CHANGE MASTER TO` statement following `RESET SLAVE`.

Connection parameters are reset if the slave `mysql` is shut down following `RESET SLAVE`. In MySQL 5.5.16 and later, you can instead use `RESET SLAVE ALL` to reset these connection parameters (Bug #11809016).

`RESET SLAVE ALL` does not clear the `IGNORE_SERVER_IDS` list set by `CHANGE MASTER TO`. This issue is fixed in MySQL 5.7. (Bug #18816897)

If the slave SQL thread was in the middle of replicating temporary tables when it was stopped, and `RESET SLAVE` is issued, these replicated temporary tables are deleted on the slave.

**Note**

When used on an NDB Cluster replication slave SQL node, `RESET SLAVE` clears the `mysql.ndb_apply_status` table. You should keep in mind when using this statement that `ndb_apply_status` uses the NDB storage engine and so is shared by all SQL nodes attached to the slave cluster.
13.4.2.4 SET GLOBAL sql_slave_skip_counter Statement

```sql
SET GLOBAL sql_slave_skip_counter = N
```

This statement skips the next \( N \) events from the master. This is useful for recovering from replication stops caused by a statement.

This statement is valid only when the slave threads are not running. Otherwise, it produces an error.

When using this statement, it is important to understand that the binary log is actually organized as a sequence of groups known as event groups. Each event group consists of a sequence of events.

- For transactional tables, an event group corresponds to a transaction.
- For nontransactional tables, an event group corresponds to a single SQL statement.

Note

A single transaction can contain changes to both transactional and nontransactional tables.

When you use `SET GLOBAL sql_slave_skip_counter` to skip events and the result is in the middle of a group, the slave continues to skip events until it reaches the end of the group. Execution then starts with the next event group.

13.4.2.5 START SLAVE Statement

```sql
START SLAVE [thread_types]
START SLAVE [SQL_THREAD] UNTIL
  MASTER_LOG_FILE = 'log_name', MASTER_LOG_POS = log_pos
START SLAVE [SQL_THREAD] UNTIL
  RELAY_LOG_FILE = 'log_name', RELAY_LOG_POS = log_pos
```

`thread_types:`

```
[thread_type [, thread_type] ... ]
```

`thread_type:` IO_THREAD | SQL_THREAD

`START SLAVE` with no `thread_type` options starts both of the slave threads. The I/O thread reads events from the master server and stores them in the relay log. The SQL thread reads events from the relay log and executes them. `START SLAVE` requires the `SUPER` privilege.

If `START SLAVE` succeeds in starting the slave threads, it returns without any error. However, even in that case, it might be that the slave threads start and then later stop (for example, because they do not manage to connect to the master or read its binary log, or some other problem). `START SLAVE` does not warn you about this. You must check the slave's error log for error messages generated by the slave threads, or check that they are running satisfactorily with `SHOW SLAVE STATUS`.

`START SLAVE` sends an acknowledgment to the user after both the I/O thread and the SQL thread have started. However, the I/O thread may not yet have connected. For this reason, a successful `START SLAVE` causes `SHOW SLAVE STATUS` to show `Slave_IO_Running=Yes`, but this does not guarantee that `Slave_IO_Running=Yes` (because `Slave_IO_Running=Yes` only if the I/O thread is running and connected). For more information, see Section 13.7.5.35, “SHOW SLAVE STATUS Statement”, and Section 17.1.4.1, “Checking Replication Status”.

You can add `IO_THREAD` and `SQL_THREAD` options to the statement to name which of the threads to start.
An `UNTIL` clause may be added to specify that the slave should start and run until the SQL thread reaches a given point in the master binary log or in the slave relay log. When the SQL thread reaches that point, it stops. If the `SQL_THREAD` option is specified in the statement, it starts only the SQL thread. Otherwise, it starts both slave threads. If the SQL thread is running, the `UNTIL` clause is ignored and a warning is issued.

For an `UNTIL` clause, you must specify both a log file name and position. Do not mix master and relay log options.

Any `UNTIL` condition is reset by a subsequent `STOP SLAVE` statement, a `START SLAVE` statement that includes no `UNTIL` clause, or a server restart.

The `UNTIL` clause can be useful for debugging replication, or to cause replication to proceed until just before the point where you want to avoid having the slave replicate an event. For example, if an unwise `DROP TABLE` statement was executed on the master, you can use `UNTIL` to tell the slave to execute up to that point but no farther. To find what the event is, use `mysqlbinlog` with the master binary log or slave relay log, or by using a `SHOW BINLOG EVENTS` statement.

If you are using `UNTIL` to have the slave process replicated queries in sections, it is recommended that you start the slave with the `--skip-slave-start` option to prevent the SQL thread from running when the slave server starts. It is probably best to use this option in an option file rather than on the command line, so that an unexpected server restart does not cause it to be forgotten.

The `SHOW SLAVE STATUS` statement includes output fields that display the current values of the `UNTIL` condition.

In old versions of MySQL (before 4.0.5), this statement was called `SLAVE START`. This usage is still accepted in MySQL 5.5 for backward compatibility, but is deprecated and is removed in MySQL 5.6.

### 13.4.2.6 STOP SLAVE Statement

```
STOP SLAVE [thread_types]
```

**thread_types:**

```
   [thread_type [, thread_type] ... ]
```

**thread_type:** `IO_THREAD` | `SQL_THREAD`

Stops the slave threads. `STOP SLAVE` requires the `SUPER` privilege. Recommended best practice is to execute `STOP SLAVE` on the slave before stopping the slave server (see Section 5.1.14, "The Server Shutdown Process", for more information).

*When using the row-based logging format:* You should execute `STOP SLAVE` on the slave prior to shutting down the slave server if you are replicating any tables that use a nontransactional storage engine (see the Note later in this section). In MySQL 5.5.9 and later, you can also use `STOP SLAVE SQL_THREAD` for this purpose.

Like `START SLAVE`, this statement may be used with the `IO_THREAD` and `SQL_THREAD` options to name the thread or threads to be stopped.

If the current replication event group has modified one or more nontransactional tables, `STOP SLAVE` waits for up to 60 seconds for the event group to complete, unless you issue a `KILL QUERY` or `KILL CONNECTION` statement for the slave SQL thread. If the event group remains incomplete after the timeout, an error message is logged. (Bug #319, Bug #38205)

In old versions of MySQL (before 4.0.5), this statement was called `SLAVE STOP`. This usage is still accepted in MySQL 5.5 for backward compatibility, but is deprecated and is removed in MySQL 5.6.
13.5 Prepared Statements

MySQL 5.5 provides support for server-side prepared statements. This support takes advantage of the efficient client/server binary protocol, provided that you use an appropriate client programming interface. Candidate interfaces include the MySQL C API client library (for C programs), MySQL Connector/J (for Java programs), and MySQL Connector/NET. For example, the C API provides a set of function calls that make up its prepared statement API. See Section 23.7.7, “C API Prepared Statements”. Other language interfaces can provide support for prepared statements that use the binary protocol by linking in the C client library, one example being the `mysqli` extension, available in PHP 5.0 and later.

An alternative SQL interface to prepared statements is available. This interface is not as efficient as using the binary protocol through a prepared statement API, but requires no programming because it is available directly at the SQL level:

- You can use it when no programming interface is available to you.
- You can use it from any program that enables you to send SQL statements to the server to be executed, such as the `mysql` client program.
- You can use it even if the client is using an old version of the client library. The only requirement is that you be able to connect to a server that is recent enough to support SQL syntax for prepared statements.

SQL syntax for prepared statements is intended to be used for situations such as these:

- You want to test how prepared statements work in your application before coding it.
- An application has problems executing prepared statements and you want to determine interactively what the problem is.
- You want to create a test case that describes a problem you are having with prepared statements, so that you can file a bug report.
- You need to use prepared statements but do not have access to a programming API that supports them.

SQL syntax for prepared statements is based on three SQL statements:

- `PREPARE` prepares a statement for execution (see Section 13.5.1, “PREPARE Statement”).
- `EXECUTE` executes a prepared statement (see Section 13.5.2, “EXECUTE Statement”).
- `DEALLOCATE PREPARE` releases a prepared statement (see Section 13.5.3, “DEALLOCATE PREPARE Statement”).

The following examples show two equivalent ways of preparing a statement that computes the hypotenuse of a triangle given the lengths of the two sides.

The first example shows how to create a prepared statement by using a string literal to supply the text of the statement:

```
mysql> PREPARE stmt1 FROM 'SELECT SQRT(POW(? ,2) + POW(? ,2)) AS hypotenuse';
mysql> SET @a = 3;
mysql> SET @b = 4;
mysql> EXECUTE stmt1 USING @a, @b;
+------------+
| hypotenuse |
+------------+
|           5 |
mysql> DEALLOCATE PREPARE stmt1;
```
The second example is similar, but supplies the text of the statement as a user variable:

```sql
mysql> SET @s = 'SELECT SQRT(POW(? ,2) + POW(?,2)) AS hypotenuse';
mysql> PREPARE stmt2 FROM @s;
mysql> SET @a = 6;
mysql> SET @b = 8;
mysql> EXECUTE stmt2 USING @a, @b;
```

```
+------------+
<table>
<thead>
<tr>
<th>hypotenuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
</tr>
</tbody>
</table>
+------------+
```

```sql
mysql> DEALLOCATE PREPARE stmt2;
```

Here is an additional example that demonstrates how to choose the table on which to perform a query at runtime, by storing the name of the table as a user variable:

```sql
mysql> USE test;
mysql> CREATE TABLE t1 (a INT NOT NULL);
mysql> INSERT INTO t1 VALUES (4), (8), (11), (32), (80);
mysql> SET @table = 't1';
mysql> SET @s = CONCAT('SELECT * FROM ', @table);
mysql> PREPARE stmt3 FROM @s;
mysql> EXECUTE stmt3;
```

```
+----+
| a  |
+----+
|  4 |
|  8 |
| 11 |
| 32 |
| 80 |
+----+
```

```sql
mysql> DEALLOCATE PREPARE stmt3;
```

A prepared statement is specific to the session in which it was created. If you terminate a session without deallocating a previously prepared statement, the server deallocates it automatically.

A prepared statement is also global to the session. If you create a prepared statement within a stored routine, it is not deallocated when the stored routine ends.

To guard against too many prepared statements being created simultaneously, set the `max_prepared_stmt_count` system variable. To prevent the use of prepared statements, set the value to 0.

The following SQL statements can be used as prepared statements:

- `ALTER TABLE`
- `ANALYZE TABLE`
- `CACHE INDEX`
- `CALL`
- `CHANGE MASTER`
- `CHECKSUM {TABLE | TABLES}`
- `COMMIT`
- `{CREATE | RENAME | DROP} DATABASE`
- `{CREATE | DROP} INDEX`
- `{CREATE | RENAME | DROP} TABLE`
- `{CREATE | RENAME | DROP} USER`
- `{CREATE | DROP} VIEW`
- `DELETE`
- `DO`
Prepared Statements

FLUSH (TABLE | TABLES | TABLES WITH READ LOCK | HOSTS | PRIVILEGES
   | LOGS | STATUS | MASTER | SLAVE | DES_KEY_FILE | USER_RESOURCES)
GRANT
INSERT
INSTALL PLUGIN
KILL
LOAD INDEX INTO CACHE
OPTIMIZE TABLE
REPAIR TABLE
REPLACE
RESET {MASTER | SLAVE | QUERY CACHE}
REVOKE
SELECT
SET
SHOW (AUTHORS | CONTRIBUTORS | WARNINGS | ERRORS)
SHOW BINLOG EVENTS
SHOW CREATE (PROCEDURE | FUNCTION | EVENT | TABLE | VIEW)
SHOW (MASTER | BINARY) LOGS
SHOW (MASTER | SLAVE) STATUS
SLAVE {START | STOP}
TRUNCATE TABLE
UNINSTALL PLUGIN
UPDATE

Other statements are not supported in MySQL 5.5.

Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. Exceptions are noted in Section 20.8, “Restrictions on Stored Programs”.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

Placeholders can be used for the arguments of the LIMIT clause when using prepared statements. See Section 13.2.9, “SELECT Statement”.

In prepared CALL statements used with PREPARE and EXECUTE, placeholder support for OUT and INOUT parameters is available beginning with MySQL 5.5. See Section 13.2.1, “CALL Statement”, for an example and a workaround for earlier versions. Placeholders can be used for IN parameters regardless of version.

SQL syntax for prepared statements cannot be used in nested fashion. That is, a statement passed to PREPARE cannot itself be a PREPARE, EXECUTE, or DEALLOCATE PREPARE statement.

SQL syntax for prepared statements is distinct from using prepared statement API calls. For example, you cannot use the mysql_stmt_prepare() C API function to prepare a PREPARE, EXECUTE, or DEALLOCATE PREPARE statement.

SQL syntax for prepared statements can be used within stored procedures, but not in stored functions or triggers. However, a cursor cannot be used for a dynamic statement that is prepared and executed with PREPARE and EXECUTE. The statement for a cursor is checked at cursor creation time, so the statement cannot be dynamic.

SQL syntax for prepared statements does not support multi-statements (that is, multiple statements within a single string separated by ; characters).

Prepared statements use the query cache under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.

To write C programs that use the CALL SQL statement to execute stored procedures that contain prepared statements, the CLIENT_MULTI_RESULTS flag must be enabled. This is because each CALL returns
a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure.

CLIENT_MULTI_RESULTS can be enabled when you call mysql_real_connect(), either explicitly by passing the CLIENT_MULTI_RESULTS flag itself, or implicitly by passing CLIENT_MULTI_STATEMENTS (which also enables CLIENT_MULTI_RESULTS). For additional information, see Section 13.2.1, “CALL Statement”.

13.5.1 PREPARE Statement

PREPARE stmt_name FROM preparable_stmt

The PREPARE statement prepares a SQL statement and assigns it a name, stmt_name, by which to refer to the statement later. The prepared statement is executed with EXECUTE and released with DEALLOCATE PREPARE. For examples, see Section 13.5, “Prepared Statements”.

Statement names are not case-sensitive. preparable_stmt is either a string literal or a user variable that contains the text of the SQL statement. The text must represent a single statement, not multiple statements. Within the statement, ? characters can be used as parameter markers to indicate where data values are to be bound to the query later when you execute it. The ? characters should not be enclosed within quotation marks, even if you intend to bind them to string values. Parameter markers can be used only where data values should appear, not for SQL keywords, identifiers, and so forth.

If a prepared statement with the given name already exists, it is deallocated implicitly before the new statement is prepared. This means that if the new statement contains an error and cannot be prepared, an error is returned and no statement with the given name exists.

The scope of a prepared statement is the session within which it is created, which as several implications:

• A prepared statement created in one session is not available to other sessions.

• When a session ends, whether normally or abnormally, its prepared statements no longer exist. If auto-reconnect is enabled, the client is not notified that the connection was lost. For this reason, clients may wish to disable auto-reconnect. See Section 23.7.19, “C API Automatic Reconnection Control”.

• A prepared statement created within a stored program continues to exist after the program finishes executing and can be executed outside the program later.

• A statement prepared in stored program context cannot refer to stored procedure or function parameters or local variables because they go out of scope when the program ends and would be unavailable were the statement to be executed later outside the program. As a workaround, refer instead to user-defined variables, which also have session scope; see Section 9.4, “User-Defined Variables”.

13.5.2 EXECUTE Statement

EXECUTE stmt_name
   [USING @var_name [, @var_name] ...]

After preparing a statement with PREPARE, you execute it with an EXECUTE statement that refers to the prepared statement name. If the prepared statement contains any parameter markers, you must supply a USING clause that lists user variables containing the values to be bound to the parameters. Parameter values can be supplied only by user variables, and the USING clause must name exactly as many variables as the number of parameter markers in the statement.

You can execute a given prepared statement multiple times, passing different variables to it or setting the variables to different values before each execution.
13.5.3 DEALLOCATE PREPARE Statement

```
(DEALLOCATE | DROP) PREPARE stmt_name
```

To deallocate a prepared statement produced with PREPARE, use a DEALLOCATE PREPARE statement that refers to the prepared statement name. Attempting to execute a prepared statement after deallocating it results in an error.

For examples, see Section 13.5, “Prepared Statements”.

13.5.4 Automatic Prepared Statement Repreparation

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. This applies to prepared statements processed at the SQL level (using the PREPARE statement) and those processed using the binary client/server protocol (using the mysql_stmt Prepare() C API function).

The server attempts repreparation up to three times. An error occurs if all attempts fail.

Metadata changes occur for DDL statements such as those that create, drop, alter, rename, or truncate tables, or that analyze, optimize, or repair tables. Repreparation also occurs after referenced tables or views are flushed from the table definition cache, either implicitly to make room for new entries in the cache, or explicitly due to FLUSH TABLES.

Table content changes (for example, with INSERT or UPDATE) do not cause repreparation, nor do SELECT statements.

Repreparation is automatic, but to the extent that it occurs, diminishes prepared statement performance.

Repreparation uses the default database and SQL mode that were in effect for the original preparation.

The Com_stmt_reprepare status variable tracks the number of repreparations.

13.6 Compound-Statements

This section describes the syntax for the BEGIN ... END compound statement and other statements that can be used in the body of stored programs: Stored procedures and functions, triggers, and events. These objects are defined in terms of SQL code that is stored on the server for later invocation (see Chapter 20, Stored Objects).

A compound statement is a block that can contain other blocks; declarations for variables, condition handlers, and cursors; and flow control constructs such as loops and conditional tests.

13.6.1 BEGIN ... END Compound Statement

```
[begin_label:] BEGIN
[statement_list]
END [end_label]
```

BEGIN ... END syntax is used for writing compound statements, which can appear within stored programs (stored procedures and functions, triggers, and events). A compound statement can contain multiple statements, enclosed by the BEGIN and END keywords. statement_list represents a list of one or more statements, each terminated by a semicolon (;) statement delimiter. The statement_list itself is optional, so the empty compound statement (BEGIN END) is legal.
BEGIN ... END blocks can be nested.

Use of multiple statements requires that a client is able to send statement strings containing the ; statement delimiter. In the mysql command-line client, this is handled with the delimiter command. Changing the ; end-of-statement delimiter (for example, to //) permit ; to be used in a program body. For an example, see Section 20.1, “Defining Stored Programs”.

A BEGIN ... END block can be labeled. See Section 13.6.2, “Statement Labels”.

The optional [NOT] ATOMIC clause is not supported. This means that no transactional savepoint is set at the start of the instruction block and the BEGIN clause used in this context has no effect on the current transaction.

**Note**

Within all stored programs, the parser treats BEGIN [WORK] as the beginning of a BEGIN ... END block. To begin a transaction in this context, use START TRANSACTION instead.

### 13.6.2 Statement Labels

```
[begin_label:] BEGIN
  [statement_list]
END [end_label]

[begin_label:] LOOP
  statement_list
END LOOP [end_label]

[begin_label:] REPEAT
  statement_list
UNTIL search_condition
END REPEAT [end_label]

[begin_label:] WHILE search_condition DO
  statement_list
END WHILE [end_label]
```

Labels are permitted for BEGIN ... END blocks and for the LOOP, REPEAT, and WHILE statements. Label use for those statements follows these rules:

- *begin_label* must be followed by a colon.

- *begin_label* can be given without *end_label*. If *end_label* is present, it must be the same as *begin_label*.

- *end_label* cannot be given without *begin_label*.

- Labels at the same nesting level must be distinct.

- Labels can be up to 16 characters long.

To refer to a label within the labeled construct, use an ITERATE or LEAVE statement. The following example uses those statements to continue iterating or terminate the loop:

```sql
CREATE PROCEDURE doiterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN ITERATE label1; END IF;
    LEAVE label1;
```

1575
DECLARE Statements

The scope of a block label does not include the code for handlers declared within the block. For details, see Section 13.6.7.2, “DECLARE ... HANDLER Statement”.

13.6.3 DECLARE Statements

The DECLARE statement is used to define various items local to a program:

• Local variables. See Section 13.6.4, “Variables in Stored Programs”.

• Conditions and handlers. See Section 13.6.7, “Condition Handling”.

• Cursors. See Section 13.6.6, “Cursors”.

DECLARE is permitted only inside a BEGIN ... END compound statement and must be at its start, before any other statements.

Declarations must follow a certain order. Cursor declarations must appear before handler declarations. Variable and condition declarations must appear before cursor or handler declarations.

13.6.4 Variables in Stored Programs

System variables and user-defined variables can be used in stored programs, just as they can be used outside stored-program context. In addition, stored programs can use DECLARE to define local variables, and stored routines (procedures and functions) can be declared to take parameters that communicate values between the routine and its caller.

• To declare local variables, use the DECLARE statement, as described in Section 13.6.4.1, “Local Variable DECLARE Statement”.

• Variables can be set directly with the SET statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.

• Results from queries can be retrieved into local variables using SELECT ... INTO var_list or by opening a cursor and using FETCH ... INTO var_list. See Section 13.2.9.1, “SELECT ... INTO Statement”, and Section 13.6.6, “Cursors”.

For information about the scope of local variables and how MySQL resolves ambiguous names, see Section 13.6.4.2, “Local Variable Scope and Resolution”.

13.6.4.1 Local Variable DECLARE Statement

DECLARE var_name [, var_name] ... type [DEFAULT value]

This statement declares local variables within stored programs. To provide a default value for a variable, include a DEFAULT clause. The value can be specified as an expression; it need not be a constant. If the DEFAULT clause is missing, the initial value is NULL.

Local variables are treated like stored routine parameters with respect to data type and overflow checking. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”.

Variable declarations must appear before cursor or handler declarations.

Local variable names are not case-sensitive. Permissible characters and quoting rules are the same as for other identifiers, as described in Section 9.2, “Schema Object Names”.
Variables in Stored Programs

The scope of a local variable is the \texttt{BEGIN} \ldots \texttt{END} block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

For examples of variable declarations, see Section 13.6.4.2, “Local Variable Scope and Resolution”.

13.6.4.2 Local Variable Scope and Resolution

The scope of a local variable is the \texttt{BEGIN} \ldots \texttt{END} block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement scope is the current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, \texttt{SELECT \ldots INTO local_var} cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, “PREPARE Statement”.

A local variable should not have the same name as a table column. If an SQL statement, such as a \texttt{SELECT \ldots INTO} statement, contains a reference to a column and a declared local variable with the same name, MySQL currently interprets the reference as the name of a variable. Consider the following procedure definition:

```sql
CREATE PROCEDURE sp1 (x VARCHAR(5))
BEGIN
    DECLARE xname VARCHAR(5) DEFAULT 'bob';
    DECLARE newname VARCHAR(5);
    DECLARE xid INT;
    SELECT xname, id INTO newname, xid
    FROM table1 WHERE xname = xname;
    SELECT newname;
END;
```

MySQL interprets \texttt{xname} in the \texttt{SELECT} statement as a reference to the \texttt{xname} variable rather than the \texttt{xname} column. Consequently, when the procedure \texttt{sp1()} is called, the \texttt{newname} variable returns the value ‘bob’ regardless of the value of the \texttt{table1.xname} column.

Similarly, the cursor definition in the following procedure contains a \texttt{SELECT} statement that refers to \texttt{xname}. MySQL interprets this as a reference to the variable of that name rather than a column reference.

```sql
CREATE PROCEDURE sp2 (x VARCHAR(5))
BEGIN
    DECLARE xname VARCHAR(5) DEFAULT 'bob';
    DECLARE newname VARCHAR(5);
    DECLARE xid INT;
    DECLARE done TINYINT DEFAULT 0;
    DECLARE cur1 CURSOR FOR SELECT xname, id FROM table1;
    DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = 1;
    OPEN cur1;
    read_loop: LOOP
        FETCH FROM cur1 INTO newname, xid;
        IF done THEN LEAVE read_loop; END IF;
        SELECT newname;
    END LOOP;
    CLOSE cur1;
END;
```

See also Section 20.8, “Restrictions on Stored Programs”.
13.6.5 Flow Control Statements

MySQL supports the `IF`, `CASE`, `ITERATE`, `LEAVE LOOP`, `WHILE`, and `REPEAT` constructs for flow control within stored programs. It also supports `RETURN` within stored functions.

Many of these constructs contain other statements, as indicated by the grammar specifications in the following sections. Such constructs may be nested. For example, an `IF` statement might contain a `WHILE` loop, which itself contains a `CASE` statement.

MySQL does not support `FOR` loops.

13.6.5.1 CASE Statement

```
CASE  case_value
  WHEN when_value THEN statement_list
  [WHEN when_value THEN statement_list] ...
  [ELSE statement_list]
END CASE
```

Or:

```
CASE
  WHEN search_condition THEN statement_list
  [WHEN search_condition THEN statement_list] ...
  [ELSE statement_list]
END CASE
```

The `CASE` statement for stored programs implements a complex conditional construct.

There is also a `CASE expr`, which differs from the `CASE statement` described here. See Section 12.4, “Control Flow Functions”. The `CASE` statement cannot have an `ELSE NULL` clause, and it is terminated with `END CASE` instead of `END`.

For the first syntax, `case_value` is an expression. This value is compared to the `when_value` expression in each `WHEN` clause until one of them is equal. When an equal `when_value` is found, the corresponding `THEN` clause `statement_list` executes. If no `when_value` is equal, the `ELSE` clause `statement_list` executes, if there is one.

This syntax cannot be used to test for equality with `NULL` because `NULL = NULL` is false. See Section 3.3.4.6, “Working with NULL Values”.

For the second syntax, each `WHEN` clause `search_condition` expression is evaluated until one is true, at which point its corresponding `THEN` clause `statement_list` executes. If no `search_condition` is equal, the `ELSE` clause `statement_list` executes, if there is one.

If no `when_value` or `search_condition` matches the value tested and the `CASE` statement contains no `ELSE` clause, a `Case not found for CASE statement` error results.

Each `statement_list` consists of one or more SQL statements; an empty `statement_list` is not permitted.

To handle situations where no value is matched by any `WHEN` clause, use an `ELSE` containing an empty `BEGIN ... END` block, as shown in this example. (The indentation used here in the `ELSE` clause is for purposes of clarity only, and is not otherwise significant.)
CREATE PROCEDURE p()
BEGIN
  DECLARE v INT DEFAULT 1;
  CASE v
  WHEN 2 THEN SELECT v;
  WHEN 3 THEN SELECT 0;
  ELSE
    BEGIN
      END;
    END CASE;
  END;
END;

13.6.5.2 IF Statement

IF search_condition THEN statement_list
  [ELSEIF search_condition THEN statement_list] ...
  [ELSE statement_list]
END IF

The IF statement for stored programs implements a basic conditional construct.

Note
There is also an IF() function, which differs from the IF statement described here. See Section 12.4, “Control Flow Functions”. The IF statement can have THEN, ELSE, and ELSEIF clauses, and it is terminated with END IF.

If a given search_condition evaluates to true, the corresponding THEN or ELSEIF clause statement_list executes. If no search_condition matches, the ELSE clause statement_list executes.

Each statement_list consists of one or more SQL statements; an empty statement_list is not permitted.

An IF ... END IF block, like all other flow-control blocks used within stored programs, must be terminated with a semicolon, as shown in this example:

DELIMITER //
CREATE FUNCTION SimpleCompare(n INT, m INT) RETURNS VARCHAR(20)
BEGIN
  DECLARE s VARCHAR(20);
  IF n > m THEN SET s = '>'; 
  ELSEIF n = m THEN SET s = '=';
  ELSE SET s = '<';
  END IF;
  SET s = CONCAT(n, ' ', s, ' ', m);
  RETURN s;
END //
DELIMITER ;

As with other flow-control constructs, IF ... END IF blocks may be nested within other flow-control constructs, including other IF statements. Each IF must be terminated by its own END IF followed by a semicolon. You can use indentation to make nested flow-control blocks more easily readable by humans (although this is not required by MySQL), as shown here:
Flow Control Statements

DELIMITER //

CREATE FUNCTION VerboseCompare (n INT, m INT)
  RETURNS VARCHAR(50)
BEGIN
  DECLARE s VARCHAR(50);
  IF n = m THEN SET s = 'equals';
  ELSE
    IF n > m THEN SET s = 'greater';
    ELSE SET s = 'less';
    END IF;
    SET s = CONCAT('is ', s, ' than');
  END IF;
  SET s = CONCAT(n, ' ', s, ' ', m, '.');
  RETURN s;
END //
DELIMITER ;

In this example, the inner IF is evaluated only if n is not equal to m.

13.6.5.3 ITERATE Statement

ITERATE label

ITERATE can appear only within LOOP, REPEAT, and WHILE statements. ITERATE means “start the loop again.”

For an example, see Section 13.6.5.5, “LOOP Statement”.

13.6.5.4 LEAVE Statement

LEAVE label

This statement is used to exit the flow control construct that has the given label. If the label is for the outermost stored program block, LEAVE exits the program.

LEAVE can be used within BEGIN ... END or loop constructs (LOOP, REPEAT, WHILE).

For an example, see Section 13.6.5.5, “LOOP Statement”.

13.6.5.5 LOOP Statement

[begin_label:] LOOP
  statement_list
END LOOP [end_label]

LOOP implements a simple loop construct, enabling repeated execution of the statement list, which consists of one or more statements, each terminated by a semicolon (;) statement delimiter. The statements within the loop are repeated until the loop is terminated. Usually, this is accomplished with a LEAVE statement. Within a stored function, RETURN can also be used, which exits the function entirely.

Neglecting to include a loop-termination statement results in an infinite loop.

A LOOP statement can be labeled. For the rules regarding label use, see Section 13.6.2, “Statement Labels”.

1580
Flow Control Statements

Example:

CREATE PROCEDURE doIterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN
      ITERATE label1;
    END IF;
    LEAVE label1;
  END LOOP label1;
  SET @x = p1;
END;

13.6.5.6 REPEAT Statement

```plaintext
[begin_label:] REPEAT
  statement_list
UNTIL search_condition
END REPEAT [end_label]
```

The statement list within a REPEAT statement is repeated until the search_condition expression is true. Thus, a REPEAT always enters the loop at least once. statement_list consists of one or more statements, each terminated by a semicolon (;) statement delimiter.

A REPEAT statement can be labeled. For the rules regarding label use, see Section 13.6.2, “Statement Labels”.

Example:

```sql
mysql> delimiter //
mysql> CREATE PROCEDURE dorepeat(p1 INT)
      BEGIN
          SET @x = 0;
          REPEAT
            SET @x = @x + 1;
            UNTIL @x > p1 END REPEAT;
      END //
Query OK, 0 rows affected (0.00 sec)

mysql> CALL dorepeat(1000) //
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x //
+------+
| @x   |
+------+
| 1001  |
+------+
1 row in set (0.00 sec)
```

13.6.5.7 RETURN Statement

RETURN expr

The RETURN statement terminates execution of a stored function and returns the value expr to the function caller. There must be at least one RETURN statement in a stored function. There may be more than one if the function has multiple exit points.

This statement is not used in stored procedures, triggers, or events. The LEAVE statement can be used to exit a stored program of those types.
13.6.5.8 WHILE Statement

```sql
[begin_label:] WHILE search_condition DO
  statement_list
END WHILE [end_label]
```

The statement list within a `WHILE` statement is repeated as long as the `search_condition` expression is true. `statement_list` consists of one or more SQL statements, each terminated by a semicolon (`;`) statement delimiter.

A `WHILE` statement can be labeled. For the rules regarding label use, see Section 13.6.2, “Statement Labels”.

Example:

```sql
CREATE PROCEDURE dowhile()
BEGIN
  DECLARE v1 INT DEFAULT 5;
  WHILE v1 > 0 DO
    ...
    SET v1 = v1 - 1;
  END WHILE;
END;
```

13.6.6 Cursors

MySQL supports cursors inside stored programs. The syntax is as in embedded SQL. Cursors have these properties:

- Asensitive: The server may or may not make a copy of its result table
- Read only: Not updatable
- Nonscrollable: Can be traversed only in one direction and cannot skip rows

Cursor declarations must appear before handler declarations and after variable and condition declarations.

Example:

```sql
CREATE PROCEDURE curdemo()
BEGIN
  DECLARE done INT DEFAULT FALSE;
  DECLARE a CHAR(16);
  DECLARE b, c INT;
  DECLARE cur1 CURSOR FOR SELECT id, data FROM test.t1;
  DECLARE cur2 CURSOR FOR SELECT i FROM test.t2;
  DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = TRUE;
  OPEN cur1;
  OPEN cur2;
  read_loop: LOOP
    FETCH cur1 INTO a, b;
    FETCH cur2 INTO c;
    IF done THEN
      LEAVE read_loop;
    END IF;
    IF b < c THEN
      INSERT INTO test.t3 VALUES (a, b);
    ELSE
      INSERT INTO test.t3 VALUES (a, c);
    END IF;
```
13.6.6.1 Cursor CLOSE Statement

```
CLOSE cursor_name
```

This statement closes a previously opened cursor. For an example, see Section 13.6.6, “Cursors”.

An error occurs if the cursor is not open.

If not closed explicitly, a cursor is closed at the end of the `BEGIN ... END` block in which it was declared.

13.6.6.2 Cursor DECLARE Statement

```
DECLARE cursor_name CURSOR FOR select_statement
```

This statement declares a cursor and associates it with a `SELECT` statement that retrieves the rows to be traversed by the cursor. To fetch the rows later, use a `FETCH` statement. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

The `SELECT` statement cannot have an `INTO` clause.

Cursor declarations must appear before handler declarations and after variable and condition declarations.

A stored program may contain multiple cursor declarations, but each cursor declared in a given block must have a unique name. For an example, see Section 13.6.6, “Cursors”.

For information available through `SHOW` statements, it is possible in many cases to obtain equivalent information by using a cursor with an `INFORMATION_SCHEMA` table.

13.6.6.3 Cursor FETCH Statement

```
FETCH [[NEXT FROM] cursor_name INTO var_name [, var_name] ...]
```

This statement fetches the next row for the `SELECT` statement associated with the specified cursor (which must be open), and advances the cursor pointer. If a row exists, the fetched columns are stored in the named variables. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

If no more rows are available, a No Data condition occurs with SQLSTATE value '02000'. To detect this condition, you can set up a handler for it (or for a `NOT FOUND` condition). For an example, see Section 13.6.6, “Cursors”.

Be aware that another operation, such as a `SELECT` or another `FETCH`, may also cause the handler to execute by raising the same condition. If it is necessary to distinguish which operation raised the condition, place the operation within its own `BEGIN ... END` block so that it can be associated with its own handler.

13.6.6.4 Cursor OPEN Statement

```
OPEN cursor_name
```

This statement opens a previously declared cursor. For an example, see Section 13.6.6, “Cursors”.

13.6.6.5 Restrictions on Server-Side Cursors
Server-side cursors are implemented in the C API using the `mysql_stmt_attr_set()` function. The same implementation is used for cursors in stored routines. A server-side cursor enables a result set to be generated on the server side, but not transferred to the client except for those rows that the client requests. For example, if a client executes a query but is only interested in the first row, the remaining rows are not transferred.

In MySQL, a server-side cursor is materialized into an internal temporary table. Initially, this is a `MEMORY` table, but is converted to a `MyISAM` table when its size exceeds the minimum value of the `max_heap_table_size` and `tmp_table_size` system variables. The same restrictions apply to internal temporary tables created to hold the result set for a cursor as for other uses of internal temporary tables. See Section 8.4.4, “Internal Temporary Table Use in MySQL”. One limitation of the implementation is that for a large result set, retrieving its rows through a cursor might be slow.

Cursors are read only; you cannot use a cursor to update rows.

`UPDATE WHERE CURRENT OF` and `DELETE WHERE CURRENT OF` are not implemented, because updatable cursors are not supported.

Cursors are nonholdable (not held open after a commit).

Cursors are asensitive.

Cursors are nonscrollable.

Cursors are not named. The statement handler acts as the cursor ID.

You can have open only a single cursor per prepared statement. If you need several cursors, you must prepare several statements.

You cannot use a cursor for a statement that generates a result set if the statement is not supported in prepared mode. This includes statements such as `CHECK TABLE`, `HANDLER READ`, and `SHOW BINLOG EVENTS`.

13.6.7 Condition Handling

Conditions may arise during stored program execution that require special handling, such as exiting the current program block or continuing execution. Handlers can be defined for general conditions such as warnings or exceptions, or for specific conditions such as a particular error code. Specific conditions can be assigned names and referred to that way in handlers.

To name a condition, use the `DECLARE ... CONDITION` statement. To declare a handler, use the `DECLARE ... HANDLER` statement. See Section 13.6.7.1, “DECLARE ... CONDITION Statement”, and Section 13.6.7.2, “DECLARE ... HANDLER Statement”.

To raise a condition, use the `SIGNAL` statement. To modify condition information within a condition handler, use `RESIGNAL`. See Section 13.6.7.1, “DECLARE ... CONDITION Statement”, and Section 13.6.7.2, “DECLARE ... HANDLER Statement”.

Another statement related to conditions is `GET DIAGNOSTICS`. The `GET DIAGNOSTICS` statement is not supported until MySQL 5.6.

Before MySQL 5.6.3, if a statement that generates a warning or error causes a condition handler to be invoked, the handler may not clear the diagnostic area. This might lead to the appearance that the handler was not invoked. The following discussion demonstrates the issue and provides a workaround.

Suppose that a table `t1` is empty. The following procedure selects from it, raising a No Data condition:
CREATE PROCEDURE p1()
BEGIN
    DECLARE a INT;
    DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
        SET @handler_invoked = 1;
    END;
    SELECT c1 INTO a FROM t1;
END;

As can be seen from the following sequence of statements, the condition is not cleared by handler invocation (otherwise, the `SHOW WARNINGS` output would be empty). But as can be seen by the value of `@handler_invoked`, the handler was indeed invoked (otherwise its value would be 0).

```sql
mysql> SET @handler_invoked = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> CALL p1();
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------------+
| Level   | Code | Message                                             |
+---------+------+-----------------------------------------------------+
| Warning | 1329 | No data - zero rows fetched, selected, or processed |
+---------+------+-----------------------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @handler_invoked;
+------------------+
| @handler_invoked |
+------------------+
| 1                |
+------------------+
1 row in set (0.00 sec)
```

To work around this issue, use a condition handler containing a statement that clears warnings:

```sql
CREATE PROCEDURE p1()
BEGIN
    DECLARE a INT;
    DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
        SELECT 1 INTO @handler_invoked FROM (SELECT 1) AS t;
    END;
    SELECT c1 INTO a FROM t1;
END;
```

This works for `CONTINUE` and `EXIT` handlers.

This issue is resolved as of MySQL 5.6.3 and no workaround is needed.

### 13.6.7.1 DECLARE ... CONDITION Statement

```
DECLARE condition_name CONDITION FOR condition_value
```

The `DECLARE ... CONDITION` statement declares a named error condition, associating a name with a condition that needs specific handling. The name can be referred to in a subsequent `DECLARE ... HANDLER` statement (see Section 13.6.7.2, “DECLARE ... HANDLER Statement”).
Condition declarations must appear before cursor or handler declarations.

The `condition_value` for `DECLARE ... CONDITION` indicates the specific condition or class of conditions to associate with the condition name. It can take the following forms:

- **mysql_error_code**: An integer literal indicating a MySQL error code.
  
  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3.1, “Server Error Message Reference”.

- **SQLSTATE [VALUE] sqlstate_value**: A 5-character string literal indicating an SQLSTATE value.

  Do not use SQLSTATE values that begin with '00' because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3.1, “Server Error Message Reference”.

Condition names referred to in `SIGNAL` or use `RESIGNAL` statements must be associated with SQLSTATE values, not MySQL error codes.

Using names for conditions can help make stored program code clearer. For example, this handler applies to attempts to drop a nonexistent table, but that is apparent only if you know that 1051 is the MySQL error code for “unknown table”:

```sql
DECLARE CONTINUE HANDLER FOR 1051
BEGIN
  -- body of handler
END;
```

By declaring a name for the condition, the purpose of the handler is more readily seen:

```sql
DECLARE no_such_table CONDITION FOR 1051;
DECLARE CONTINUE HANDLER FOR no_such_table
BEGIN
  -- body of handler
END;
```

Here is a named condition for the same condition, but based on the corresponding SQLSTATE value rather than the MySQL error code:

```sql
DECLARE no_such_table CONDITION FOR SQLSTATE '42S02';
DECLARE CONTINUE HANDLER FOR no_such_table
BEGIN
  -- body of handler
END;
```

### 13.6.7.2 DECLARE ... HANDLER Statement

```sql
DECLARE handler_action HANDLER
FOR condition_value [, condition_value] ...
statement

handler_action: { 
  CONTINUE 
  | EXIT 
  | UNDO 
}

condition_value: {
  mysql_error_code 
  | SQLSTATE [VALUE] sqlstate_value 
  | condition_name 
  | SQLWARNING 
  | NOT FOUND 

```
The `DECLARE ... HANDLER` statement specifies a handler that deals with one or more conditions. If one of these conditions occurs, the specified `statement` executes. `statement` can be a simple statement such as `SET var_name = value`, or a compound statement written using `BEGIN` and `END` (see Section 13.6.1, “BEGIN ... END Compound Statement”).

Handler declarations must appear after variable or condition declarations.

The `handler_action` value indicates what action the handler takes after execution of the handler statement:

- **CONTINUE**: Execution of the current program continues.
- **EXIT**: Execution terminates for the `BEGIN ... END` compound statement in which the handler is declared. This is true even if the condition occurs in an inner block.
- **UNDO**: Not supported.

The `condition_value` for `DECLARE ... HANDLER` indicates the specific condition or class of conditions that activates the handler. It can take the following forms:

- **mysql_error_code**: An integer literal indicating a MySQL error code, such as 1051 to specify “unknown table”:

  ```sql
  DECLARE CONTINUE HANDLER FOR 1051
  BEGIN
    -- body of handler
  END;
  ```

  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3.1, “Server Error Message Reference”.

- **SQLSTATE [VALUE] sqlstate_value**: A 5-character string literal indicating an SQLSTATE value, such as ‘42S01’ to specify “unknown table”:

  ```sql
  DECLARE CONTINUE HANDLER FOR SQLSTATE '42S02'
  BEGIN
    -- body of handler
  END;
  ```

  Do not use SQLSTATE values that begin with ‘00’ because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3.1, “Server Error Message Reference”.

- **condition_name**: A condition name previously specified with `DECLARE ... CONDITION`. A condition name can be associated with a MySQL error code or SQLSTATE value. See Section 13.6.7.1, “DECLARE ... CONDITION Statement”.

- **SQLWARNING**: Shorthand for the class of SQLSTATE values that begin with ‘01’.

  ```sql
  DECLARE CONTINUE HANDLER FOR SQLWARNING
  BEGIN
    -- body of handler
  END;
  ```

- **NOT FOUND**: Shorthand for the class of SQLSTATE values that begin with ‘02’. This is relevant within the context of cursors and is used to control what happens when a cursor reaches the end of a data set. If no more rows are available, a No Data condition occurs with SQLSTATE value ‘02000’. To detect this condition, you can set up a handler for it or for a `NOT FOUND` condition.
For another example, see Section 13.6.6, “Cursors”. The **NOT FOUND** condition also occurs for `SELECT ... INTO var_list` statements that retrieve no rows.

- **SQLEXCEPTION**: Shorthand for the class of SQLSTATE values that do not begin with '00', '01', or '02'.

  DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
  BEGIN
  -- body of handler
  END;

If a condition occurs for which no handler has been declared, the action taken depends on the condition class:

- For **SQLEXCEPTION** conditions, the stored program terminates at the statement that raised the condition, as if there were an `EXIT` handler. If the program was called by another stored program, the calling program handles the condition using the handler selection rules applied to its own handlers.

- For **SQLWARNING** conditions, the program continues executing, as if there were a `CONTINUE` handler.

- For **NOT FOUND** conditions, if the condition was raised normally, the action is `CONTINUE`. If it was raised by `SIGNAL` or `RESIGNAL`, the action is **EXIT**.

The following example uses a handler for SQLSTATE '23000', which occurs for a duplicate-key error:

```sql
mysql> CREATE TABLE test.t (s1 INT, PRIMARY KEY (s1));
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter //

mysql> CREATE PROCEDURE handlerdemo()
BEGIN
  DECLARE CONTINUE HANDLER FOR SQLSTATE '23000' SET @x2 = 1;
  SET @x = 1;
  INSERT INTO test.t VALUES (1);
  SET @x = 2;
  INSERT INTO test.t VALUES (1);
  SET @x = 3;
END;
//
Query OK, 0 rows affected (0.00 sec)

mysql> CALL handlerdemo();//
Query OK, 0 rows affected, 1 warning (0.01 sec)

mysql> SHOW WARNINGS;//
+-------+------+---------------------------------------+
| Level | Code | Message                               |
|-------+------|---------------------------------------|
| Error | 1062 | Duplicate entry '1' for key 'PRIMARY' |
+-------+------|---------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @x;//
+------+
<table>
<thead>
<tr>
<th>@x</th>
</tr>
</thead>
</table>
```
Notice that \( \alpha \) is 3 after the procedure executes, which shows that execution continued to the end of the procedure after the error occurred. If the `DECLARE ... HANDLER` statement had not been present, MySQL would have taken the default action (EXIT) after the second \texttt{INSERT} failed due to the \texttt{PRIMARY KEY} constraint, and \texttt{SELECT \( \alpha \)} would have returned 2.

To ignore a condition, declare a \texttt{CONTINUE} handler for it and associate it with an empty block. For example:

```sql
DECLARE CONTINUE HANDLER FOR SQLWARNING BEGIN END;
```

The scope of a block label does not include the code for handlers declared within the block. Therefore, the statement associated with a handler cannot use \texttt{ITERATE} or \texttt{LEAVE} to refer to labels for blocks that enclose the handler declaration. Consider the following example, where the \texttt{REPEAT} block has a label of \texttt{retry}:

```sql
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 3;
  retry:
  REPEAT
    BEGIN
      DECLARE CONTINUE HANDLER FOR SQLWARNING
      BEGIN
        ITERATE retry;  # illegal
      END;
      IF i < 0 THEN
        LEAVE retry;    # legal
      END IF;
      SET i = i - 1;
    END;
  UNTIL FALSE END REPEAT;
END;
```

The \texttt{retry} label is in scope for the \texttt{IF} statement within the block. It is not in scope for the \texttt{CONTINUE} handler, so the reference there is invalid and results in an error:

```
ERROR 1308 (42000): LEAVE with no matching label: retry
```

To avoid references to outer labels in handlers, use one of these strategies:

- To leave the block, use an \texttt{EXIT} handler. If no block cleanup is required, the \texttt{BEGIN ... END} handler body can be empty:

  ```sql
  DECLARE EXIT HANDLER FOR SQLWARNING BEGIN END;
  ```

- Otherwise, put the cleanup statements in the handler body:

  ```sql
  DECLARE EXIT HANDLER FOR SQLWARNING
  BEGIN
    block cleanup statements
  END;
  ```

- To continue execution, set a status variable in a \texttt{CONTINUE} handler that can be checked in the enclosing block to determine whether the handler was invoked. The following example uses the variable \texttt{done} for this purpose:

  ```sql
  CREATE PROCEDURE p ()
  BEGIN
  ```
DECLARE i INT DEFAULT 3;
DECLARE done INT DEFAULT FALSE;
retry:
    REPEAT
        BEGIN
            DECLARE CONTINUE HANDLER FOR SQLWARNING
            BEGIN
                SET done = TRUE;
            END;
            IF done OR i < 0 THEN
                LEAVE retry;
            END IF;
            SET i = i - 1;
        END;
        UNTIL FALSE END REPEAT;
END;

13.6.7.3 RESIGNAL Statement

RESIGNAL [condition_value]
    [SET signal_information_item
    [, signal_information_item] ...]

condition_value: {
    SQLSTATE [VALUE] sqlstate_value
    | condition_name
}

signal_information_item:
    condition_information_item_name = simple_value_specification

collection_information_item_name: {
    CLASS_ORIGIN
    | SUBCLASS_ORIGIN
    | MESSAGE_TEXT
    | MYSQL_ERRNO
    | CONSTRAINT_CATALOG
    | CONSTRAINT_SCHEMA
    | CONSTRAINT_NAME
    | CATALOG_NAME
    | SCHEMA_NAME
    | TABLE_NAME
    | COLUMN_NAME
    | CURSOR_NAME
}

condition_name, simple_value_specification:
    (see following discussion)

RESIGNAL passes on the error condition information that is available during execution of a condition handler within a compound statement inside a stored procedure or function, trigger, or event. RESIGNAL may change some or all information before passing it on. RESIGNAL is related to SIGNAL, but instead of originating a condition as SIGNAL does, RESIGNAL relays existing condition information, possibly after modifying it.

RESIGNAL makes it possible to both handle an error and return the error information. Otherwise, by executing an SQL statement within the handler, information that caused the handler’s activation is destroyed. RESIGNAL also can make some procedures shorter if a given handler can handle part of a situation, then pass the condition “up the line” to another handler.

No privileges are required to execute the RESIGNAL statement.

All forms of RESIGNAL require that the current context be a condition handler. Otherwise, RESIGNAL is illegal and a RESIGNAL when handler not active error occurs.
RESIGNAL Overview

For condition_value and signal_information_item, the definitions and rules are the same for RESIGNAL as for SIGNAL. For example, the condition_value can be an SQLSTATE value, and the value can indicate errors, warnings, or “not found.” For additional information, see Section 13.6.7.4, “SIGNAL Statement”.

The RESIGNAL statement takes condition_value and SET clauses, both of which are optional. This leads to several possible uses:

• RESIGNAL alone:

```
RESIGNAL;
```

• RESIGNAL with new signal information:

```
RESIGNAL SET signal_information_item [, signal_information_item] ...;
```

• RESIGNAL with a condition value and possibly new signal information:

```
RESIGNAL condition_value
    [SET signal_information_item [, signal_information_item] ...];
```

These use cases all cause changes to the diagnostics and condition areas:

• A diagnostics area contains one or more condition areas.

• A condition area contains condition information items, such as the SQLSTATE value, MYSQL_ERRNO, or MESSAGE_TEXT.

The maximum number of condition areas in a diagnostics area is determined by the value of the max_error_count system variable.

RESIGNAL Alone

A simple RESIGNAL alone means “pass on the error with no change.” It restores the last diagnostics area and makes it the current diagnostics area. That is, it “pops” the diagnostics area stack.

Within a condition handler that catches a condition, one use for RESIGNAL alone is to perform some other actions, and then pass on without change the original condition information (the information that existed before entry into the handler).

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
    DECLARE EXIT HANDLER FOR SQLEXCEPTION
    BEGIN
```

1591
Suppose that the `DROP TABLE xx` statement fails. The diagnostics area stack looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

Then execution enters the `EXIT` handler. It starts by pushing a diagnostics area to the top of the stack, which now looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
DA 2. ERROR 1051 (42S02): Unknown table 'xx'
```

Usually a procedure statement clears the first diagnostics area (also called the “current” diagnostics area). `BEGIN` is an exception, it does not clear, it does nothing. `SET` is not an exception, it clears, performs the operation, and produces a result of “success.” The diagnostics area stack now looks like this:

```
DA 1. ERROR 0000 (00000): Successful operation
DA 2. ERROR 1051 (42S02): Unknown table 'xx'
```

At this point, if `@a = 0`, `RESIGNAL` pops the diagnostics area stack, which now looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

And that is what the caller sees.

If `@a` is not 0, the handler simply ends, which means that there is no more use for the current diagnostics area (it has been “handled”), so it can be thrown away, causing the stacked diagnostics area to become the current diagnostics area again. The diagnostics area stack looks like this:

```
DA 1. ERROR 0000 (00000): Successful operation
```

The details make it look complex, but the end result is quite useful: Handlers can execute without destroying information about the condition that caused activation of the handler.

### RESIGNAL with New Signal Information

`RESIGNAL` with a `SET` clause provides new signal information, so the statement means “pass on the error with changes”:

```
RESIGNAL SET signal_information_item [, signal_information_item] ...;
```

As with `RESIGNAL` alone, the idea is to pop the diagnostics area stack so that the original information will go out. Unlike `RESIGNAL` alone, anything specified in the `SET` clause changes.

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
    DECLARE EXIT HANDLER FOR SQLEXCEPTION
    BEGIN
        SET @error_count = @error_count + 1;
        IF @a = 0 THEN RESIGNAL SET MYSQL_ERRNO = 5; END IF;
```
Remember from the previous discussion that `RESIGNAL` alone results in a diagnostics area stack like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

The `RESIGNAL SET MYSQL_ERRNO = 5` statement results in this stack instead, which is what the caller sees:

```
DA 1. ERROR 5 (42S02): Unknown table 'xx'
```

In other words, it changes the error number, and nothing else.

The `RESIGNAL` statement can change any or all of the signal information items, making the first condition area of the diagnostics area look quite different.

**RESIGNAL with a Condition Value and Optional New Signal Information**

`RESIGNAL` with a condition value means “push a condition into the current diagnostics area.” If the `SET` clause is present, it also changes the error information.

```
RESIGNAL condition_value
  [SET signal_information_item [, signal_information_item] ...];
```

This form of `RESIGNAL` restores the last diagnostics area and makes it the current diagnostics area. That is, it “pops” the diagnostics area stack, which is the same as what a simple `RESIGNAL` alone would do. However, it also changes the diagnostics area depending on the condition value or signal information.

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION
  BEGIN
    SET @error_count = @error_count + 1;
    IF @a = 0 THEN RESIGNAL SQLSTATE '45000' SET MYSQL_ERRNO=5; END IF;
  END;
  DROP TABLE xx;
END;
delimiter ;
SET @error_count = 0;
SET @a = 0;
SET @@max_error_count = 2;
CALL p();
SHOW ERRORS;
```

This is similar to the previous example, and the effects are the same, except that if `RESIGNAL` happens, the current condition area looks different at the end. (The reason the condition adds to rather than replaces the existing condition is the use of a condition value.)

The `RESIGNAL` statement includes a condition value (SQLSTATE '45000'), so it adds a new condition area, resulting in a diagnostics area stack that looks like this:

```
DA 1. (condition 2) ERROR 1051 (42S02): Unknown table 'xx'
```
The result of **CALL p()** and **SHOW ERRORS** for this example is:

```sql
mysql> CALL p();
ERROR 5 (45000): Unknown table 'xx'
mysql> SHOW ERRORS;
```

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error</td>
<td>1051</td>
<td>Unknown table 'xx'</td>
</tr>
<tr>
<td>Error</td>
<td>5</td>
<td>Unknown table 'xx'</td>
</tr>
</tbody>
</table>

**RESIGNAL Requires Condition Handler Context**

All forms of **RESIGNAL** require that the current context be a condition handler. Otherwise, **RESIGNAL** is illegal and a **RESIGNAL when handler not active** error occurs. For example:

```sql
mysql> CREATE PROCEDURE p () RESIGNAL;
Query OK, 0 rows affected (0.00 sec)
mysql> CALL p();
ERROR 1645 (0K000): RESIGNAL when handler not active
```

Here is a more difficult example:

```sql
delimiter //
CREATE FUNCTION f () RETURNS INT
BEGIN
  RESIGNAL;
  RETURN 5;
END//
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION SET @a=f();
  SIGNAL SQLSTATE '55555';
END//
delimiter ;
CALL p();
```

**RESIGNAL** occurs within the stored function `f()`, which is invoked from within the **EXIT** handler. Thus, a handler is active at the time **RESIGNAL** executes, even though **RESIGNAL** is not defined inside the handler.

**Note**

In MySQL 5.6 and higher, handler scope rules are more well developed. Although `f()` itself is invoked within the context of the **EXIT** handler, execution within `f()` has its own context, which is not handler context. Thus, **RESIGNAL** within `f()` results in a “handler not active” error.

13.6.7.4 **SIGNAL Statement**

```sql
SIGNAL condition_value
  [SET signal_information_item
  [, signal_information_item] ...]
condition_value: {
  SQLSTATE [VALUE] sqlstate_value
  | condition_name
}
signal_information_item:
  condition_information_item_name = simple_value_specification
```
SIGNAL is the way to “return” an error. SIGNAL provides error information to a handler, to an outer portion of the application, or to the client. Also, it provides control over the error’s characteristics (error number, SQLSTATE value, message). Without SIGNAL, it is necessary to resort to workarounds such as deliberately referring to a nonexistent table to cause a routine to return an error.

No privileges are required to execute the SIGNAL statement.

- SIGNAL Overview
- Signal Condition Information Items
- Effect of Signals on Handlers, Cursors, and Statements

**SIGNAL Overview**

The condition_value in a SIGNAL statement indicates the error value to be returned. It can be an SQLSTATE value (a 5-character string literal) or a condition_name that refers to a named condition previously defined with DECLARE ... CONDITION (see Section 13.6.7.1, “DECLARE ... CONDITION Statement”).

An SQLSTATE value can indicate errors, warnings, or “not found.” The first two characters of the value indicate its error class, as discussed in Signal Condition Information Items. Some signal values cause statement termination; see Effect of Signals on Handlers, Cursors, and Statements.

The SQLSTATE value for a SIGNAL statement should not start with '00' because such values indicate success and are not valid for signaling an error. This is true whether the SQLSTATE value is specified directly in the SIGNAL statement or in a named condition referred to in the statement. If the value is invalid, a Bad SQLSTATE error occurs.

To signal a generic SQLSTATE value, use '45000', which means “unhandled user-defined exception.”

The SIGNAL statement optionally includes a SET clause that contains multiple signal items, in a list of condition_information_item_name = simple_value_specification assignments, separated by commas.

Each condition_information_item_name may be specified only once in the SET clause. Otherwise, a Duplicate condition information item error occurs.

Valid simple_value_specification designators can be specified using stored procedure or function parameters, stored program local variables declared with DECLARE, user-defined variables, system variables, or literals. A character literal may include a _charset introducer.
For information about permissible `condition_information_item_name` values, see Signal Condition Information Items.

The following procedure signals an error or warning depending on the value of `pval`, its input parameter:

```sql
CREATE PROCEDURE p (pval INT)
BEGIN
  DECLARE specialty CONDITION FOR SQLSTATE '45000';
  IF pval = 0 THEN
    SIGNAL SQLSTATE '01000';
  ELSEIF pval = 1 THEN
    SIGNAL SQLSTATE '45000'
    SET MESSAGE_TEXT = 'An error occurred';
  ELSEIF pval = 2 THEN
    SIGNAL specialty
    SET MESSAGE_TEXT = 'An error occurred';
  ELSE
    SIGNAL SQLSTATE '01000'
    SET MESSAGE_TEXT = 'A warning occurred', MYSQL_ERRNO = 1000;
    SIGNAL SQLSTATE '45000'
    SET MESSAGE_TEXT = 'An error occurred', MYSQL_ERRNO = 1001;
  END IF;
END;
```

If `pval` is 0, `p()` signals a warning because SQLSTATE values that begin with '01' are signals in the warning class. The warning does not terminate the procedure, and can be seen with `SHOW WARNINGS` after the procedure returns.

If `pval` is 1, `p()` signals an error and sets the `MESSAGE_TEXT` condition information item. The error terminates the procedure, and the text is returned with the error information.

If `pval` is 2, the same error is signaled, although the SQLSTATE value is specified using a named condition in this case.

If `pval` is anything else, `p()` first signals a warning and sets the message text and error number condition information items. This warning does not terminate the procedure, so execution continues and `p()` then signals an error. The error does terminate the procedure. The message text and error number set by the warning are replaced by the values set by the error, which are returned with the error information.

`SIGNAL` is typically used within stored programs, but it is a MySQL extension that it is permitted outside handler context. For example, if you invoke the `mysql` client program, you can enter any of these statements at the prompt:

```sql
SIGNAL SQLSTATE '77777';
CREATE TRIGGER t_bi BEFORE INSERT ON t 
  FOR EACH ROW SIGNAL SQLSTATE '77777';
CREATE EVENT e ON SCHEDULE EVERY 1 SECOND 
  DO SIGNAL SQLSTATE '77777';
```

`SIGNAL` executes according to the following rules:

If the `SIGNAL` statement indicates a particular SQLSTATE value, that value is used to signal the condition specified. Example:

```sql
CREATE PROCEDURE p (divisor INT)
BEGIN
  IF divisor = 0 THEN
    SIGNAL SQLSTATE '22012';
  END IF;
```
If the `SIGNAL` statement uses a named condition, the condition must be declared in some scope that applies to the `SIGNAL` statement, and must be defined using an `SQLSTATE` value, not a MySQL error number. Example:

```sql
CREATE PROCEDURE p (divisor INT)
BEGIN
    DECLARE divide_by_zero CONDITION FOR SQLSTATE '22012';
    IF divisor = 0 THEN
        SIGNAL divide_by_zero;
    END IF;
END;
```

If the named condition does not exist in the scope of the `SIGNAL` statement, an `Undefined CONDITION` error occurs.

If `SIGNAL` refers to a named condition that is defined with a MySQL error number rather than an `SQLSTATE` value, a `SIGNAL/RESIGNAL` can only use a `CONDITION` defined with `SQLSTATE` error occurs. The following statements cause that error because the named condition is associated with a MySQL error number:

```sql
DECLARE no_such_table CONDITION FOR 1051;
SIGNAL no_such_table;
```

If a condition with a given name is declared multiple times in different scopes, the declaration with the most local scope applies. Consider the following procedure:

```sql
CREATE PROCEDURE p (divisor INT)
BEGIN
    DECLARE my_error CONDITION FOR SQLSTATE '45000';
    IF divisor = 0 THEN
        BEGIN
            DECLARE my_error CONDITION FOR SQLSTATE '22012';
            SIGNAL my_error;
        END;
    END IF;
    SIGNAL my_error;
END;
```

If `divisor` is 0, the first `SIGNAL` statement executes. The innermost `my_error` condition declaration applies, raising `SQLSTATE '22012'`.

If `divisor` is not 0, the second `SIGNAL` statement executes. The outermost `my_error` condition declaration applies, raising `SQLSTATE '45000'`.

Signals can be raised within exception handlers:

```sql
CREATE PROCEDURE p ()
BEGIN
    DECLARE EXIT HANDLER FOR SQLEXCEPTION
    BEGIN
        SIGNAL SQLSTATE VALUE '99999'
        SET MESSAGE_TEXT = 'An error occurred';
    END;
    DROP TABLE no_such_table;
END;
```

`CALL p ()` reaches the `DROP TABLE` statement. There is no table named `no_such_table`, so the error handler is activated. The error handler destroys the original error ("no such table") and makes a new error with `SQLSTATE '99999'` and message `An error occurred`. 
Signal Condition Information Items

The following table lists the names of diagnostics area condition information items that can be set in a SIGNAL (or RESIGNAL) statement. All items are standard SQL except MYSQL_ERRNO, which is a MySQL extension.

<table>
<thead>
<tr>
<th>Item Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS_ORIGIN</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>SUBCLASS_ORIGIN</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>CONSTRAINT_CATALOG</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>CONSTRAINT_SCHEMA</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>CONSTRAINT_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>CATALOG_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>SCHEMA_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>TABLE_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>COLUMN_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>CURSOR_NAME</td>
<td>VARCHAR(64)</td>
</tr>
<tr>
<td>MESSAGE_TEXT</td>
<td>VARCHAR(128)</td>
</tr>
<tr>
<td>MYSQL_ERRNO</td>
<td>SMALLINT UNSIGNED</td>
</tr>
</tbody>
</table>

The character set for character items is UTF-8.

It is illegal to assign NULL to a condition information item in a SIGNAL statement.

A SIGNAL statement always specifies an SQLSTATE value, either directly, or indirectly by referring to a named condition defined with an SQLSTATE value. The first two characters of an SQLSTATE value are its class, and the class determines the default value for the condition information items:

- **Class = '00' (success)**
  - Illegal. SQLSTATE values that begin with '00' indicate success and are not valid for SIGNAL.

- **Class = '01' (warning)**
  - MESSAGE_TEXT = 'Unhandled user-defined warning condition';
  - MYSQL_ERRNO = ER_SIGNAL_WARN

- **Class = '02' (not found)**
  - MESSAGE_TEXT = 'Unhandled user-defined not found condition';
  - MYSQL_ERRNO = ER_SIGNAL_NOT_FOUND

- **Class > '02' (exception)**
  - MESSAGE_TEXT = 'Unhandled user-defined exception condition';
  - MYSQL_ERRNO = ER_SIGNAL_EXCEPTION

For legal classes, the other condition information items are set as follows:

CLASS_ORIGIN = SUBCLASS_ORIGIN = '';
CONSTRAINT_CATALOG = CONSTRAINT_SCHEMA = CONSTRAINT_NAME = '';
CATALOG_NAME = SCHEMA_NAME = TABLE_NAME = COLUMN_NAME = '';
CURSOR_NAME = '';

The error values that are accessible after SIGNAL executes are the SQLSTATE value raised by the SIGNAL statement and the MESSAGE_TEXT and MYSQL_ERRNO items. These values are available from the C API:

- mysql_sqlstate() returns the SQLSTATE value.
- mysql_errno() returns the MYSQL_ERRNO value.
Condition Handling

- `mysql_error()` returns the `MESSAGE_TEXT` value.

At the SQL level, the output from `SHOW WARNINGS` and `SHOW ERRORS` indicates the `MYSQL_ERRNO` and `MESSAGE_TEXT` values in the `Code` and `Message` columns.

Other condition information items can be set, but currently have no effect, in the sense that they are not accessible from error returns. For example, you can set `CLASS_ORIGIN` in a `SIGNAL` statement, but cannot see it after `SIGNAL` executes. In MySQL 5.6, condition information can be inspected with the `GET DIAGNOSTICS` statement.

Effect of Signals on Handlers, Cursors, and Statements

Signals have different effects on statement execution depending on the signal class. The class determines how severe an error is. MySQL ignores the value of the `sql_mode` system variable; in particular, strict SQL mode does not matter. MySQL also ignores `IGNORE`: The intent of `SIGNAL` is to raise a user-generated error explicitly, so a signal is never ignored.

In the following descriptions, “unhandled” means that no handler for the signaled `SQLSTATE` value has been defined with `DECLARE ... HANDLER`.

- **Class = '00'** (success)
  
  Illegal. `SQLSTATE` values that begin with '00' indicate success and are not valid for `SIGNAL`.

- **Class = '01'** (warning)
  
  The value of the `warning_count` system variable goes up. `SHOW WARNINGS` shows the signal. `SQLWARNING` handlers catch the signal. If the signal is unhandled in a stored function, statements do not end.

- **Class = '02'** (not found)
  
  `NOT FOUND` handlers catch the signal. There is no effect on cursors. If the signal is unhandled in a stored function, statements end.

- **Class > '02'** (exception)
  
  `SQLWARNING` handlers catch the signal. If the signal is unhandled in a stored function, statements end.

- **Class = '40'**
  
  Treated as an ordinary exception.

Example:

```sql
delimiter //
CREATE FUNCTION f () RETURNS INT
BEGIN
  SIGNAL SQLSTATE '01234'; -- signal a warning
  RETURN 5;
END;//
delimiter ;
CREATE TABLE t (s1 INT);
INSERT INTO t VALUES (f());
```

The result is that a row containing 5 is inserted into table `t`. The warning that is signaled can be viewed with `SHOW WARNINGS`.


13.6.7.5 Condition Handling and OUT or INOUT Parameters

If a stored procedure exits with an unhandled exception, modified values of OUT and INOUT parameters are not propagated back to the caller.

If an exception is handled by a CONTINUE or EXIT handler that contains a RESIGNAL statement, execution of RESIGNAL signals the exception (that is, the information that existed before entry into the handler). If the exception is an error, the values of OUT and INOUT parameters are not propagated back to the caller.

13.6.7.6 Restrictions on Condition Handling

SIGNAL and RESIGNAL are not permissible as prepared statements. For example, this statement is invalid:

```
PREPARE stmt1 FROM 'SIGNAL SQLSTATE "02000"';
```

SQLSTATE values in class '04' are not treated specially. They are handled the same as other exceptions.

13.7 Database Administration Statements

13.7.1 Account Management Statements

MySQL account information is stored in the tables of the mysql system database. This database and the access control system are discussed extensively in Chapter 5, MySQL Server Administration, which you should consult for additional details.

Important

Some MySQL releases introduce changes to the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to the current structure whenever you upgrade MySQL. See Section 2.11, “Upgrading MySQL”.

When the read_only system variable is enabled, account-management statements require the SUPER privilege, in addition to any other required privileges. This is because they modify tables in the mysql system database.

13.7.1.1 CREATE USER Statement

```
CREATE USER
    user [auth_option] [, user [auth_option]] ...

user:
    (see Section 6.2.4, “Specifying Account Names”)

auth_option:
    IDENTIFIED BY [PASSWORD] 'auth_string'
```
The `CREATE USER` statement creates new MySQL accounts. An error occurs if you try to create an account that already exists.

To use `CREATE USER`, you must have the global `CREATE USER` privilege, or the `INSERT` privilege for the `mysql` system database. When the `read_only` system variable is enabled, `CREATE USER` additionally requires the `SUPER` privilege.

**Important**

`CREATE USER` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Client Logging”.

For each account, `CREATE USER` creates a new row in the `mysql.user` system table with no privileges and assigns the account an authentication plugin. Depending on the syntax used, `CREATE USER` may also assign the account a password.

An account when first created has no privileges. To assign privileges, use the `GRANT` statement.

Each `user` value naming an account may be followed by an optional `auth_option` value that specifies how authentication occurs for clients that use the account. This part of `CREATE USER` syntax is shared with `GRANT`, so the description here applies to `GRANT` as well.

Each account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

The host name part of the account name, if omitted, defaults to `'%`.

The server assigns an authentication plugin and password to each account as follows, depending on whether the user specification clause includes `IDENTIFIED BY` or `IDENTIFIED WITH` to specify authentication information:

- With `IDENTIFIED BY`, the server assigns no plugin. The `'auth_string'` value is cleartext, which is hashed before being stored as the password. If the optional `PASSWORD` keyword is given, the behavior is the same except that if the plugin requires a hashed string, the string is assumed to be already hashed in the format the plugin requires, and is stored as is as the password.

- With `IDENTIFIED WITH`, the server assigns the specified plugin and the account has no password. If the optional `AS 'auth_string'` clause is given, the string is stored as is as the password. If the plugin requires a hashed string, the string is assumed to be already hashed in the format the plugin requires.

- With neither `IDENTIFIED BY` nor `IDENTIFIED WITH`, the server assigns no plugin and the account has no password.

If the account has no password, the password information in the account row in the `mysql.user` table remains empty, which is insecure. To set the password, use `SET PASSWORD`. See Section 13.7.1.6, “SET PASSWORD Statement”.

If the server assigns no plugin to the account, the `plugin` column in the account's `mysql.user` table row remains empty.
For client connections that use a given account, the server invokes the authentication plugin assigned to the account and the client must provide credentials as required by the authentication method that the plugin implements. If the server cannot find the plugin, either at account-creation time or connect time, an error occurs.

If an account's `mysql.user` table row has a nonempty `plugin` column:

- The server authenticates client connection attempts using the named plugin.
- Changes to the account password using `SET PASSWORD` with `PASSWORD()` must be made with the `old_passwords` system variable set to the value required by the authentication plugin, so that `PASSWORD()` uses the appropriate password hashing method. If the plugin is `mysql_old_password`, the password can also be changed using `SET PASSWORD` with `OLD_PASSWORD()`, which uses pre-4.1 password hashing regardless of the value of `old_passwords`.

If an account's `mysql.user` table row has an empty `plugin` column:

- The server authenticates client connection attempts using the `mysql_native_password` or `mysql_old_password` authentication plugin, depending on the hash format of the password stored in the `Password` column.
- Changes to the account password using `SET PASSWORD` can be made with `PASSWORD()`, with `old_passwords` set to 0 or 1 for 4.1 or pre-4.1 password hashing, respectively, or with `OLD_PASSWORD()`, which uses pre-4.1 password hashing regardless of the value of `old_passwords`.

**CREATE USER** examples:

- To specify an authentication plugin for an account, use `IDENTIFIED WITH auth_plugin`. The plugin name can be a quoted string literal or an unquoted name. 'auth_string' is an optional quoted string literal to pass to the plugin. The plugin interprets the meaning of the string, so its format is plugin specific and it is stored in the `authentication_string` column as given. (This value is meaningful only for plugins that use that column.) Consult the documentation for a given plugin for information about the authentication string values it accepts, if any.

  ```sql
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED WITH mysql_native_password;
  ```

  The server assigns the given authentication plugin to the account but no password. Clients must provide no password when they connect. However, an account with no password is insecure. To ensure that an account uses a specific authentication plugin and has a password with the corresponding hash format, specify the plugin explicitly with `IDENTIFIED WITH`, then use `SET PASSWORD` to set the password:

  ```sql
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED WITH mysql_native_password;
  SET old_passwords = 0;
  SET PASSWORD FOR 'jeffrey'@'localhost' = PASSWORD('password');
  ```

  Changes to the account password using `SET PASSWORD` with `PASSWORD()` must be made with the `old_passwords` system variable set to the value required by the account's authentication plugin, so that `PASSWORD()` uses the appropriate password hashing method. Therefore, to use the `mysql_old_password` plugin instead, name that plugin in the `CREATE USER` statement and set `old_passwords` to 1 before using `SET PASSWORD`.

- To specify a password for an account at account-creation time, use `IDENTIFIED BY` with the literal cleartext password value:

  ```sql
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
  ```

  The server assigns the given password to the account but no authentication plugin. Clients must provide the password when they connect.
Account Management Statements

- To avoid specifying the cleartext password if you know its hash value (the value that `PASSWORD()` would return for the password), specify the hash value preceded by the keyword `PASSWORD`:

```
CREATE USER 'jeffrey'@'localhost'
IDENTIFIED BY PASSWORD '*90E462C37378CED12064BB388827D2BA3A9B689';
```

The server assigns the given password to the account but no authentication plugin. Clients must provide the password when they connect.

- To enable the user to connect with no password, include no `IDENTIFIED BY` clause:

```
CREATE USER 'jeffrey'@'localhost';
```

The server assigns no authentication plugin or password to the account. Clients must provide no password when they connect. However, an account with no password is insecure. To avoid this, use `SET PASSWORD` to set the account password.

For additional information about setting passwords and authentication plugins, see Section 6.2.9, “Assigning Account Passwords”, and Section 6.2.10, “Pluggable Authentication”.

### 13.7.1.2 DROP USER Statement

```
DROP USER user [, user] ... 
```

The `DROP USER` statement removes one or more MySQL accounts and their privileges. It removes privilege rows for the account from all grant tables. An error occurs for accounts that do not exist.

To use `DROP USER`, you must have the global `CREATE USER` privilege, or the `DELETE` privilege for the `mysql` system database. When the `read_only` system variable is enabled, `DROP USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```
DROP USER 'jeffrey'@'localhost';
```

The host name part of the account name, if omitted, defaults to '%'.

**Important**

`DROP USER` does not automatically close any open user sessions. Rather, in the event that a user with an open session is dropped, the statement does not take effect until that user's session is closed. Once the session is closed, the user is dropped, and that user's next attempt to log in will fail. *This is by design.*

`DROP USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the dropped user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 20.6, “Stored Object Access Control”.)

### 13.7.1.3 GRANT Statement

```
GRANT
  priv_type [(column_list)]
  [, priv_type [(column_list)]] ... 
ON object_type priv_level
TO user [auth_option] [, user [auth_option]] ... 
[REQUIRE {NONE | tls_option [[AND] tls_option] ...}]
[WITH {GRANT OPTION | resource_option} ...]
GRANT PROXY ON user 
  TO user [, user] ...
```
The `GRANT` statement grants privileges to MySQL user accounts. There are several aspects to the `GRANT` statement, described under the following topics:

- **GRANT General Overview**
- **Object Quoting Guidelines**
- **Account Names and Passwords**
- **Privileges Supported by MySQL**
- **Global Privileges**
- **Database Privileges**
- **Table Privileges**
- **Column Privileges**
- **Stored Routine Privileges**
- **Proxy User Privileges**
- **Implicit Account Creation**
Account Management Statements

- Other Account Characteristics
- MySQL and Standard SQL Versions of GRANT

**GRANT General Overview**

The `GRANT` statement grants privileges to MySQL user accounts. `GRANT` also serves to specify other account characteristics such as use of secure connections and limits on access to server resources.

To use `GRANT`, you must have the `GRANT OPTION` privilege, and you must have the privileges that you are granting. When the `read_only` system variable is enabled, `GRANT` additionally requires the `SUPER` privilege.

The `REVOKE` statement is related to `GRANT` and enables administrators to remove account privileges. See Section 13.7.1.5, “REVOKE Statement”.

Each account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```
GRANT ALL ON db1.* TO 'jeffrey'@'localhost';
```

The host name part of the account, if omitted, defaults to '%'.

Normally, a database administrator first uses `CREATE USER` to create an account, then `GRANT` to define its privileges and characteristics. For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
GRANT ALL ON db1.* TO 'jeffrey'@'localhost';
GRANT SELECT ON db2.invoice TO 'jeffrey'@'localhost';
GRANT USAGE ON *.* TO 'jeffrey'@'localhost' WITH MAX_QUERIES_PER_HOUR 90;
```

**Note**

Examples shown here include no `IDENTIFIED` clause. It is assumed that you establish passwords with `CREATE USER` at account-creation time to avoid creating insecure accounts.

If an account named in a `GRANT` statement does not already exist, `GRANT` may create it under the conditions described later in the discussion of the `NO_AUTO_CREATE_USER` SQL mode.

From the `mysql` program, `GRANT` responds with `Query OK, 0 rows affected` when executed successfully. To determine what privileges result from the operation, use `SHOW GRANTS`. See Section 13.7.5.22, “SHOW GRANTS Statement”.

**Important**

`GRANT` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Client Logging”.

`GRANT` supports host names up to 60 characters long. User names can be up to 16 characters. Database, table, column, and routine names can be up to 64 characters.

**Warning**

Do not attempt to change the permissible length for user names by altering the `mysql.user` system table. Doing so results in unpredictable behavior which may
Account Management Statements

even make it impossible for users to log in to the MySQL server. Never alter the
structure of tables in the mysql system database in any manner except by means
of the procedure described in Section 2.11, “Upgrading MySQL”.

Object Quoting Guidelines

Several objects within GRANT statements are subject to quoting, although quoting is optional in many
cases: Account, database, table, column, and routine names. For example, if a user_name or host_name
value in an account name is legal as an unquoted identifier, you need not quote it. However, quotation
marks are necessary to specify a user_name string containing special characters (such as -), or a
host_name string containing special characters or wildcard characters such as % (for example, 'test-
user'@'%.com'). Quote the user name and host name separately.

To specify quoted values:

• Quote database, table, column, and routine names as identifiers.
• Quote user names and host names as identifiers or as strings.
• Quote passwords as strings.

For string-quoting and identifier-quoting guidelines, see Section 9.1.1, “String Literals”, and Section 9.2,
“Schema Object Names”.

The _ and % wildcards are permitted when specifying database names in GRANT statements that grant
privileges at the database level (GRANT ... ON db_name.*). This means, for example, that to use a _
character as part of a database name, specify it as \_ in the GRANT statement, to prevent the user from
being able to access additional databases matching the wildcard pattern (for example, GRANT ... ON
`foo\_bar`.* TO ...).

When a database name not is used to grant privileges at the database level, but as a qualifier for
granting privileges to some other object such as a table or routine (for example, GRANT ... ON
db_name.tbl_name), wildcard characters are treated as normal characters.

Account Names and Passwords

A user value in a GRANT statement indicates a MySQL account to which the statement applies. To
accommodate granting rights to users from arbitrary hosts, MySQL supports specifying the user value in
the form 'user_name'@'host_name'.

You can specify wildcards in the host name. For example, 'user_name'@'%.example.com' applies to
user_name for any host in the example.com domain, and 'user_name'@'198.51.100.%' applies to
user_name for any host in the 198.51.100 class C subnet.

The simple form 'user_name' is a synonym for 'user_name'@'%'.

MySQL does not support wildcards in user names. To refer to an anonymous user, specify an account with
an empty user name with the GRANT statement:

\begin{verbatim}
GRANT ALL ON test.* TO ''@'localhost' ...;
\end{verbatim}

In this case, any user who connects from the local host with the correct password for the anonymous user
will be permitted access, with the privileges associated with the anonymous-user account.

For additional information about user name and host name values in account names, see Section 6.2.4,
“Specifying Account Names”.
Warning

If you permit local anonymous users to connect to the MySQL server, you should also grant privileges to all local users as 'user_name'@'localhost'. Otherwise, the anonymous user account for localhost in the mysql.user system table (created during MySQL installation) is used when named users try to log in to the MySQL server from the local machine. For details, see Section 6.2.5, “Access Control, Stage 1: Connection Verification”.

To determine whether this issue applies to you, execute the following query, which lists any anonymous users:

```sql
SELECT Host, User FROM mysql.user WHERE User='';
```

To avoid the problem just described, delete the local anonymous user account using this statement:

```sql
DROP USER ''@'localhost';
```

For GRANT syntax that permits an auth_option value to follow a user value, auth_option begins with IDENTIFIED and indicates how the account authenticates by specifying an account authentication plugin, credentials (for example, a password), or both. Syntax of the auth_option clause is the same as for the CREATE USER statement. For details, see Section 13.7.1.1, “CREATE USER Statement”.

When IDENTIFIED is present and you have the global grant privilege (GRANT OPTION), any password specified becomes the new password for the account, even if the account exists and already has a password. Without IDENTIFIED, the account password remains unchanged.

Privileges Supported by MySQL

The following table summarizes the permissible priv_type privilege types that can be specified for the GRANT and REVOKE statements, and the levels at which each privilege can be granted. For additional information about each privilege, see Section 6.2.2, “Privileges Provided by MySQL”.

<table>
<thead>
<tr>
<th>Privilege</th>
<th>Meaning and Grantable Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL [PRIVILEGES]</td>
<td>Grant all privileges at specified access level except GRANT OPTION and PROXY.</td>
</tr>
<tr>
<td>ALTER</td>
<td>Enable use of ALTER TABLE. Levels: Global, database, table.</td>
</tr>
<tr>
<td>ALTER ROUTINE</td>
<td>Enable stored routines to be altered or dropped. Levels: Global, database, routine.</td>
</tr>
<tr>
<td>CREATE</td>
<td>Enable database and table creation. Levels: Global, database, table.</td>
</tr>
<tr>
<td>CREATE ROUTINE</td>
<td>Enable stored routine creation. Levels: Global, database.</td>
</tr>
<tr>
<td>CREATE TABLESPACE</td>
<td>Enable tablespaces and log file groups to be created, altered, or dropped. Level: Global.</td>
</tr>
<tr>
<td>CREATE TEMORARY TABLES</td>
<td>Enable use of CREATE TEMPORARY TABLE. Levels: Global, database.</td>
</tr>
<tr>
<td>CREATE USER</td>
<td>Enable use of CREATE USER, DROP USER, RENAME USER, and REVOKE ALL PRIVILEGES. Level: Global</td>
</tr>
<tr>
<td>CREATE VIEW</td>
<td>Enable views to be created or altered. Levels: Global, database, table.</td>
</tr>
<tr>
<td>Privilege</td>
<td>Meaning and Grantable Levels</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DELETE</td>
<td>Enable use of DELETE. Level: Global, database, table.</td>
</tr>
<tr>
<td>DROP</td>
<td>Enable databases, tables, and views to be dropped. Levels: Global, database, table.</td>
</tr>
<tr>
<td>EVENT</td>
<td>Enable use of events for the Event Scheduler. Levels: Global, database.</td>
</tr>
<tr>
<td>EXECUTE</td>
<td>Enable the user to execute stored routines. Levels: Global, database, routine.</td>
</tr>
<tr>
<td>FILE</td>
<td>Enable the user to cause the server to read or write files. Level: Global.</td>
</tr>
<tr>
<td>GRANT OPTION</td>
<td>Enable privileges to be granted to or removed from other accounts. Levels: Global, database, table, routine, proxy.</td>
</tr>
<tr>
<td>INDEX</td>
<td>Enable indexes to be created or dropped. Levels: Global, database, table.</td>
</tr>
<tr>
<td>INSERT</td>
<td>Enable use of INSERT. Levels: Global, database, table, column.</td>
</tr>
<tr>
<td>LOCK TABLES</td>
<td>Enable use of LOCK TABLES on tables for which you have the SELECT privilege. Levels: Global, database.</td>
</tr>
<tr>
<td>PROCESS</td>
<td>Enable the user to see all processes with SHOW PROCESSLIST. Level: Global.</td>
</tr>
<tr>
<td>PROXY</td>
<td>Enable user proxying. Level: From user to user.</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>Enable foreign key creation. Levels: Global, database, table, column.</td>
</tr>
<tr>
<td>RELOAD</td>
<td>Enable use of FLUSH operations. Level: Global.</td>
</tr>
<tr>
<td>REPLICATION CLIENT</td>
<td>Enable the user to ask where master or slave servers are. Level: Global.</td>
</tr>
<tr>
<td>REPLICATION SLAVE</td>
<td>Enable replication slaves to read binary log events from the master. Level: Global.</td>
</tr>
<tr>
<td>SELECT</td>
<td>Enable use of SELECT. Levels: Global, database, table, column.</td>
</tr>
<tr>
<td>SHOW DATABASES</td>
<td>Enable SHOW DATABASES to show all databases. Level: Global.</td>
</tr>
<tr>
<td>SHOW VIEW</td>
<td>Enable use of SHOW CREATE VIEW. Levels: Global, database, table.</td>
</tr>
<tr>
<td>SHUTDOWN</td>
<td>Enable use of mysqladmin shutdown. Level: Global.</td>
</tr>
<tr>
<td>SUPER</td>
<td>Enable use of other administrative operations such as CHANGE MASTER TO, KILL, PURGE BINARY LOGS, SET GLOBAL, and mysqladmin debug command. Level: Global.</td>
</tr>
<tr>
<td>TRIGGER</td>
<td>Enable trigger operations. Levels: Global, database, table.</td>
</tr>
<tr>
<td>UPDATE</td>
<td>Enable use of UPDATE. Levels: Global, database, table, column.</td>
</tr>
<tr>
<td>USAGE</td>
<td>Synonym for “no privileges”</td>
</tr>
</tbody>
</table>

A trigger is associated with a table. To create or drop a trigger, you must have the TRIGGER privilege for the table, not the trigger.

In GRANT statements, the ALL [PRIVILEGES] or PROXY privilege must be named by itself and cannot be specified along with other privileges. ALL [PRIVILEGES] stands for all privileges available for the level at which privileges are to be granted except for the GRANT OPTION and PROXY privileges.

USAGE can be specified to create a user that has no privileges, or to specify the REQUIRE or WITH clauses for an account without changing its existing privileges.

MySQL account information is stored in the tables of the mysql system database. For additional details, consult Section 6.2, “Access Control and Account Management”, which discusses the mysql system database and the access control system extensively.
Account Management Statements

If the grant tables hold privilege rows that contain mixed-case database or table names and the `lower_case_table_names` system variable is set to a nonzero value, REVOKE cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (GRANT will not create such rows when `lower_case_table_names` is set, but such rows might have been created prior to setting that variable.)

Privileges can be granted at several levels, depending on the syntax used for the ON clause. For REVOKE, the same ON syntax specifies which privileges to remove.

For the global, database, table, and routine levels, GRANT ALL assigns only the privileges that exist at the level you are granting. For example, GRANT ALL ON `db_name`.* is a database-level statement, so it does not grant any global-only privileges such as FILE. Granting ALL does not assign the GRANT OPTION or PROXY privilege.

The object_type clause, if present, should be specified as TABLE, FUNCTION, or PROCEDURE when the following object is a table, a stored function, or a stored procedure.

The privileges that a user holds for a database, table, column, or routine are formed additively as the logical OR of the account privileges at each of the privilege levels, including the global level. It is not possible to deny a privilege granted at a higher level by absence of that privilege at a lower level. For example, this statement grants the SELECT and INSERT privileges globally:

```
GRANT SELECT, INSERT ON *.* TO u1;
```

The globally granted privileges apply to all databases, tables, and columns, even though not granted at any of those lower levels.

Details of the privilege-checking procedure are presented in Section 6.2.6, “Access Control, Stage 2: Request Verification”.

If you are using table, column, or routine privileges for even one user, the server examines table, column, and routine privileges for all users and this slows down MySQL a bit. Similarly, if you limit the number of queries, updates, or connections for any users, the server must monitor these values.

MySQL enables you to grant privileges on databases or tables that do not exist. For tables, the privileges to be granted must include the CREATE privilege. This behavior is by design, and is intended to enable the database administrator to prepare user accounts and privileges for databases or tables that are to be created at a later time.

---

**Important**

MySQL does not automatically revoke any privileges when you drop a database or table. However, if you drop a routine, any routine-level privileges granted for that routine are revoked.

---

**Global Privileges**

Global privileges are administrative or apply to all databases on a given server. To assign global privileges, use ON `*.*` syntax:

```
GRANT ALL ON `*.*` TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON `*.*` TO 'someuser'@'somehost';
```

The CREATE TABLESPACE, CREATE USER, FILE, PROCESS, RELOAD, REPLICATION CLIENT, REPLICATION SLAVE, SHOW DATABASES, SHUTDOWN, and SUPER privileges are administrative and can only be granted globally.
Other privileges can be granted globally or at more specific levels.

**GRANT OPTION** granted at the global level for any global privilege applies to all global privileges.

MySQL stores global privileges in the `mysql.user` system table.

### Database Privileges

Database privileges apply to all objects in a given database. To assign database-level privileges, use `ON db_name.*` syntax:

```sql
GRANT ALL ON mydb.* TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.* TO 'someuser'@'somehost';
```

If you use `ON *` syntax (rather than `ON *.*`), privileges are assigned at the database level for the default database. An error occurs if there is no default database.

The `CREATE, DROP, EVENT, GRANT OPTION, LOCK TABLES, and REFERENCES` privileges can be specified at the database level. Table or routine privileges also can be specified at the database level, in which case they apply to all tables or routines in the database.

MySQL stores database privileges in the `mysql.db` system table.

### Table Privileges

Table privileges apply to all columns in a given table. To assign table-level privileges, use `ON db_name.tbl_name` syntax:

```sql
GRANT ALL ON mydb.mytbl TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.mytbl TO 'someuser'@'somehost';
```

If you specify `tbl_name` rather than `db_name.tbl_name`, the statement applies to `tbl_name` in the default database. An error occurs if there is no default database.

The permissible `priv_type` values at the table level are `ALTER, CREATE VIEW, CREATE, DELETE, DROP, GRANT OPTION, INDEX, INSERT, REFERENCES, SELECT, SHOW VIEW, TRIGGER, and UPDATE`.

MySQL stores table privileges in the `mysql.tables_priv` system table.

### Column Privileges

Column privileges apply to single columns in a given table. Each privilege to be granted at the column level must be followed by the column or columns, enclosed within parentheses.

```sql
GRANT SELECT (col1), INSERT (col1, col2) ON mydb.mytbl TO 'someuser'@'somehost';
```

The permissible `priv_type` values for a column (that is, when you use a `column_list` clause) are `INSERT, REFERENCES, SELECT, and UPDATE`.

MySQL stores column privileges in the `mysql.columns_priv` system table.

### Stored Routine Privileges

The `ALTER ROUTINE, CREATE ROUTINE, EXECUTE, and GRANT OPTION` privileges apply to stored routines (procedures and functions). They can be granted at the global and database levels. Except for `CREATE ROUTINE`, these privileges can be granted at the routine level for individual routines.

```sql
GRANT CREATE ROUTINE ON mydb.* TO 'someuser'@'somehost';
GRANT EXECUTE ON PROCEDURE mydb.myproc TO 'someuser'@'somehost';
```
The permissible `priv_type` values at the routine level are `ALTER ROUTINE`, `EXECUTE`, and `GRANT OPTION`. `CREATE ROUTINE` is not a routine-level privilege because you must have the privilege at the global or database level to create a routine in the first place.

MySQL stores routine-level privileges in the `mysql.procs_priv` system table.

**Proxy User Privileges**

The `PROXY` privilege enables one user to be a proxy for another. The proxy user impersonates or takes the identity of the proxied user; that is, it assumes the privileges of the proxied user.

```
GRANT PROXY ON 'localuser'@'localhost' TO 'externaluser'@'somehost';
```

When `PROXY` is granted, it must be the only privilege named in the `GRANT` statement, the `REQUIRE` clause cannot be given, and the only permitted `WITH` option is `WITH GRANT OPTION`.

Proxying requires that the proxy user authenticate through a plugin that returns the name of the proxied user to the server when the proxy user connects, and that the proxy user have the `PROXY` privilege for the proxied user. For details and examples, see Section 6.2.11, “Proxy Users”.

MySQL stores proxy privileges in the `mysql.proxies_priv` system table.

**Implicit Account Creation**

If an account named in a `GRANT` statement does not exist, the action taken depends on the `NO_AUTO_CREATE_USER` SQL mode:

- If `NO_AUTO_CREATE_USER` is not enabled, `GRANT` creates the account. *This is very insecure* unless you specify a nonempty password using `IDENTIFIED BY`.

- If `NO_AUTO_CREATE_USER` is enabled, `GRANT` fails and does not create the account, unless you specify a nonempty password using `IDENTIFIED BY` or name an authentication plugin using `IDENTIFIED WITH`.

**Other Account Characteristics**

MySQL can check X.509 certificate attributes in addition to the usual authentication that is based on the user name and credentials. For background information on the use of SSL with MySQL, see Section 6.3, “Using Encrypted Connections”.

The optional `REQUIRE` clause specifies SSL-related options for a MySQL account, using one or more `tls_option` values.

Order of `REQUIRE` options does not matter, but no option can be specified twice. The `AND` keyword is optional between `REQUIRE` options.

`GRANT` permits these `tls_option` values:

- **NONE**

  Indicates that the account has no SSL or X.509 requirements.

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE NONE;
```

Unencrypted connections are permitted if the user name and password are valid. Encrypted connections can be used, at the client's option, if the client has the proper certificate and key files. That is, the client...
need not specify any SSL command options, in which case the connection will be unencrypted. To use an encrypted connection, the client must specify either the `--ssl-ca` option, or all three of the `--ssl-ca, --ssl-key, and --ssl-cert` options.

NONE is the default if no SSL-related REQUIRE options are specified.

- **SSL**
  Tells the server to permit only encrypted connections for the account.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE SSL;
```

To connect, the client must specify the `--ssl-ca` option to authenticate the server certificate, and may additionally specify the `--ssl-key` and `--ssl-cert` options. If neither the `--ssl-ca` option nor `--ssl-capath` option is specified, the client does not authenticate the server certificate.

- **X509**
  Requires that clients present a valid certificate, but the exact certificate, issuer, and subject do not matter. The only requirement is that it should be possible to verify its signature with one of the CA certificates. Use of X.509 certificates always implies encryption, so the SSL option is unnecessary in this case.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE X509;
```

For accounts with REQUIRE X509, clients must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.) This is true for ISSUER and SUBJECT as well because those REQUIRE options imply the requirements of X509.

- **ISSUER 'issuer'**
  Requires that clients present a valid X.509 certificate issued by CA 'issuer'. If a client presents a certificate that is valid but has a different issuer, the server rejects the connection. Use of X.509 certificates always implies encryption, so the SSL option is unnecessary in this case.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE ISSUER '/C=SE/ST=Stockholm/L=Stockholm/O=MySQL/CN=CA/emailAddress=ca@example.com';
```

Because ISSUER implies the requirements of X509, clients must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.)

- **SUBJECT 'subject'**
  Requires that clients present a valid X.509 certificate containing the subject subject. If a client presents a certificate that is valid but has a different subject, the server rejects the connection. Use of X.509 certificates always implies encryption, so the SSL option is unnecessary in this case.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/

Note
If MySQL is linked against a version of OpenSSL older than 0.9.6h, use Email rather than emailAddress in the 'issuer' value.

- **SUBJECT 'subject'**
  Requires that clients present a valid X.509 certificate containing the subject subject. If a client presents a certificate that is valid but has a different subject, the server rejects the connection. Use of X.509 certificates always implies encryption, so the SSL option is unnecessary in this case.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
```
MySQL does a simple string comparison of the 'subject' value to the value in the certificate, so lettercase and component ordering must be given exactly as present in the certificate.

**Note**

Regarding emailAddress, see the note in the description of REQUIRE ISSUER.

Because SUBJECT implies the requirements of X509, clients must specify the --ssl-key and --ssl-cert options to connect. (It is recommended but not required that --ssl-ca also be specified so that the public certificate provided by the server can be verified.)

- **CIPHER 'cipher'**

Requires a specific cipher method for encrypting connections. This option is needed to ensure that ciphers and key lengths of sufficient strength are used. SSL itself can be weak if old algorithms using short encryption keys are used.

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The SUBJECT, ISSUER, and CIPHER options can be combined in the REQUIRE clause like this:

```sql
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
O=MySQL demo client certificate/
CN=client/emailAddress=client@example.com'
AND ISSUER '/C=SE/ST=Stockholm/L=Stockholm/
O=MySQL/CA/emailAddress=ca@example.com'
AND CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The optional WITH clause is used for these purposes:

- To enable a user to grant privileges to other users
- To specify resource limits for a user

The **WITH GRANT OPTION** clause gives the user the ability to give to other users any privileges the user has at the specified privilege level.

To grant the **GRANT OPTION** privilege to an account without otherwise changing its privileges, do this:

```sql
GRANT USAGE ON *.* TO 'someuser'@'somehost' WITH GRANT OPTION;
```

Be careful to whom you give the **GRANT OPTION** privilege because two users with different privileges may be able to combine privileges!

You cannot grant another user a privilege which you yourself do not have; the **GRANT OPTION** privilege enables you to assign only those privileges which you yourself possess.

Be aware that when you grant a user the **GRANT OPTION** privilege at a particular privilege level, any privileges the user possesses (or may be given in the future) at that level can also be granted by that user to other users. Suppose that you grant a user the **INSERT** privilege on a database. If you then grant the **SELECT** privilege on the database and specify **WITH GRANT OPTION**, that user can give to other users not only the **SELECT** privilege, but also **INSERT**. If you then grant the **UPDATE** privilege to the user on the database, the user can grant **INSERT**, **SELECT**, and **UPDATE**.
For a nonadministrative user, you should not grant the `ALTER` privilege globally or for the `mysql` system database. If you do that, the user can try to subvert the privilege system by renaming tables!

For additional information about security risks associated with particular privileges, see Section 6.2.2, “Privileges Provided by MySQL”.

It is possible to place limits on use of server resources by an account, as discussed in Section 6.2.12, “Setting Account Resource Limits”. To do so, use a `WITH` clause that specifies one or more `resource_option` values. Limits not specified retain their current values.

Order of `WITH` options does not matter, except that if a given resource limit is specified multiple times, the last instance takes precedence.

`GRANT` permits these `resource_option` values:

- `MAX_QUERIES_PER_HOUR count`, `MAX_UPDATES_PER_HOUR count`, `MAX_CONNECTIONS_PER_HOUR count`

  These options restrict how many queries, updates, and connections to the server are permitted to this account during any given one-hour period. (Queries for which results are served from the query cache do not count against the `MAX_QUERIES_PER_HOUR` limit.) If `count` is 0 (the default), this means that there is no limitation for the account.

- `MAX_USER_CONNECTIONS count`

  Restricts the maximum number of simultaneous connections to the server by the account. A nonzero `count` specifies the limit for the account explicitly. If `count` is 0 (the default), the server determines the number of simultaneous connections for the account from the global value of the `max_user_connections` system variable. If `max_user_connections` is also zero, there is no limit for the account.

To specify resource limits for an existing user without affecting existing privileges, use `GRANT USAGE` at the global level (`ON *.*`) and name the limits to be changed. For example:

```
GRANT USAGE ON *.* TO ... WITH MAX_QUERIES_PER_HOUR 500 MAX_UPDATES_PER_HOUR 100;
```

### MySQL and Standard SQL Versions of GRANT

The biggest differences between the MySQL and standard SQL versions of `GRANT` are:

- MySQL associates privileges with the combination of a host name and user name and not with only a user name.

- Standard SQL does not have global or database-level privileges, nor does it support all the privilege types that MySQL supports.

- MySQL does not support the standard SQL `UNDER` privilege.

- Standard SQL privileges are structured in a hierarchical manner. If you remove a user, all privileges the user has been granted are revoked. This is also true in MySQL if you use `DROP USER`. See Section 13.7.1.2, “DROP USER Statement”.

- In standard SQL, when you drop a table, all privileges for the table are revoked. In standard SQL, when you revoke a privilege, all privileges that were granted based on that privilege are also revoked. In MySQL, privileges can be dropped only with explicit `DROP USER` or `REVOKE` statements or by manipulating the MySQL grant tables directly.
In MySQL, it is possible to have the `INSERT` privilege for only some of the columns in a table. In this case, you can still execute `INSERT` statements on the table, provided that you insert values only for those columns for which you have the `INSERT` privilege. The omitted columns are set to their implicit default values if strict SQL mode is not enabled. In strict mode, the statement is rejected if any of the omitted columns have no default value. (Standard SQL requires you to have the `INSERT` privilege on all columns.) For information about strict SQL mode and implicit default values, see Section 5.1.10, “Server SQL Modes”, and Section 11.5, “Data Type Default Values”.

### 13.7.1.4 RENAME USER Statement

```sql
RENAME USER old_user TO new_user
[, old_user TO new_user] ...
```

The `RENAME USER` statement renames existing MySQL accounts. An error occurs for old accounts that do not exist or new accounts that already exist.

To use `RENAME USER`, you must have the global `CREATE USER` privilege, or the `UPDATE` privilege for the `mysql` system database. When the `read_only` system variable is enabled, `RENAME USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```sql
RENAME USER 'jeffrey'@'localhost' TO 'jeff'@'127.0.0.1';
```

The host name part of the account name, if omitted, defaults to `'%'`.

`RENAME USER` causes the privileges held by the old user to be those held by the new user. However, `RENAME USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the old user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 20.6, “Stored Object Access Control”.)

The privilege changes take effect as indicated in Section 6.2.8, “When Privilege Changes Take Effect”.

### 13.7.1.5 REVOKE Statement

```sql
REVOKE
   priv_type [(column_list)]
   [, priv_type [(column_list)]] ...
ON [object_type] priv_level
FROM user [, user] ...
REVOKE ALL [PRIVILEGES], GRANT OPTION
   FROM user [, user] ...
REVOKE PROXY ON user
   FROM user [, user] ...
```

The `REVOKE` statement enables system administrators to revoke privileges from MySQL accounts.

For details on the levels at which privileges exist, the permissible `priv_type, priv_level, and object_type` values, and the syntax for specifying users and passwords, see Section 13.7.1.3, “GRANT Statement”.

When the `read_only` system variable is enabled, `REVOKE` requires the `SUPER` privilege in addition to any other required privileges described in the following discussion.

Each account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```sql
REVOKE INSERT ON *.* FROM 'jeffrey'@'localhost';
```
The host name part of the account name, if omitted, defaults to '%'.

To use the first `REVOKE` syntax, you must have the `GRANT OPTION` privilege, and you must have the privileges that you are revoking.

To revoke all privileges, use the second syntax, which drops all global, database, table, column, and routine privileges for the named user or users:

```
REVOKE ALL PRIVILEGES, GRANT OPTION FROM user [, user] ...
```

To use this `REVOKE` syntax, you must have the global `CREATE USER` privilege, or the `UPDATE` privilege for the `mysql` system database.

User accounts from which privileges are to be revoked must exist, but the privileges to be revoked need not be currently granted to them.

`REVOKE` removes privileges, but does not remove rows from the `mysql.user` system table. To remove a user account entirely, use `DROP USER`. See Section 13.7.1.2, “DROP USER Statement”.

If the grant tables hold privilege rows that contain mixed-case database or table names and the `lower_case_table_names` system variable is set to a nonzero value, `REVOKE` cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (`GRANT` will not create such rows when `lower_case_table_names` is set, but such rows might have been created prior to setting the variable.)

When successfully executed from the `mysql` program, `REVOKE` responds with Query OK, 0 rows affected. To determine what privileges remain after the operation, use `SHOW GRANTS`. See Section 13.7.5.22, “SHOW GRANTS Statement”.

### 13.7.1.6 SET PASSWORD Statement

```
SET PASSWORD [FOR user] = password_option
```

```
password_option: {
    PASSWORD('auth_string')
    | OLD_PASSWORD('auth_string')
    | 'hash_string'
}
```

The `SET PASSWORD` statement assigns a password to a MySQL user account, specified as either a cleartext (unencrypted) or encrypted value:

- `'auth_string'` represents a cleartext password.
- `'hash_string'` represents an encrypted password.

**Important**

`SET PASSWORD` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Client Logging”.

`SET PASSWORD` can be used with or without a `FOR` clause that explicitly names a user account:

- With a `FOR user` clause, the statement sets the password for the named account, which must exist:

  ```
  SET PASSWORD FOR 'jeffrey'@'localhost' = password_option;
  ```
With no `FOR user` clause, the statement sets the password for the current user:

```
SET PASSWORD = password_option;
```

Any client who connects to the server using a nonanonymous account can change the password for that account. (In particular, you can change your own password.) To see which account the server authenticated you as, invoke the `CURRENT_USER()` function:

```
SELECT CURRENT_USER();
```

If a `FOR user` clause is given, the account name uses the format described in Section 6.2.4, “Specifying Account Names”. For example:

```
SET PASSWORD FOR 'bob'@'%'.example.org' = PASSWORD('auth_string');
```

The host name part of the account name, if omitted, defaults to '%'.

Setting the password for a named account (with a `FOR` clause) requires the `UPDATE` privilege for the `mysql` system database. Setting the password for yourself (for a nonanonymous account with no `FOR` clause) requires no special privileges. When the `read_only` system variable is enabled, `SET PASSWORD` requires the `SUPER` privilege in addition to any other required privileges.

The password can be specified in these ways:

• Use the `PASSWORD()` function

  The `PASSWORD()` argument is the cleartext (unencrypted) password. `PASSWORD()` hashes the password and returns the encrypted password string for storage in the account row in the `mysql.user` system table.

  The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. It should be set to a value compatible with the hash format required by the account authentication plugin. For example, if the account uses the `mysql_native_password` authentication plugin, `old_passwords` should be 0 for `PASSWORD()` to produce a hash value in the correct format. For `mysql_old_password`, `old_passwords` should be 1.

  Permitted `old_passwords` values are described later in this section.

• Use the `OLD_PASSWORD()` function:

  The `'auth_string'` function argument is the cleartext (unencrypted) password. `OLD_PASSWORD()` hashes the password using pre-4.1 hashing and returns the encrypted password string for storage in the account row in the `mysql.user` system table. This hashing method is appropriate only for accounts that use the `mysql_old_password` authentication plugin.

• Use an already encrypted password string

  The password is specified as a string literal. It must represent the already encrypted password value, in the hash format required by the authentication method used for the account.

The following table shows, for each password hashing method, the permitted value of `old_passwords` and which authentication plugins use the hashing method.

<table>
<thead>
<tr>
<th>Password Hashing Method</th>
<th><code>old_passwords</code> Value</th>
<th>Associated Authentication Plugin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MySQL 4.1 native hashing</td>
<td>0 or OFF</td>
<td><code>mysql_native_password</code></td>
</tr>
<tr>
<td>Pre-4.1 (“old”) hashing</td>
<td>1 or ON</td>
<td><code>mysql_old_password</code></td>
</tr>
</tbody>
</table>
Caution

If you are connecting to a MySQL 4.1 or later server using a pre-4.1 client program, do not change your password without first reading Section 6.1.2.4, "Password Hashing in MySQL". The default password hashing format changed in MySQL 4.1, and if you change your password, it might be stored using a hashing format that pre-4.1 clients cannot generate, thus preventing you from connecting to the server afterward.

For additional information about setting passwords and authentication plugins, see Section 6.2.9, "Assigning Account Passwords", and Section 6.2.10, "Pluggable Authentication".

### 13.7.2 Table Maintenance Statements

#### 13.7.2.1 ANALYZE TABLE Statement

```
ANALYZE [NO_WRITE_TO_BINLOG | LOCAL] TABLE tbl_name [, tbl_name] ...
```

ANALYZE TABLE performs a key distribution analysis and stores the distribution for the named table or tables. For MyISAM tables, this statement is equivalent to using `myisamchk --analyze`.

This statement requires SELECT and INSERT privileges for the table.

ANALYZE TABLE works with InnoDB, NDB, and MyISAM tables. It does not work with views.

ANALYZE TABLE is supported for partitioned tables, and you can use `ALTER TABLE ... ANALYZE PARTITION` to analyze one or more partitions; for more information, see Section 13.1.7, "ALTER TABLE Statement", and Section 19.3.3, "Maintenance of Partitions".

During the analysis, the table is locked with a read lock for InnoDB and MyISAM.

ANALYZE TABLE removes the table from the table definition cache, which requires a flush lock. If there are long running statements or transactions still using the table, subsequent statements and transactions must wait for those operations to finish before the flush lock is released. Because ANALYZE TABLE itself typically finishes quickly, it may not be apparent that delayed transactions or statements involving the same table are due to the remaining flush lock.

By default, the server writes ANALYZE TABLE statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional NO_WRITE_TO_BINLOG keyword or its alias LOCAL.

- **ANALYZE TABLE Output**
- **Key Distribution Analysis**

**ANALYZE TABLE Output**

ANALYZE TABLE returns a result set with the columns shown in the following table.

<table>
<thead>
<tr>
<th>Column</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>The table name</td>
</tr>
<tr>
<td>Op</td>
<td>Always analyze</td>
</tr>
<tr>
<td>Msg_type</td>
<td>status, error, info, note, or warning</td>
</tr>
<tr>
<td>Msg_text</td>
<td>An informational message</td>
</tr>
</tbody>
</table>
Key Distribution Analysis

If the table has not changed since the last key distribution analysis, the table is not analyzed again.

MySQL uses the stored key distribution to decide the table join order for joins on something other than a constant. In addition, key distributions can be used when deciding which indexes to use for a specific table within a query.

To check the stored key distribution cardinality, use the `SHOW INDEX` statement or the `INFORMATION_SCHEMA STATISTICS` table. See Section 13.7.5.23, “SHOW INDEX Statement”, and Section 21.21, “The INFORMATION_SCHEMA STATISTICS Table”.

For InnoDB tables, `ANALYZE TABLE` determines index cardinality by performing random dives on each of the index trees and updating index cardinality estimates accordingly. Because these are only estimates, repeated runs of `ANALYZE TABLE` could produce different numbers. This makes `ANALYZE TABLE` fast on InnoDB tables but not 100% accurate because it does not take all rows into account. You can adjust the number of random dives by modifying the `innodb_stats_sample_pages` system variable.

For more information about key distribution in InnoDB, see Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”, and Section 14.11.10.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”.

MySQL uses index cardinality estimates in join optimization. If a join is not optimized in the right way, try running `ANALYZE TABLE`. In the few cases that `ANALYZE TABLE` does not produce values good enough for your particular tables, you can use `FORCE_INDEX` with your queries to force the use of a particular index, or set the `max_seeks_for_key` system variable to ensure that MySQL prefers index lookups over table scans. See Section B.4.5, “Optimizer-Related Issues”.

13.7.2.2 CHECK TABLE Statement

`CHECK TABLE tbl_name [ , tbl_name ] ... [option] ...`

```
option: {  
  FOR UPGRADE  
  | QUICK  
  | FAST  
  | MEDIUM  
  | EXTENDED  
  | CHANGED  
}
```

`CHECK TABLE` checks a table or tables for errors. For MyISAM tables, the key statistics are updated as well. `CHECK TABLE` can also check views for problems, such as tables that are referenced in the view definition that no longer exist.

To check a table, you must have some privilege for it.

`CHECK TABLE` works for InnoDB, MyISAM, ARCHIVE, and CSV tables.

Before running `CHECK TABLE` on InnoDB tables, see `CHECK TABLE Usage Notes for InnoDB Tables`.

`CHECK TABLE` is supported for partitioned tables, and you can use `ALTER TABLE ... CHECK PARTITION` to check one or more partitions; for more information, see Section 13.1.7, “ALTER TABLE Statement”, and Section 19.3.3, “Maintenance of Partitions”.

- CHECK TABLE Output
- Checking Version Compatibility
Table Maintenance Statements

- Checking Data Consistency
- CHECK TABLE Usage Notes for InnoDB Tables

**CHECK TABLE Output**

`CHECK TABLE` returns a result set with the columns shown in the following table.

<table>
<thead>
<tr>
<th>Column</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>The table name</td>
</tr>
<tr>
<td>Op</td>
<td>Always check</td>
</tr>
<tr>
<td>Msg_type</td>
<td>status, error, info, note, or warning</td>
</tr>
<tr>
<td>Msg_text</td>
<td>An informational message</td>
</tr>
</tbody>
</table>

The statement might produce many rows of information for each checked table. The last row has a `Msg_type` value of `status` and the `Msg_text` normally should be `OK`. For a MyISAM table, if you don’t get `OK` or `Table is already up to date`, you should normally run a repair of the table. See Section 7.6, “MyISAM Table Maintenance and Crash Recovery”. `Table is already up to date` means that the storage engine for the table indicated that there was no need to check the table.

**Checking Version Compatibility**

The `FOR UPGRADE` option checks whether the named tables are compatible with the current version of MySQL. With `FOR UPGRADE`, the server checks each table to determine whether there have been any incompatible changes in any of the table's data types or indexes since the table was created. If not, the check succeeds. Otherwise, if there is a possible incompatibility, the server runs a full check on the table (which might take some time). If the full check succeeds, the server marks the table's `.frm` file with the current MySQL version number. Marking the `.frm` file ensures that further checks for the table with the same version of the server will be fast.

Incompatibilities might occur because the storage format for a data type has changed or because its sort order has changed. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases.

`FOR UPGRADE` discovers these incompatibilities:

- The indexing order for end-space in `TEXT` columns for InnoDB and MyISAM tables changed between MySQL 4.1 and 5.0.
- The storage method of the new `DECIMAL` data type changed between MySQL 5.0.3 and 5.0.5.
- If your table was created by a different version of the MySQL server than the one you are currently running, `FOR UPGRADE` indicates that the table has an `.frm` file with an incompatible version. In this case, the result set returned by `CHECK TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Table upgrade required. Please do "REPAIR TABLE `tbl_name`" to fix it!`.
- Changes are sometimes made to character sets or collations that require table indexes to be rebuilt. For details about such changes, see Section 2.11.3, “Changes in MySQL 5.5”. For information about rebuilding tables, see Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”.

**Checking Data Consistency**

The following table shows the other check options that can be given. These options are passed to the storage engine, which may use or ignore them.
Table Maintenance Statements

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUICK</td>
<td>Do not scan the rows to check for incorrect links. Applies to InnoDB and MyISAM tables and views.</td>
</tr>
<tr>
<td>FAST</td>
<td>Check only tables that have not been closed properly. Applies only to MyISAM tables and views; ignored for InnoDB.</td>
</tr>
<tr>
<td>CHANGED</td>
<td>Check only tables that have been changed since the last check or that have not been closed properly. Applies only to MyISAM tables and views; ignored for InnoDB.</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>Scan rows to verify that deleted links are valid. This also calculates a key checksum for the rows and verifies this with a calculated checksum for the keys. Applies only to MyISAM tables and views; ignored for InnoDB.</td>
</tr>
<tr>
<td>EXTENDED</td>
<td>Do a full key lookup for all keys for each row. This ensures that the table is 100% consistent, but takes a long time. Applies only to MyISAM tables and views; ignored for InnoDB.</td>
</tr>
</tbody>
</table>

If none of the options QUICK, MEDIUM, or EXTENDED are specified, the default check type for dynamic-format MyISAM tables is MEDIUM. This has the same result as running myisamchk --medium-check tbl_name on the table. The default check type also is MEDIUM for static-format MyISAM tables, unless CHANGED or FAST is specified. In that case, the default is QUICK. The row scan is skipped for CHANGED and FAST because the rows are very seldom corrupted.

You can combine check options, as in the following example that does a quick check on the table to determine whether it was closed properly:

```
CHECK TABLE test_table FAST QUICK;
```

Note

If CHECK TABLE finds no problems with a table that is marked as “corrupted” or “not closed properly”, CHECK TABLE may remove the mark.

If a table is corrupted, the problem is most likely in the indexes and not in the data part. All of the preceding check types check the indexes thoroughly and should thus find most errors.

To check a table that you assume is okay, use no check options or the QUICK option. The latter should be used when you are in a hurry and can take the very small risk that QUICK does not find an error in the data file. (In most cases, under normal usage, MySQL should find any error in the data file. If this happens, the table is marked as “corrupted” and cannot be used until it is repaired.)

FAST and CHANGED are mostly intended to be used from a script (for example, to be executed from cron) to check tables periodically. In most cases, FAST is to be preferred over CHANGED. (The only case when it is not preferred is when you suspect that you have found a bug in the MyISAM code.)

EXTENDED is to be used only after you have run a normal check but still get errors from a table when MySQL tries to update a row or find a row by key. This is very unlikely if a normal check has succeeded.

Use of CHECK TABLE ... EXTENDED might influence execution plans generated by the query optimizer.

Some problems reported by CHECK TABLE cannot be corrected automatically:

- Found row where the auto_increment column has the value 0.

This means that you have a row in the table where the AUTO_INCREMENT index column contains the value 0. (It is possible to create a row where the AUTO_INCREMENT column is 0 by explicitly setting the column to 0 with an UPDATE statement.)
Table Maintenance Statements

This is not an error in itself, but could cause trouble if you decide to dump the table and restore it or do an `ALTER TABLE` on the table. In this case, the `AUTO_INCREMENT` column changes value according to the rules of `AUTO_INCREMENT` columns, which could cause problems such as a duplicate-key error.

To get rid of the warning, execute an `UPDATE` statement to set the column to some value other than 0.

### CHECK TABLE Usage Notes for InnoDB Tables

The following notes apply to InnoDB tables:

- If `CHECK TABLE` encounters a corrupt page, the server exits to prevent error propagation (Bug #10132). If the corruption occurs in a secondary index but table data is readable, running `CHECK TABLE` can still cause a server exit.

- If `CHECK TABLE` encounters a corrupted `DB_TRX_ID` or `DB_ROLL_PTR` field in a clustered index, `CHECK TABLE` can cause InnoDB to access an invalid undo log record, resulting in an MVCC-related server exit.

- If `CHECK TABLE` encounters errors in InnoDB tables or indexes, it reports an error, and usually marks the index and sometimes marks the table as corrupted, preventing further use of the index or table. Such errors include an incorrect number of entries in a secondary index or incorrect links.

- If `CHECK TABLE` finds an incorrect number of entries in a secondary index, it reports an error but does not cause a server exit or prevent access to the file.

- `CHECK TABLE` surveys the index page structure, then surveys each key entry. It does not validate the key pointer to a clustered record or follow the path for `BLOB` pointers.

- When an InnoDB table is stored in its own `.ibd` file, the first 3 pages of the `.ibd` file contain header information rather than table or index data. The `CHECK TABLE` statement does not detect inconsistencies that affect only the header data. To verify the entire contents of an InnoDB `.ibd` file, use the `innochecksum` command.

- When running `CHECK TABLE` on large InnoDB tables, other threads may be blocked during `CHECK TABLE` execution. To avoid timeouts, the semaphore wait threshold (600 seconds) is extended by 2 hours (7200 seconds) for `CHECK TABLE` operations. If InnoDB detects semaphore waits of 240 seconds or more, it starts printing InnoDB monitor output to the error log. If a lock request extends beyond the semaphore wait threshold, InnoDB aborts the process. To avoid the possibility of a semaphore wait time out entirely, run `CHECK TABLE QUICK` instead of `CHECK TABLE`.

### 13.7.2.3 CHECKSUM TABLE Statement

```
CHECKSUM TABLE tbl_name [, tbl_name] ... [QUICK | EXTENDED]
```

`CHECKSUM TABLE` reports a table checksum.

This statement requires the `SELECT` privilege for the table.

This statement is not supported for views. If you run `CHECKSUM TABLE` against a view, the Checksum value is always `NULL`, and a warning is returned.

For a nonexistent table, `CHECKSUM TABLE` returns `NULL` and generates a warning.

During the checksum operation, the table is locked with a read lock for InnoDB and MyISAM.

With `QUICK`, the live table checksum is reported if it is available, or `NULL` otherwise. This is very fast. A live checksum is enabled by specifying the `CHECKSUM=1` table option when you create the table; currently,
Table Maintenance Statements

this is supported only for MyISAM tables. The **QUICK** method is not supported with InnoDB tables. See Section 13.1.17, “CREATE TABLE Statement”.

With **EXTENDED**, the entire table is read row by row and the checksum is calculated. This can be very slow for large tables.

If neither **QUICK** nor **EXTENDED** is specified, MySQL returns a live checksum if the table storage engine supports it and scans the table otherwise.

In MySQL 5.5, **CHECKSUM TABLE** returns 0 for partitioned tables unless you include the **EXTENDED** option. This issue is resolved in MySQL 5.6. (Bug #11933226, Bug #60681)

The checksum value depends on the table row format. If the row format changes, the checksum also changes. For example, the storage format for temporal types such as **TIME**, **DATETIME**, and **TIMESTAMP** changes in MySQL 5.6 prior to MySQL 5.6.5, so if a 5.5 table is upgraded to MySQL 5.6, the checksum value may change.

---

Important

If the checksums for two tables are different, then it is almost certain that the tables are different in some way. However, because the hashing function used by **CHECKSUM TABLE** is not guaranteed to be collision-free, there is a slight chance that two tables which are not identical can produce the same checksum.

### 13.7.2.4 OPTIMIZE TABLE Statement

```sql
OPTIMIZE [NO_WRITE_TO_BINLOG | LOCAL] TABLE tbl_name [, tbl_name] ...
```

**OPTIMIZE TABLE** reorganizes the physical storage of table data and associated index data, to reduce storage space and improve I/O efficiency when accessing the table. The exact changes made to each table depend on the storage engine used by that table.

Use **OPTIMIZE TABLE** in these cases, depending on the type of table:

- After doing substantial insert, update, or delete operations on an InnoDB table that has its own .ibd file because it was created with the **innodb_file_per_table** option enabled. The table and indexes are reorganized, and disk space can be reclaimed for use by the operating system.

- After deleting a large part of a MyISAM or ARCHIVE table, or making many changes to a MyISAM or ARCHIVE table with variable-length rows (tables that have VARCHAR, VARBINARY, BLOB, or TEXT columns). Deleted rows are maintained in a linked list and subsequent **INSERT** operations reuse old row positions. You can use **OPTIMIZE TABLE** to reclaim the unused space and to defragment the data file. After extensive changes to a table, this statement may also improve performance of statements that use the table, sometimes significantly.

This statement requires **SELECT** and **INSERT** privileges for the table.

**OPTIMIZE TABLE** works for InnoDB, MyISAM, and ARCHIVE tables. **OPTIMIZE TABLE** is also supported for dynamic columns of in-memory NDB tables. It does not work for fixed-width columns of in-memory tables, nor does it work for Disk Data tables. The performance of **OPTIMIZE** on NDB Cluster tables can be tuned using **--ndb-optimization-delay**, which controls the length of time to wait between processing batches of rows by **OPTIMIZE TABLE**. For more information, see Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”.

For NDB Cluster tables, **OPTIMIZE TABLE** can be interrupted by (for example) killing the SQL thread performing the **OPTIMIZE** operation.
By default, `OPTIMIZE TABLE` does not work for tables created using any other storage engine and returns a result indicating this lack of support. You can make `OPTIMIZE TABLE` work for other storage engines by starting `mysqld` with the `--skip-new` option. In this case, `OPTIMIZE TABLE` is just mapped to `ALTER TABLE`.

This statement does not work with views.

`OPTIMIZE TABLE` is supported for partitioned tables. For information about using this statement with partitioned tables and table partitions, see Section 19.3.3, “Maintenance of Partitions”.

By default, the server writes `OPTIMIZE TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

- **OPTIMIZE TABLE Output**
- **InnoDB Details**
- **MyISAM Details**
- **Other Considerations**

**OPTIMIZE TABLE Output**

`OPTIMIZE TABLE` returns a result set with the columns shown in the following table.

<table>
<thead>
<tr>
<th>Column</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>The table name</td>
</tr>
<tr>
<td>Op</td>
<td>Always optimize</td>
</tr>
<tr>
<td>Msg_type</td>
<td>status, error, info, note, or warning</td>
</tr>
<tr>
<td>Msg_text</td>
<td>An informational message</td>
</tr>
</tbody>
</table>

`OPTIMIZE TABLE` table catches and throws any errors that occur while copying table statistics from the old file to the newly created file. For example, if the user ID of the owner of the .frm, .MYD, or .MYI file is different from the user ID of the `mysqld` process, `OPTIMIZE TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the root user.

**InnoDB Details**

For InnoDB tables, `OPTIMIZE TABLE` is mapped to `ALTER TABLE`, which rebuilds the table to update index statistics and free unused space in the clustered index. This is displayed in the output of `OPTIMIZE TABLE` when you run it on an InnoDB table, as shown here:

```
mysql> OPTIMIZE TABLE foo;
+----------+----------+----------+-------------------------------------------------------------------+
| Table    | Op       | Msg_type | Msg_text                                                          |
+----------+----------+----------+-------------------------------------------------------------------+
| test.foo | optimize | note     | Table does not support optimize, doing recreate + analyze instead |
| test.foo | optimize | status   | OK                                                                |
```

This operation does not use fast index creation. Secondary indexes are not created as efficiently because keys are inserted in the order they appeared in the primary key. See Section 14.16.6, “Limitations of Fast Index Creation”.

InnoDB stores data using a page-allocation method and does not suffer from fragmentation in the same way that legacy storage engines (such as MyISAM) will. When considering whether or not to run optimize, consider the workload of transactions that your server will process:
Table Maintenance Statements

• Some level of fragmentation is expected. InnoDB only fills pages 93% full, to leave room for updates without having to split pages.

• Delete operations might leave gaps that leave pages less filled than desired, which could make it worthwhile to optimize the table.

• Updates to rows usually rewrite the data within the same page, depending on the data type and row format, when sufficient space is available. See Section 14.12.5, “How Compression Works for InnoDB Tables” and Section 14.14, “InnoDB Row Formats”.

• High-concurrency workloads might leave gaps in indexes over time, as InnoDB retains multiple versions of the same data due through its MVCC mechanism. See Section 14.6, “InnoDB Multi-Versioning”.

MyISAM Details

For MyISAM tables, OPTIMIZE TABLE works as follows:

1. If the table has deleted or split rows, repair the table.
2. If the index pages are not sorted, sort them.
3. If the table’s statistics are not up to date (and the repair could not be accomplished by sorting the index), update them.

Other Considerations

Note that MySQL locks the table during the time OPTIMIZE TABLE is running.

OPTIMIZE TABLE does not sort R-tree indexes, such as spatial indexes on POINT columns. (Bug #23578)

13.7.2.5 REPAIR TABLE Statement

REPAIR [NO_WRITE_TO_BINLOG | LOCAL]
    TABLE tbl_name [, tbl_name] ...
    [QUICK] [EXTENDED] [USE_FRM]

REPAIR TABLE repairs a possibly corrupted table, for certain storage engines only.

This statement requires SELECT and INSERT privileges for the table.

Although normally you should never have to run REPAIR TABLE, if disaster strikes, this statement is very likely to get back all your data from a MyISAM table. If your tables become corrupted often, try to find the reason for it, to eliminate the need to use REPAIR TABLE. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”, and Section 15.3.4, “MyISAM Table Problems”.

REPAIR TABLE checks the table to see whether an upgrade is required. If so, it performs the upgrade, following the same rules as CHECK TABLE ... FOR UPGRADE. See Section 13.7.2.2, “CHECK TABLE Statement”, for more information.

Important

• Make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors. See Chapter 7, Backup and Recovery.

• If the server crashes during a REPAIR TABLE operation, it is essential after restarting it that you immediately execute another REPAIR TABLE statement.
Table Maintenance Statements

for the table before performing any other operations on it. In the worst case, you might have a new clean index file without information about the data file, and then the next operation you perform could overwrite the data file. This is an unlikely but possible scenario that underscores the value of making a backup first.

- In the event that a table on the master becomes corrupted and you run `REPAIR TABLE` on it, any resulting changes to the original table are not propagated to slaves.

- **REPAIR TABLE Storage Engine and Partitioning Support**
- **REPAIR TABLE Options**
- **REPAIR TABLE Output**
- **Table Repair Considerations**

**REPAIR TABLE Storage Engine and Partitioning Support**

`REPAIR TABLE` works for MyISAM, ARCHIVE, and CSV tables. For MyISAM tables, it has the same effect as `myisamchk --recover tbl_name` by default. This statement does not work with views.

`REPAIR TABLE` is supported for partitioned tables. However, the USE_FRM option cannot be used with this statement on a partitioned table.

You can use `ALTER TABLE ... REPAIR PARTITION` to repair one or more partitions; for more information, see Section 13.1.7, “ALTER TABLE Statement”, and Section 19.3.3, “Maintenance of Partitions”.

**REPAIR TABLE Options**

- **NO_WRITE_TO_BINLOG** or **LOCAL**

  By default, the server writes `REPAIR TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

- **QUICK**

  If you use the **QUICK** option, `REPAIR TABLE` tries to repair only the index file, and not the data file. This type of repair is like that done by `myisamchk --recover --quick`.

- **EXTENDED**

  If you use the **EXTENDED** option, MySQL creates the index row by row instead of creating one index at a time with sorting. This type of repair is like that done by `myisamchk --safe-recover`.

- **USE_FRM**

  The **USE_FRM** option is available for use if the `.MYI` index file is missing or if its header is corrupted. This option tells MySQL not to trust the information in the `.MYI` file header and to re-create it using information from the `.frm` file. This kind of repair cannot be done with `myisamchk`.

**Caution**

Use the **USE_FRM** option only if you cannot use regular `REPAIR` modes. Telling the server to ignore the `.MYI` file makes important table metadata stored
in the `.MYI` unavailable to the repair process, which can have deleterious consequences:

- The current `AUTO_INCREMENT` value is lost.
- The link to deleted records in the table is lost, which means that free space for deleted records will remain unoccupied thereafter.
- The `.MYI` header indicates whether the table is compressed. If the server ignores this information, it cannot tell that a table is compressed and repair can cause change or loss of table contents. This means that `USE_FRM` should not be used with compressed tables. That should not be necessary, anyway: Compressed tables are read only, so they should not become corrupt.

If you use `USE_FRM` for a table that was created by a different version of the MySQL server than the one you are currently running, `REPAIR TABLE` does not attempt to repair the table. In this case, the result set returned by `REPAIR TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Failed repairing incompatible .FRM file`.

If `USE_FRM` is used, `REPAIR TABLE` does not check the table to see whether an upgrade is required.

### REPAIR TABLE Output

`REPAIR TABLE` returns a result set with the columns shown in the following table.

<table>
<thead>
<tr>
<th>Column</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>The table name</td>
</tr>
<tr>
<td>Op</td>
<td><code>Always repair</code></td>
</tr>
<tr>
<td>Msg_type</td>
<td><code>status, error, info, note, or warning</code></td>
</tr>
<tr>
<td>Msg_text</td>
<td>An informational message</td>
</tr>
</tbody>
</table>

The `REPAIR TABLE` statement might produce many rows of information for each repaired table. The last row has a `Msg_type` value of `status` and `Msg_text` normally should be `OK`. For a MyISAM table, if you do not get `OK`, you should try repairing it with `myisamchk --safe-recover`. (`REPAIR TABLE` does not implement all the options of `myisamchk`. With `myisamchk --safe-recover`, you can also use options that `REPAIR TABLE` does not support, such as `--max-record-length`.)

`REPAIR TABLE` table catches and throws any errors that occur while copying table statistics from the old corrupted file to the newly created file. For example, if the user ID of the owner of the `.frm`, `.MYD`, or `.MYI` file is different from the user ID of the `mysqld` process, `REPAIR TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the `root` user.

### Table Repair Considerations

You may be able to increase `REPAIR TABLE` performance by setting certain system variables. See Section 8.6.3, "Optimizing REPAIR TABLE Statements".

### 13.7.3 Plugin and User-Defined Function Statements

#### 13.7.3.1 CREATE FUNCTION Syntax for User-Defined Functions

```
CREATE [AGGREGATE] FUNCTION function_name
    RETURNS {STRING|INTEGER|REAL|DECIMAL}
```
A user-defined function (UDF) is a way to extend MySQL with a new function that works like a native (built-in) MySQL function such as \texttt{ABS()} or \texttt{CONCAT()}.

\textit{function\_name} is the name that should be used in SQL statements to invoke the function. The \textbf{RETURNS} clause indicates the type of the function's return value. \texttt{DECIMAL} is a legal value after \textbf{RETURNS}, but currently \texttt{DECIMAL} functions return string values and should be written like \texttt{STRING} functions.

\textit{shared\_library\_name} is the base name of the shared library file that contains the code that implements the function. The file must be located in the plugin directory. This directory is given by the value of the \texttt{plugin\_dir} system variable. For more information, see Section 5.6.1, "Installing and Uninstalling User-Defined Functions".

To create a function, you must have the \texttt{INSERT} privilege for the \texttt{mysql} system database. This is necessary because \texttt{CREATE FUNCTION} adds a row to the \texttt{mysql.func} system table that records the function's name, type, and shared library name.

An active function is one that has been loaded with \texttt{CREATE FUNCTION} and not removed with \texttt{DROP FUNCTION}. All active functions are reloaded each time the server starts, unless you start \texttt{mysqld} with the \texttt{--skip-grant-tables} option. In this case, UDF initialization is skipped and UDFs are unavailable.

For instructions on writing user-defined functions, see Section 24.4.2, "Adding a User-Defined Function". For the UDF mechanism to work, functions must be written in C or C++ (or another language that can use C calling conventions), your operating system must support dynamic loading and you must have compiled \texttt{mysqld} dynamically (not statically).

An \texttt{AGGREGATE} function works exactly like a native MySQL aggregate (summary) function such as \texttt{SUM} or \texttt{COUNT()}.

\textbf{Note}

To upgrade the shared library associated with a UDF, issue a \texttt{DROP FUNCTION} statement, upgrade the shared library, and then issue a \texttt{CREATE FUNCTION} statement. If you upgrade the shared library first and then use \texttt{DROP FUNCTION}, the server may crash.

13.7.3.2 DROP FUNCTION Statement

\texttt{DROP FUNCTION function\_name}

This statement drops the user-defined function (UDF) named \textit{function\_name}.

To drop a function, you must have the \texttt{DELETE} privilege for the \texttt{mysql} system database. This is because \texttt{DROP FUNCTION} removes a row from the \texttt{mysql.func} system table that records the function's name, type, and shared library name.

\textbf{Note}

To upgrade the shared library associated with a UDF, issue a \texttt{DROP FUNCTION} statement, upgrade the shared library, and then issue a \texttt{CREATE FUNCTION} statement. If you upgrade the shared library first and then use \texttt{DROP FUNCTION}, the server may crash.

\texttt{DROP FUNCTION} is also used to drop stored functions (see Section 13.1.26, "DROP PROCEDURE and DROP FUNCTION Statements").

13.7.3.3 INSTALL PLUGIN Statement
INSTALL PLUGIN  

This statement installs a server plugin. It requires the INSERT privilege for the mysql.plugin system table.

**plugin_name** is the name of the plugin as defined in the plugin descriptor structure contained in the library file (see Section 24.2.4.2, “Plugin Data Structures”). Plugin names are not case-sensitive. For maximal compatibility, plugin names should be limited to ASCII letters, digits, and underscore because they are used in C source files, shell command lines, M4 and Bourne shell scripts, and SQL environments.

**shared_library_name** is the name of the shared library that contains the plugin code. The name includes the file name extension (for example, libmyplugin.so, libmyplugin.dll, or libmyplugin.dylib).

The shared library must be located in the plugin directory (the directory named by the plugin_dir system variable). The library must be in the plugin directory itself, not in a subdirectory. By default, plugin_dir is the plugin directory under the directory named by the pkglibdir configuration variable, but it can be changed by setting the value of plugin_dir at server startup. For example, set its value in a my.cnf file:

```sql
[mysqld]
plugin_dir=/path/to/plugin/directory
```

If the value of plugin_dir is a relative path name, it is taken to be relative to the MySQL base directory (the value of the basedir system variable).

INSTALL PLUGIN loads and initializes the plugin code to make the plugin available for use. A plugin is initialized by executing its initialization function, which handles any setup that the plugin must perform before it can be used. When the server shuts down, it executes the deinitialization function for each plugin that is loaded so that the plugin has a chance to perform any final cleanup.

INSTALL PLUGIN also registers the plugin by adding a line that indicates the plugin name and library file name to the mysql.plugin system table. At server startup, the server loads and initializes any plugin that is listed in mysql.plugin. This means that a plugin is installed with INSTALL PLUGIN only once, not every time the server starts. Plugin loading at startup does not occur if the server is started with the --skip-grant-tables option.

A plugin library can contain multiple plugins. For each of them to be installed, use a separate INSTALL PLUGIN statement. Each statement names a different plugin, but all of them specify the same library name.

INSTALL PLUGIN causes the server to read option (my.cnf) files just as during server startup. This enables the plugin to pick up any relevant options from those files. It is possible to add plugin options to an option file even before loading a plugin (if the loose prefix is used). It is also possible to uninstall a plugin, edit my.cnf, and install the plugin again. Restarting the plugin this way enables it to the new option values without a server restart.

For options that control individual plugin loading at server startup, see Section 5.5.1, “Installing and Uninstalling Plugins”. If you need to load plugins for a single server startup when the --skip-grant-tables option is given (which tells the server not to read system tables), use the --plugin-load option. See Section 5.1.6, “Server Command Options”.

To remove a plugin, use the UNINSTALL PLUGIN statement.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To see what plugins are installed, use the SHOW PLUGINS statement or query the INFORMATION_SCHEMA the PLUGINS table.

If you recompile a plugin library and need to reinstall it, you can use either of the following methods:
SET Statements

- Use `UNINSTALL PLUGIN` to uninstall all plugins in the library, install the new plugin library file in the plugin directory, and then use `INSTALL PLUGIN` to install all plugins in the library. This procedure has the advantage that it can be used without stopping the server. However, if the plugin library contains many plugins, you must issue many `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements.

- Stop the server, install the new plugin library file in the plugin directory, and restart the server.

13.7.3.4 UNINSTALL PLUGIN Statement

`UNINSTALL PLUGIN plugin_name`

This statement removes an installed server plugin. It requires the `DELETE` privilege for the `mysql.plugin` system table. `UNINSTALL PLUGIN` is the complement of `INSTALL PLUGIN`.

`plugin_name` must be the name of some plugin that is listed in the `mysql.plugin` table. The server executes the plugin's deinitialization function and removes the row for the plugin from the `mysql.plugin` system table, so that subsequent server restarts will not load and initialize the plugin. `UNINSTALL PLUGIN` does not remove the plugin's shared library file.

You cannot uninstall a plugin if any table that uses it is open.

Plugin removal has implications for the use of associated tables. For example, if a full-text parser plugin is associated with a `FULLTEXT` index on the table, uninstalling the plugin makes the table unusable. Any attempt to access the table results in an error. The table cannot even be opened, so you cannot drop an index for which the plugin is used. This means that uninstalling a plugin is something to do with care unless you do not care about the table contents. If you are uninstalling a plugin with no intention of reinstalling it later and you care about the table contents, you should dump the table with `mysqldump` and remove the `WITH PARSER` clause from the dumped `CREATE TABLE` statement so that you can reload the table later. If you do not care about the table, `DROP TABLE` can be used even if any plugins associated with the table are missing.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

13.7.4 SET Statements

The `SET` statement has several forms. Descriptions for those forms that are not associated with a specific server capability appear in subsections of this section:

- `SET var_name = value` enables you to assign values to variables that affect the operation of the server or clients. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.

- `SET CHARACTER SET` and `SET NAMES` assign values to character set and collation variables associated with the current connection to the server. See Section 13.7.4.2, “SET CHARACTER SET Statement”, and Section 13.7.4.3, “SET NAMES Statement”.

Descriptions for the other forms appear elsewhere, grouped with other statements related to the capability they help implement:

- `SET PASSWORD` assigns account passwords. See Section 13.7.1.6, “SET PASSWORD Statement”.

- `SET TRANSACTION ISOLATION LEVEL` sets the isolation level for transaction processing. See Section 13.3.6, “SET TRANSACTION Statement”.

13.7.4.1 SET Syntax for Variable Assignment

`SET variable = expr [, variable = expr] ...`
### SET Statements

**variable:**

- `user_var_name`
- `param_name`
- `local_var_name`
- `{GLOBAL | @@GLOBAL.}` `system_var_name`
- `{SESSION | @@SESSION. | @@}` `system_var_name`

**SET ONE_SHOT**

```
SET ONE_SHOT system_var_name = expr
```

**SET** syntax for variable assignment enables you to assign values to different types of variables that affect the operation of the server or clients:

- **User-defined variables.** See Section 9.4, “User-Defined Variables”.
- **Stored procedure and function parameters, and stored program local variables.** See Section 13.6.4, “Variables in Stored Programs”.
- **System variables.** See Section 5.1.7, “Server System Variables”. System variables also can be set at server startup, as described in Section 5.1.8, “Using System Variables”.

Older versions of MySQL employed **SET OPTION**, but this syntax is deprecated in favor of **SET** without **OPTION**.

A **SET** statement that assigns variable values is not written to the binary log, so in replication scenarios it affects only the host on which you execute it. To affect all replication hosts, execute the statement on each host.

The following sections describe **SET** syntax for setting variables. They use the `=` assignment operator, but the `:=` assignment operator is also permitted for this purpose.

- **User-Defined Variable Assignment**
- **Parameter and Local Variable Assignment**
- **System Variable Assignment**
- **SET Error Handling**
- **Multiple Variable Assignment**
- **System Variable References in Expressions**
- **ONE_SHOT Assignment**

#### User-Defined Variable Assignment

User-defined variables are created locally within a session and exist only within the context of that session; see Section 9.4, “User-Defined Variables”.

A user-defined variable is written as `@var_name` and is assigned an expression value as follows:

```
SET @var_name = expr;
```

Examples:

```
SET @name = 43;
SET @total_tax = (SELECT SUM(tax) FROM taxable_transactions);
```

As demonstrated by those statements, **expr** can range from simple (a literal value) to more complex (the value returned by a scalar subquery).
Parameter and Local Variable Assignment

`SET` applies to parameters and local variables in the context of the stored object within which they are defined. The following procedure uses the `increment` procedure parameter and `counter` local variable:

```sql
CREATE PROCEDURE p(increment INT)
BEGIN
  DECLARE counter INT DEFAULT 0;
  WHILE counter < 10 DO
    -- ... do work ...
    SET counter = counter + increment;
  END WHILE;
END;
```

System Variable Assignment

The MySQL server maintains system variables that configure its operation. A system variable can have a global value that affects server operation as a whole, a session value that affects the current session, or both. Many system variables are dynamic and can be changed at runtime using the `SET` statement to affect operation of the current server instance. (To make a global system variable setting permanent so that it applies across server restarts, you should also set it in an option file.)

If you change a session system variable, the value remains in effect within your session until you change the variable to a different value or the session ends. The change has no effect on other sessions.

If you change a global system variable, the value is remembered and used to initialize the session value for new sessions until you change the variable to a different value or the server exits. The change is visible to any client that accesses the global value. However, the change affects the corresponding session value only for clients that connect after the change. The global variable change does not affect the session value for any current client sessions (not even the session within which the global value change occurs).

**Note**

Setting a global system variable value always requires special privileges. Setting a session system variable value normally requires no special privileges and can be done by any user, although there are exceptions. For more information, see Section 5.1.8.1, "System Variable Privileges".

The following discussion describes the syntax options for setting system variables:

- To assign a value to a global system variable, precede the variable name by the `GLOBAL` keyword or the `@@GLOBAL` qualifier:

  ```sql
  SET GLOBAL max_connections = 1000;
  SET @@GLOBAL.max_connections = 1000;
  ```

- To assign a value to a session system variable, precede the variable name by the `SESSION` or `LOCAL` keyword, by the `@@SESSION`, `@@LOCAL`, or `@@` qualifier, or by no keyword or no modifier at all:

  ```sql
  SET SESSION sql_mode = 'TRADITIONAL';
  SET LOCAL sql_mode = 'TRADITIONAL';
  SET @@SESSION.sql_mode = 'TRADITIONAL';
  SET @@LOCAL.sql_mode = 'TRADITIONAL';
  SET @@sql_mode = 'TRADITIONAL';
  SET sql_mode = 'TRADITIONAL';
  ```

  A client can change its own session variables, but not those of any other client.

To set a global system variable value to the compiled-in MySQL default value or a session system variable to the current corresponding global value, set the variable to the value `DEFAULT`. For example, the
following two statements are identical in setting the session value of `max_join_size` to the current global value:

```sql
SET @@SESSION.max_join_size = DEFAULT;
SET @@SESSION.max_join_size = @@GLOBAL.max_join_size;
```

To display system variable names and values:

- Use the `SHOW VARIABLES` statement; see Section 13.7.5.40, "SHOW VARIABLES Statement".

### SET Error Handling

If any variable assignment in a `SET` statement fails, the entire statement fails and no variables are changed.

`SET` produces an error under the circumstances described here. Most of the examples show `SET` statements that use keyword syntax (for example, `GLOBAL` or `SESSION`), but the principles are also true for statements that use the corresponding modifiers (for example, `@@GLOBAL` or `@@SESSION`).

- Use of `SET` (any variant) to set a read-only variable:

  ```sql
  mysql> SET GLOBAL version = 'abc';
  ERROR 1238 (HY000): Variable 'version' is a read only variable
  ```

- Use of `GLOBAL` to set a variable that has only a session value:

  ```sql
  mysql> SET GLOBAL sql_log_bin = ON;
  ERROR 1231 (42000): Variable 'sql_log_bin' can't be set to the value of 'ON'
  ```

- Use of `SESSION` to set a variable that has only a global value:

  ```sql
  mysql> SET SESSION max_connections = 1000;
  ERROR 1229 (HY000): Variable 'max_connections' is a GLOBAL variable and should be set with SET GLOBAL
  ```

- Omission of `GLOBAL` to set a variable that has only a global value:

  ```sql
  mysql> SET max_connections = 1000;
  ERROR 1229 (HY000): Variable 'max_connections' is a GLOBAL variable and should be set with SET GLOBAL
  ```

- The `@@GLOBAL`, `@@SESSION`, and `@@` modifiers apply only to system variables. An error occurs for attempts to apply them to user-defined variables, stored procedure or function parameters, or stored program local variables.

- Not all system variables can be set to `DEFAULT`. In such cases, assigning `DEFAULT` results in an error.

- It is not permitted to assign `DEFAULT` to user-defined variables, and not supported for stored procedure or function parameters or stored program local variables. This results in an error for user-defined variables, and the results are undefined for parameters or local variables.

### Multiple Variable Assignment

A `SET` statement can contain multiple variable assignments, separated by commas. This statement assigns a value to a user-defined variable and a system variable:

```sql
SET @x = 1, SESSION sql_mode = '';
```

If you set multiple system variables in a single statement, the most recent `GLOBAL` or `SESSION` keyword in the statement is used for following assignments that have no keyword specified.
Examples of multiple-variable assignment:

```sql
SET GLOBAL sort_buffer_size = 1000000, SESSION sort_buffer_size = 1000000;
SET @@GLOBAL.sort_buffer_size = 1000000, @@SESSION.sort_buffer_size = 1000000;
SET GLOBAL max_connections = 1000, sort_buffer_size = 1000000;
```

The `@@GLOBAL`, `@@SESSION`, and `@` modifiers apply only to the immediately following system variable, not any remaining system variables. This statement sets the `sort_buffer_size` global value to 50000 and the session value to 1000000:

```sql
SET @@GLOBAL.sort_buffer_size = 50000, sort_buffer_size = 1000000;
```

**System Variable References in Expressions**

To refer to the value of a system variable in expressions, use one of the `@@`-modifiers. For example, you can retrieve system variable values in a `SELECT` statement like this:

```sql
SELECT @@GLOBAL.sql_mode, @@SESSION.sql_mode, @@sql_mode;
```

**Note**

A reference to a system variable in an expression as `@@var_name` (with `@@` rather than `@@GLOBAL` or `@@SESSION`) returns the session value if it exists and the global value otherwise. This differs from `SET @@var_name = expr`, which always refers to the session value.

**ONE_SHOT Assignment**

The `SET ONE_SHOT` syntax is only for internal use for replication: `mysqlbinlog` uses `SET ONE_SHOT` to modify temporarily the values of character set, collation, and time zone variables to reflect at rollforward what they were originally. `ONE_SHOT` is for internal use only and is deprecated.

`ONE_SHOT` is intended for use only with the permitted set of variables. It changes the variables as requested, but only for the next non-`SET` statement. After that, the server resets all character set, collation, and time zone-related system variables to their previous values. Example:

```sql
mysql> SET ONE_SHOT character_set_connection = latin5;
mysql> SET ONE_SHOT collation_connection = latin5_turkish_ci;
mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin5            |
| collation_connection     | latin5_turkish_ci |
+--------------------------+-------------------+
mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin1            |
| collation_connection     | latin1_swedish_ci |
+--------------------------+-------------------+
```

**13.7.4.2 SET CHARACTER SET Statement**

```sql
SET {CHARACTER SET | CHARSET}
{'charset_name' | DEFAULT}
```
SHOW Statements

This statement maps all strings sent between the server and the current client with the given mapping. 

SET CHARACTER SET sets three session system variables: \texttt{character_set_client} and \texttt{character_set_results} are set to the given character set, and \texttt{character_set_connection} to the value of \texttt{character_set_database}. See Section 10.4, “Connection Character Sets and Collations”.

\texttt{charset_name} may be quoted or unquoted.

The default character set mapping can be restored by using the value \texttt{DEFAULT}. The default depends on the server configuration.

Some character sets cannot be used as the client character set. Attempting to use them with \texttt{SET CHARACTER SET} produces an error. See Impermissible Client Character Sets.

13.7.4.3 SET NAMES Statement

\texttt{SET NAMES \{'charset_name'\} \[COLLATE \{'collation_name'\} \| \texttt{DEFAULT}\]}

This statement sets the three session system variables \texttt{character_set_client}, \texttt{character_set_connection}, and \texttt{character_set_results} to the given character set. Setting \texttt{character_set_connection} to \texttt{charset_name} also sets \texttt{collation_connection} to the default collation for \texttt{charset_name}. See Section 10.4, “Connection Character Sets and Collations”.

The optional \texttt{COLLATE} clause may be used to specify a collation explicitly. If given, the collation must one of the permitted collations for \texttt{charset_name}.

\texttt{charset_name} and \texttt{collation_name} may be quoted or unquoted.

The default mapping can be restored by using a value of \texttt{DEFAULT}. The default depends on the server configuration.

Some character sets cannot be used as the client character set. Attempting to use them with \texttt{SET NAMES} produces an error. See Impermissible Client Character Sets.

13.7.5 SHOW Statements

\texttt{SHOW} has many forms that provide information about databases, tables, columns, or status information about the server. This section describes those following:

\begin{itemize}
  \item \texttt{SHOW AUTHORS}
  \item \texttt{SHOW (BINARY \| MASTER) LOGS}
  \item \texttt{SHOW BINLOG EVENTS [IN \{'log_name'\}] [FROM \texttt{pos}] [LIMIT \[\texttt{offset},\] \texttt{row_count}]}
  \item \texttt{SHOW CHARACTER SET [like_or_where]}
  \item \texttt{SHOW COLLATION [like_or_where]}
  \item \texttt{SHOW [FULL] COLUMNS FROM \texttt{tbl_name} [FROM \texttt{db_name}] [like_or_where]}
  \item \texttt{SHOW CONTRIBUTORS}
  \item \texttt{SHOW CREATE DATABASE \texttt{db_name}}
  \item \texttt{SHOW CREATE EVENT \texttt{event_name}}
  \item \texttt{SHOW CREATE FUNCTION \texttt{func_name}}
  \item \texttt{SHOW CREATE PROCEDURE \texttt{proc_name}}
  \item \texttt{SHOW CREATE TABLE \texttt{tbl_name}}
  \item \texttt{SHOW CREATE TRIGGER \texttt{trigger_name}}
  \item \texttt{SHOW CREATE VIEW \texttt{view_name}}
  \item \texttt{SHOW DATABASES [like_or_where]}
  \item \texttt{SHOW ENGINE \texttt{engine_name} (STATUS \| MUTEX)}
  \item \texttt{SHOW \[STORAGE\] ENGINES}
  \item \texttt{SHOW ERRORS [LIMIT \[\texttt{offset},\] \texttt{row_count}]}
  \item \texttt{SHOW EVENTS}
  \item \texttt{SHOW FUNCTION CODE \texttt{func_name}}
  \item \texttt{SHOW FUNCTION STATUS [like_or_where]}
  \item \texttt{SHOW GRANTS FOR \texttt{user}}
\end{itemize}
SHOW INDEX FROM `tbl_name` [FROM `db_name`]
SHOW MASTER STATUS
SHOW OPEN TABLES [FROM `db_name`] [like_or_where]
SHOW PLUGINS
SHOW PROCEDURE CODE `proc_name`
SHOW PROCEDURE STATUS [like_or_where]
SHOW PRIVILEGES
SHOW [FULL] PROCEESSLIST
SHOW PROFILE [types] [FOR QUERY `n`] [OFFSET `n`] [LIMIT `n`]
SHOW PROFILES
SHOW RELAYLOG EVENTS [IN 'log_name'] [FROM `pos`] [LIMIT [offset,] row_count]
SHOW SLAVE HOSTS
SHOW SLAVE STATUS
SHOW [GLOBAL | SESSION] STATUS [like_or_where]
SHOW TABLE STATUS [FROM `db_name`] [like_or_where]
SHOW [FULL] TABLES [FROM `db_name`] [like_or_where]
SHOW TRIGGERS [FROM `db_name`] [like_or_where]
SHOW [GLOBAL | SESSION] VARIABLES [like_or_where]
SHOW WARNINGS [LIMIT [offset,] row_count]

like_or_where:
  - LIKE 'pattern'
  - WHERE expr

If the syntax for a given SHOW statement includes a LIKE 'pattern' part, 'pattern' is a string that can contain the SQL % and _ wildcard characters. The pattern is useful for restricting statement output to matching values.

Several SHOW statements also accept a WHERE clause that provides more flexibility in specifying which rows to display. See Section 21.32, "Extensions to SHOW Statements".

Many MySQL APIs (such as PHP) enable you to treat the result returned from a SHOW statement as you would a result set from a SELECT; see Chapter 23, Connectors and APIs, or your API documentation for more information. In addition, you can work in SQL with results from queries on tables in the INFORMATION_SCHEMA database, which you cannot easily do with results from SHOW statements. See Chapter 21, INFORMATION_SCHEMA Tables.

13.7.5.1 SHOW AUTHORS Statement

SHOW AUTHORS

The SHOW AUTHORS statement displays information about the people who work on MySQL. For each author, it displays Name, Location, and Comment values.

This statement is deprecated as of MySQL 5.5.29 and is removed in MySQL 5.6.

13.7.5.2 SHOW BINARY LOGS Statement

SHOW BINARY LOGS
SHOW MASTER LOGS

Lists the binary log files on the server. This statement is used as part of the procedure described in Section 13.4.1.1, "PURGE BINARY LOGS Statement", that shows how to determine which logs can be purged.

```
mysql> SHOW BINARY LOGS;
+-----------------+-----------+
| Log_name        | File_size |
+-----------------+-----------+
| binlog.000015   | 724935    |
| binlog.000016   | 733481    |
+-----------------+-----------+
```
SHOW MASTER LOGS is equivalent to SHOW BINARY LOGS.

In MySQL 5.5.24 and earlier, the SUPER privilege was required to use this statement. Starting with MySQL 5.5.25, a user with the REPLICATION CLIENT privilege may also execute this statement.

13.7.5.3 SHOW BINLOG EVENTS Statement

```
SHOW BINLOG EVENTS
  [IN 'log_name']
  [FROM pos]
  [LIMIT [offset,] row_count]
```

Shows the events in the binary log. If you do not specify 'log_name', the first binary log is displayed.

The LIMIT clause has the same syntax as for the SELECT statement. See Section 13.2.9, “SELECT Statement”.

Note
Issuing a SHOW BINLOG EVENTS with no LIMIT clause could start a very time-and resource-consuming process because the server returns to the client the complete contents of the binary log (which includes all statements executed by the server that modify data). As an alternative to SHOW BINLOG EVENTS, use the mysqlbinlog utility to save the binary log to a text file for later examination and analysis. See Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”.

SHOW BINLOG EVENTS displays the following fields for each event in the binary log:

- **Log_name**
  The name of the file that is being listed.

- **Pos**
  The position at which the event occurs.

- **Event_type**
  An identifier that describes the event type.

- **Server_id**
  The server ID of the server on which the event originated.

- **End_log_pos**
  The position at which the next event begins, which is equal to Pos plus the size of the event.

- **Info**
  More detailed information about the event type. The format of this information depends on the event type.

Note
Some events relating to the setting of user and system variables are not included in the output from SHOW BINLOG EVENTS. To get complete coverage of events within a binary log, use mysqlbinlog.
SHOW Statements

Note
SHOW BINLOG EVENTS does not work with relay log files. You can use SHOW RELAYLOG EVENTS for this purpose.

13.7.5.4 SHOW CHARACTER SET Statement

SHOW CHARACTER SET
[LIKE 'pattern' | WHERE expr]

The SHOW CHARACTER SET statement shows all available character sets. The LIKE clause, if present, indicates which character set names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”. For example:

mysql> SHOW CHARACTER SET LIKE 'latin%';

<table>
<thead>
<tr>
<th>Charset</th>
<th>Description</th>
<th>Default collation</th>
<th>Maxlen</th>
</tr>
</thead>
<tbody>
<tr>
<td>latin1</td>
<td>cp1252 West European</td>
<td>latin1_swedish_ci</td>
<td>1</td>
</tr>
<tr>
<td>latin2</td>
<td>ISO 8859-2 Central European</td>
<td>latin2_general_ci</td>
<td>1</td>
</tr>
<tr>
<td>latin5</td>
<td>ISO 8859-9 Turkish</td>
<td>latin5_turkish_ci</td>
<td>1</td>
</tr>
<tr>
<td>latin7</td>
<td>ISO 8859-13 Baltic</td>
<td>latin7_general_ci</td>
<td>1</td>
</tr>
</tbody>
</table>

SHOW CHARACTER SET output has these columns:

• Charset
  The character set name.

• Description
  A description of the character set.

• Default collation
  The default collation for the character set.

• Maxlen
  The maximum number of bytes required to store one character.

The filename character set is for internal use only; consequently, SHOW CHARACTER SET does not display it.

Character set information is also available from the INFORMATION_SCHEMA CHARACTER_SETS table. See Section 21.2, “The INFORMATION_SCHEMA CHARACTER_SETS Table”.

13.7.5.5 SHOW COLLATION Statement

SHOW COLLATION
[LIKE 'pattern' | WHERE expr]

This statement lists collations supported by the server. By default, the output from SHOW COLLATION includes all available collations. The LIKE clause, if present, indicates which collation names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”. For example:

mysql> SHOW COLLATION WHERE Charset = 'latin1';
SHOW Statements

| Collation         | Charset | Id | Default | Compiled | Sortlen |
|-------------------+---------+----+---------+----------+---------|
| latin1_german1_ci | latin1  |  5 |         | Yes      |       1 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       1 |
| latin1_danish_ci  | latin1  | 15 |         | Yes      |       1 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       1 |
| latin1_general_ci | latin1  | 48 |         | Yes      |       1 |
| latin1_general_cs | latin1  | 49 |         | Yes      |       1 |
| latin1_spanish_ci | latin1  | 94 |         | Yes      |       1 |

SHOW COLLATION output has these columns:

- **Collation**
  The collation name.
- **Charset**
  The name of the character set with which the collation is associated.
- **Id**
  The collation ID.
- **Default**
  Whether the collation is the default for its character set.
- **Compiled**
  Whether the character set is compiled into the server.
- **Sortlen**
  This is related to the amount of memory required to sort strings expressed in the character set.

To see the default collation for each character set, use the following statement. `Default` is a reserved word, so to use it as an identifier, it must be quoted as such:

```sql
mysql> SHOW COLLATION WHERE `Default` = 'Yes';
```

Collation information is also available from the `INFORMATION_SCHEMA COLLATIONS` table. See Section 21.3, “The INFORMATION_SCHEMA COLLATIONS Table”.

13.7.5.6 SHOW COLUMNS Statement

```
SHOW [FULL] {COLUMNS | FIELDS}
{FROM | IN} tbl_name
[({FROM | IN} db_name]
[LIKE 'pattern' | WHERE expr]
```
**SHOW Statements**

**SHOW COLUMNS** displays information about the columns in a given table. It also works for views. **SHOW COLUMNS** displays information only for those columns for which you have some privilege.

```sql
mysql> SHOW COLUMNS FROM City;
```

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Null</th>
<th>Key</th>
<th>Default</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>int(11)</td>
<td>NO</td>
<td>PRI</td>
<td>NULL</td>
<td>auto_increment</td>
</tr>
<tr>
<td>Name</td>
<td>char(35)</td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CountryCode</td>
<td>char(3)</td>
<td>NO</td>
<td>MUL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>District</td>
<td>char(20)</td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>int(11)</td>
<td>NO</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

An alternative to `tbl_name FROM db_name` syntax is `db_name.tbl_name`. These two statements are equivalent:

```sql
SHOW COLUMNS FROM mytable FROM mydb;
SHOW COLUMNS FROM mydb.mytable;
```

The optional **FULL** keyword causes the output to include the column collation and comments, as well as the privileges you have for each column.

The **LIKE** clause, if present, indicates which column names to match. The **WHERE** clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

The data types may differ from what you expect them to be based on a **CREATE TABLE** statement because MySQL sometimes changes data types when you create or alter a table. The conditions under which this occurs are described in Section 13.1.17.7, “Silent Column Specification Changes”.

**SHOW COLUMNS** displays the following values for each table column:

- **Field**
  The column name.

- **Type**
  The column data type.

- **Collation**
  The collation for nonbinary string columns, or **NULL** for other columns. This value is displayed only if you use the **FULL** keyword.

- **Null**
  The column nullability. The value is **YES** if **NULL** values can be stored in the column, **NO** if not.

- **Key**
  Whether the column is indexed:
  - If **Key** is empty, the column either is not indexed or is indexed only as a secondary column in a multiple-column, nonunique index.
  - If **Key** is **PRI**, the column is a **PRIMARY KEY** or is one of the columns in a multiple-column **PRIMARY KEY**.
SHOW Statements

• If Key is UNI, the column is the first column of a UNIQUE index. (A UNIQUE index permits multiple NULL values, but you can tell whether the column permits NULL by checking the Null field.)

• If Key is MUL, the column is the first column of a nonunique index in which multiple occurrences of a given value are permitted within the column.

If more than one of the Key values applies to a given column of a table, Key displays the one with the highest priority, in the order PRI, UNI, MUL.

A UNIQUE index may be displayed as PRI if it cannot contain NULL values and there is no PRIMARY KEY in the table. A UNIQUE index may display as MUL if several columns form a composite UNIQUE index; although the combination of the columns is unique, each column can still hold multiple occurrences of a given value.

• Default

The default value for the column. This is NULL if the column has an explicit default of NULL, or if the column definition includes no DEFAULT clause.

• Extra

Any additional information that is available about a given column. The value is nonempty in these cases: auto_increment for columns that have the AUTO_INCREMENT attribute; on update CURRENT_TIMESTAMP for TIMESTAMP columns that have the ON UPDATE CURRENT_TIMESTAMP attribute.

• Privileges

The privileges you have for the column. This value is displayed only if you use the FULL keyword.

• Comment

Any comment included in the column definition. This value is displayed only if you use the FULL keyword.

Table column information is also available from the INFORMATION_SCHEMA COLUMNS table. See Section 21.5, “The INFORMATION_SCHEMA COLUMNS Table”.

You can list a table’s columns with the mysqlshow db_name tbl_name command.

The DESCRIBE statement provides information similar to SHOW COLUMNS. See Section 13.8.1, “DESCRIBE Statement”.

The SHOW CREATE TABLE, SHOW TABLE STATUS, and SHOW INDEX statements also provide information about tables. See Section 13.7.5, “SHOW Statements”.

13.7.5.7 SHOW CONTRIBUTORS Statement

SHOW CONTRIBUTORS

The SHOW CONTRIBUTORS statement displays information about the people who contribute to MySQL source or to causes that we support. For each contributor, it displays Name, Location, and Comment values.

This statement is deprecated as of MySQL 5.5.29 and is removed in MySQL 5.6.

13.7.5.8 SHOW CREATE DATABASE Statement
SHOW Statements

SHOW CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name

Shows the CREATE DATABASE statement that creates the named database. If the SHOW statement includes an IF NOT EXISTS clause, the output too includes such a clause. SHOW CREATE SCHEMA is a synonym for SHOW CREATE DATABASE.

```
mysql> SHOW CREATE DATABASE test\G
*************************** 1. row ***************************
  Database: test
  Create Database: CREATE DATABASE `test`
  /*!40100 DEFAULT CHARACTER SET latin1 */
mysql>
```

SHOW CREATE SCHEMA test\G
*************************** 1. row ***************************
  Database: test
  Create Database: CREATE DATABASE `test`
  /*!40100 DEFAULT CHARACTER SET latin1 */

SHOW CREATE DATABASE quotes table and column names according to the value of the sql_quote_show_create option. See Section 5.1.7, “Server System Variables”.

13.7.5.9 SHOW CREATE EVENT Statement

SHOW CREATE EVENT event_name

This statement displays the CREATE EVENT statement needed to re-create a given event. It requires the EVENT privilege for the database from which the event is to be shown. For example (using the same event e_daily defined and then altered in Section 13.7.5.19, “SHOW EVENTS Statement”):

```
mysql> SHOW CREATE EVENT myschema.e_daily\G
*************************** 1. row ***************************
  Event: e_daily
  sql_mode: SYSTEM
  time_zone: SYSTEM
  Create Event: CREATE DEFINER=`jon`@`ghidora` EVENT `e_daily`
    ON SCHEDULE EVERY 1 DAY
    STARTS CURRENT_TIMESTAMP + INTERVAL 6 HOUR
    ON COMPLETION NOT PRESERVE
    ENABLE
    COMMENT 'Saves total number of sessions then clears the table each day'
    DO BEGIN
    INSERT INTO site_activity.totals (time, total)
    SELECT CURRENT_TIMESTAMP, COUNT(*)
    FROM site_activity.sessions;
    DELETE FROM site_activity.sessions;
    END
  character_set_client: utf8
  collation_connection: utf8_general_ci
  Database Collation: latin1_swedish_ci
```

character_set_client is the session value of the character_set_client system variable when the event was created. collation_connection is the session value of the collation_connection system variable when the event was created. Database Collation is the collation of the database with which the event is associated.

Note that the output reflects the current status of the event (ENABLE) rather than the status with which it was created.

13.7.5.10 SHOW CREATE FUNCTION Statement

SHOW CREATE FUNCTION func_name
SHOW Statements

This statement is similar to `SHOW CREATE PROCEDURE` but for stored functions. See Section 13.7.5.11, “SHOW CREATE PROCEDURE Statement”.

13.7.5.11 SHOW CREATE PROCEDURE Statement

```
SHOW CREATE PROCEDURE proc_name
```

This statement is a MySQL extension. It returns the exact string that can be used to re-create the named stored procedure. A similar statement, `SHOW CREATE FUNCTION`, displays information about stored functions (see Section 13.7.5.10, “SHOW CREATE FUNCTION Statement”).

To use either statement, you must be the user named in the routine `DEFINER` clause or have `SELECT` access to the `mysql.proc` table. If you do not have privileges for the routine itself, the value displayed for the `Create Procedure` or `Create Function` field will be `NULL`.

```
mysql> SHOW CREATE PROCEDURE test.simpleproc\G
*************************** 1. row ***************************
Procedure: simpleproc
sql_mode: CREATE PROCEDURE `simpleproc`(OUT param1 INT)
BEGIN
    SELECT COUNT(*) INTO param1 FROM t;
END
character_set_client: utf8
collation_connection: utf8_general_ci
Database Collation: latin1_swedish_ci

mysql> SHOW CREATE FUNCTION test.hello\G
*************************** 1. row ***************************
Function: hello
sql_mode: CREATE FUNCTION `hello`(s CHAR(20))
    RETURNS CHAR(50)
    RETURN CONCAT('Hello, ',s,'!')
character_set_client: utf8
collation_connection: utf8_general_ci
Database Collation: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated.

13.7.5.12 SHOW CREATE TABLE Statement

```
SHOW CREATE TABLE tbl_name
```

Shows the `CREATE TABLE` statement that creates the named table. To use this statement, you must have some privilege for the table. This statement also works with views.

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
Table: t
Create Table: CREATE TABLE `t` (  `id` int(11) NOT NULL AUTO_INCREMENT,  `s` char(60) DEFAULT NULL,  PRIMARY KEY (`id`)) ENGINE=InnoDB DEFAULT CHARSET=latin1
```

`SHOW CREATE TABLE` quotes table and column names according to the value of the `sql_quote_show_create` option. See Section 5.1.7, “Server System Variables”.

1643
SHOW Statements

For information about how `CREATE TABLE` statements are stored by MySQL, see Section 13.1.17.1, “CREATE TABLE Statement Retention”.

### 13.7.5.13 SHOW CREATE TRIGGER Statement

**SHOW CREATE TRIGGER** *trigger_name*

This statement shows the `CREATE TRIGGER` statement that creates the named trigger. This statement requires the `TRIGGER` privilege for the table associated with the trigger.

```sql
mysql> SHOW CREATE TRIGGER ins_sum\G
*************************** 1. row ***************************
Trigger: ins_sum
SQL Original Statement: CREATE DEFINER=`me`@`localhost` TRIGGER ins_sum
BEFORE INSERT ON account
FOR EACH ROW SET @sum = @sum + NEW.amount
```

**SHOW CREATE TRIGGER** output has these columns:

- **Trigger**: The trigger name.
- **sql_mode**: The SQL mode in effect when the trigger executes.
- **SQL Original Statement**: The `CREATE TRIGGER` statement that defines the trigger.
- **character_set_client**: The session value of the `character_set_client` system variable when the trigger was created.
- **collation_connection**: The session value of the `collation_connection` system variable when the trigger was created.
- **Database Collation**: The collation of the database with which the trigger is associated.

Trigger information is also available from the `INFORMATION_SCHEMA TRIGGERS` table. See Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”.

### 13.7.5.14 SHOW CREATE VIEW Statement

**SHOW CREATE VIEW** *view_name*

This statement shows the `CREATE VIEW` statement that creates the named view.

```sql
mysql> SHOW CREATE VIEW v\G
*************************** 1. row ***************************
View: v
Create View: CREATE ALGORITHM=UNDEFINED
DEFINER=`bob`@`localhost` SQL SECURITY DEFINER VIEW
`v` AS select 1 AS `a`,2 AS `b`
```

**character_set_client** is the session value of the `character_set_client` system variable when the view was created. **collation_connection** is the session value of the `collation_connection` system variable when the view was created.

Use of **SHOW CREATE VIEW** requires the **SHOW VIEW** privilege, and the **SELECT** privilege for the view in question.
View information is also available from the INFORMATION_SCHEMA VIEWS table. See Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”.

MySQL lets you use different sql_mode settings to tell the server the type of SQL syntax to support. For example, you might use the ANSI SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (||), in your queries. If you then create a view that concatenates items, you might worry that changing the sql_mode setting to a value different from ANSI could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a CONCAT() function:

```sql
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)
mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.01 sec)
mysql> SHOW CREATE VIEW test.v\G
*************************** 1. row ***************************
View: v
Create View: CREATE VIEW "v" AS select concat('a','b') AS "col1"
...
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of sql_mode will not affect the results from the view. However an additional consequence is that comments prior to SELECT are stripped from the definition by the server.

### 13.7.5.15 SHOW DATABASES Statement

SHOW {DATABASES | SCHEMAS} 
[LIKE 'pattern' | WHERE expr]

SHOW DATABASES lists the databases on the MySQL server host. SHOW SCHEMAS is a synonym for SHOW DATABASES. The LIKE clause, if present, indicates which database names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

You see only those databases for which you have some kind of privilege, unless you have the global SHOW DATABASES privilege. You can also get this list using the mysqlshow command.

If the server was started with the --skip-show-database option, you cannot use this statement at all unless you have the SHOW DATABASES privilege.

MySQL implements databases as directories in the data directory, so this statement simply lists directories in that location. However, the output may include names of directories that do not correspond to actual databases.

Database information is also available from the INFORMATION_SCHEMA SCHEMATA table. See Section 21.19, “The INFORMATION_SCHEMA SCHEMATA Table”.

---

**Caution**

Because a global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with SHOW DATABASES or by examining the INFORMATION_SCHEMA SCHEMATA table.

### 13.7.5.16 SHOW ENGINE Statement

SHOW ENGINE engine_name {STATUS | MUTEX}
**SHOW Statements**

**SHOW ENGINE** displays operational information about a storage engine. It requires the **PROCESS** privilege. The statement has these variants:

- **SHOW ENGINE INNODB STATUS**
- **SHOW ENGINE INNODB MUTEX**
- **SHOW ENGINE {NDB | NDBCLUSTER} STATUS**
- **SHOW ENGINE PERFORMANCE_SCHEMA STATUS**

**SHOW ENGINE INNODB STATUS** displays extensive information from the standard InnoDB Monitor about the state of the InnoDB storage engine. For information about the standard monitor and other InnoDB Monitors that provide information about InnoDB processing, see Section 14.20, “InnoDB Monitors”.

**SHOW ENGINE INNODB MUTEX** displays InnoDB mutex and rw-lock statistics. Statement output has the following columns:

- **Type**
  - Always InnoDB.

- **Name**
  - The source file where the mutex is implemented, and the line number in the file where the mutex is created. The line number is specific to your version of MySQL.

- **Status**
  - The mutex status. This field displays several values if **UNIV_DEBUG** was defined at MySQL compilation time (for example, in **include/univ.i** in the InnoDB part of the MySQL source tree). If **UNIV_DEBUG** was not defined, the statement displays only the **os_waits** value. In the latter case (without **UNIV_DEBUG**), the information on which the output is based is insufficient to distinguish regular mutexes and mutexes that protect rw-locks (which permit multiple readers or a single writer). Consequently, the output may appear to contain multiple rows for the same mutex.

  - **count** indicates how many times the mutex was requested.
  - **spin_waits** indicates how many times the spinlock had to run.
  - **spin_rounds** indicates the number of spinlock rounds. (**spin_rounds** divided by **spin_waits** provides the average round count.)
  - **os_waits** indicates the number of operating system waits. This occurs when the spinlock did not work (the mutex was not locked during the spinlock and it was necessary to yield to the operating system and wait).
  - **os_yields** indicates the number of times a thread trying to lock a mutex gave up its timeslice and yielded to the operating system (on the presumption that permitting other threads to run will free the mutex so that it can be locked).
  - **os_wait_times** indicates the amount of time (in ms) spent in operating system waits. In MySQL 5.5 timing is disabled and this value is always 0.

**SHOW ENGINE INNODB MUTEX** skips the mutexes and rw-locks of buffer pool blocks, as the amount of output can be overwhelming on systems with a large buffer pool. (There is one mutex and one rw-lock in each 16K buffer pool block, and there are 65,536 blocks per gigabyte.) **SHOW ENGINE INNODB MUTEX** also does not list any mutexes or rw-locks that have never been waited on (**os_waits=0**). Thus, **SHOW ENGINE INNODB MUTEX** only displays information about mutexes and rw-locks outside of the buffer pool that have caused at least one OS-level wait.
SHOW Statements

SHOW ENGINE INNODB_MUTEX information can be used to diagnose system problems. For example, large values of spin_waits and spin_rounds may indicate scalability problems.

Use SHOW ENGINE PERFORMANCE_SCHEMA STATUS to inspect the internal operation of the Performance Schema code:

```
mysql> SHOW ENGINE PERFORMANCE_SCHEMA STATUS\G
```

```
*************************** 3. row ***************************
 Type: performance_schema
 Name: events_waits_history.row_size
 Status: 76

*************************** 4. row ***************************
 Type: performance_schema
 Name: events_waits_history.row_count
 Status: 10000

*************************** 5. row ***************************
 Type: performance_schema
 Name: events_waits_history.memory
 Status: 7'60000

... 

*************************** 57. row ***************************
 Type: performance_schema
 Name: performance_schema.memory
 Status: 2'645'9600

... 
```

This statement is intended to help the DBA understand the effects that different Performance Schema options have on memory requirements.

**Name** values consist of two parts, which name an internal buffer and a buffer attribute, respectively. Interpret buffer names as follows:

- An internal buffer that is not exposed as a table is named within parentheses. Examples: (pfs_cond_class).row_size, (pfs_mutex_class).memory.

- An internal buffer that is exposed as a table in the performance_schema database is named after the table, without parentheses. Examples: events_waits_history.row_size, mutex_instances.row_count.


Buffer attributes have these meanings:

- **row_size** is the size of the internal record used by the implementation, such as the size of a row in a table. row_size values cannot be changed.

- **row_count** is the number of internal records, such as the number of rows in a table. row_count values can be changed using Performance Schema configuration options.

- For a table, tbl_name.memory is the product of row_size and row_count. For the Performance Schema as a whole, performance_schema.memory is the sum of all the memory used (the sum of all other memory values).

In some cases, there is a direct relationship between a Performance Schema configuration parameter and a SHOW ENGINE value. For example, events_waits_history_long.row_count corresponds to performance_schema_events_waits_history_long_size. In other cases, the relationship is more complex. For example, events_waits_history.row_count corresponds to performance_schema_events_waits_history_size (the number of rows per thread) multiplied by performance_schema_max_thread_instances (the number of threads).
If the server has the **NDB** storage engine enabled, **SHOW ENGINE NDB STATUS** displays cluster status information such as the number of connected data nodes, the cluster connectstring, and cluster binary log epochs, as well as counts of various Cluster API objects created by the MySQL Server when connected to the cluster. Sample output from this statement is shown here:

```
mysql> SHOW ENGINE NDB STATUS;
+------------+-----------------------+--------------------------------------------------+
| Type       | Name                  | Status                                           |
+------------+-----------------------+--------------------------------------------------+
| ndbcluster | connection            | cluster_node_id=7, connected_host=198.51.100.103, connected_port=1186, number_of_data_nodes=4, number_of_ready_data_nodes=3, connect_count=0 |
| ndbcluster | NdbTransaction        | created=6, free=0, sizeof=212                   |
| ndbcluster | NdbOperation          | created=8, free=8, sizeof=660                   |
| ndbcluster | NdbIndexScanOperation | created=1, free=1, sizeof=744                   |
| ndbcluster | NdbIndexOperation     | created=0, free=0, sizeof=664                   |
| ndbcluster | NdbRecAttr            | created=1285, free=1285, sizeof=60             |
| ndbcluster | NdbApiSignal          | created=16, free=16, sizeof=136                 |
| ndbcluster | NdbLabel              | created=0, free=0, sizeof=196                   |
| ndbcluster | NdbBranch             | created=0, free=0, sizeof=24                    |
| ndbcluster | NdbSubroutine         | created=0, free=0, sizeof=68                    |
| ndbcluster | NdbCall               | created=0, free=0, sizeof=16                    |
| ndbcluster | NdbBlob               | created=4, free=0, sizeof=68                    |
| ndbcluster | NdbReceiver           | created=4, free=0, sizeof=68                    |
| ndbcluster | binlog                | latest_epoch=155467, latest_trans_epoch=148126, latest_received_binlog_epoch=0, latest_handled_binlog_epoch=0, latest_applied_binlog_epoch=0 |
+------------+-----------------------+--------------------------------------------------+
```

The **Status** column in each of these rows provides information about the MySQL server's connection to the cluster and about the cluster binary log's status, respectively. The **Status** information is in the form of comma-delimited set of name/value pairs.

The **connection** row's **Status** column contains the name/value pairs described in the following table.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>cluster_node_id</td>
<td>The node ID of the MySQL server in the cluster</td>
</tr>
<tr>
<td>connected_host</td>
<td>The host name or IP address of the cluster management server to which the MySQL server is connected</td>
</tr>
<tr>
<td>connected_port</td>
<td>The port used by the MySQL server to connect to the management server (connected_host)</td>
</tr>
<tr>
<td>number_of_data_nodes</td>
<td>The number of data nodes configured for the cluster (that is, the number of [ndbd] sections in the cluster config.ini file)</td>
</tr>
<tr>
<td>number_of_ready_data_nodes</td>
<td>The number of data nodes in the cluster that are actually running</td>
</tr>
<tr>
<td>connect_count</td>
<td>The number of times this mysqld has connected or reconnected to cluster data nodes</td>
</tr>
</tbody>
</table>

The **binlog** row's **Status** column contains information relating to NDB Cluster Replication. The name/value pairs it contains are described in the following table.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>latest_epoch</td>
<td>The most recent epoch most recently run on this MySQL server (that is, the sequence number of the most recent transaction run on the server)</td>
</tr>
</tbody>
</table>
### SHOW Statements

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>latest_trans_epoch</td>
<td>The most recent epoch processed by the cluster's data nodes</td>
</tr>
<tr>
<td>latest_received_binlog_epoch</td>
<td>The most recent epoch received by the binary log thread</td>
</tr>
<tr>
<td>latest_handled_binlog_epoch</td>
<td>The most recent epoch processed by the binary log thread (for writing to the binary log)</td>
</tr>
<tr>
<td>latest_applied_binlog_epoch</td>
<td>The most recent epoch actually written to the binlog</td>
</tr>
</tbody>
</table>

See Section 18.6, "NDB Cluster Replication", for more information.

The remaining rows from the output of `SHOW ENGINE NDB STATUS` which are most likely to prove useful in monitoring the cluster are listed here by **Name**:

- **NdbTransaction**: The number and size of `NdbTransaction` objects that have been created. An `NdbTransaction` is created each time a table schema operation (such as `CREATE TABLE` or `ALTER TABLE`) is performed on an `NDB` table.

- **NdbOperation**: The number and size of `NdbOperation` objects that have been created.

- **NdbIndexScanOperation**: The number and size of `NdbIndexScanOperation` objects that have been created.

- **NdbIndexOperation**: The number and size of `NdbIndexOperation` objects that have been created.

- **NdbRecAttr**: The number and size of `NdbRecAttr` objects that have been created. In general, one of these is created each time a data manipulation statement is performed by an SQL node.

- **NdbBlob**: The number and size of `NdbBlob` objects that have been created. An `NdbBlob` is created for each new operation involving a `BLOB` column in an `NDB` table.

- **NdbReceiver**: The number and size of any `NdbReceiver` object that have been created. The number in the `created` column is the same as the number of data nodes in the cluster to which the MySQL server has connected.

### Note

**SHOW ENGINE NDB STATUS** returns an empty result if no operations involving `NDB` tables have been performed during the current session by the MySQL client accessing the SQL node on which this statement is run.

### 13.7.5.17 SHOW ENGINES Statement

**SHOW [STORAGE] ENGINES**

**SHOW ENGINES** displays status information about the server’s storage engines. This is particularly useful for checking whether a storage engine is supported, or to see what the default engine is.

For information about MySQL storage engines, see Chapter 14, *The InnoDB Storage Engine*, and Chapter 15, *Alternative Storage Engines*.

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
  Engine: FEDERATED
  Support: NO
  Comment: Federated MySQL storage engine
Transactions: NULL
  XA: NULL
Savepoints: NULL
```
**SHOW Statements**

<table>
<thead>
<tr>
<th>Row</th>
<th>Engine</th>
<th>Support</th>
<th>Comment</th>
<th>Transactions</th>
<th>XA</th>
<th>Savepoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>MRG_MYISAM</td>
<td>YES</td>
<td>Collection of identical MyISAM tables</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>MyISAM</td>
<td>YES</td>
<td>MyISAM storage engine</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>4</td>
<td>BLACKHOLE</td>
<td>YES</td>
<td>/dev/null storage engine (anything you write to it disappears)</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>CSV</td>
<td>YES</td>
<td>CSV storage engine</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>MEMORY</td>
<td>YES</td>
<td>Hash based, stored in memory, useful for temporary tables</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>7</td>
<td>ARCHIVE</td>
<td>YES</td>
<td>Archive storage engine</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>8</td>
<td>InnoDB</td>
<td>DEFAULT</td>
<td>Supports transactions, row-level locking, and foreign keys</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>9</td>
<td>PERFORMANCE_SCHEMA</td>
<td>YES</td>
<td>Performance Schema</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

The output from **SHOW ENGINES** may vary according to the MySQL version used and other factors.

**SHOW ENGINES** output has these columns:

- **Engine**
  - The name of the storage engine.
- **Support**
The server's level of support for the storage engine, as shown in the following table.

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>The engine is supported and is active</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>Like YES, plus this is the default engine</td>
</tr>
<tr>
<td>NO</td>
<td>The engine is not supported</td>
</tr>
<tr>
<td>DISABLED</td>
<td>The engine is supported but has been disabled</td>
</tr>
</tbody>
</table>

A value of **NO** means that the server was compiled without support for the engine, so it cannot be enabled at runtime.

A value of **DISABLED** occurs either because the server was started with an option that disables the engine, or because not all options required to enable it were given. In the latter case, the error log should contain a reason indicating why the option is disabled. See Section 5.4.2, “The Error Log”.

You might also see **DISABLED** for a storage engine if the server was compiled to support it, but was started with a **--skip-engine_name** option. For the **NDB** storage engine, **DISABLED** means the server was compiled with support for NDB Cluster, but was not started with the **--ndbcluster** option.

All MySQL servers support **MyISAM** tables. It is not possible to disable **MyISAM**.

- **Comment**
  A brief description of the storage engine.

- **Transactions**
  Whether the storage engine supports transactions.

- **XA**
  Whether the storage engine supports XA transactions.

- **Savepoints**
  Whether the storage engine supports savepoints.

Storage engine information is also available from the **INFORMATION_SCHEMA ENGINES** table. See Section 21.7, “The INFORMATION_SCHEMA ENGINES Table”.

### 13.7.5.18 SHOW ERRORS Statement

```
SHOW ERRORS [LIMIT [offset,] row_count]
SHOW COUNT(*) ERRORS
```

**SHOW ERRORS** is a diagnostic statement that is similar to **SHOW WARNINGS**, except that it displays information only for errors, rather than for errors, warnings, and notes.

The **LIMIT** clause has the same syntax as for the **SELECT** statement. See Section 13.2.9, “SELECT Statement”.

The **SHOW COUNT(*) ERRORS** statement displays the number of errors. You can also retrieve this number from the **error_count** variable:

```
SHOW COUNT(*) ERRORS;
```
SHOW Statements

```sql
SELECT @@error_count;
```

SHOW ERRORS and `error_count` apply only to errors, not warnings or notes. In other respects, they are similar to SHOW WARNINGS and `warning_count`. In particular, SHOW ERRORS cannot display information for more than `max_error_count` messages, and `error_count` can exceed the value of `max_error_count` if the number of errors exceeds `max_error_count`.

For more information, see Section 13.7.5.41, “SHOW WARNINGS Statement”.

### 13.7.5.19 SHOW EVENTS Statement

```sql
SHOW EVENTS
[[FROM | IN] schema_name]
[LIKE 'pattern' | WHERE expr]
```

This statement displays information about Event Manager events, which are discussed in Section 20.4, “Using the Event Scheduler”. It requires the `EVENT` privilege for the database from which the events are to be shown.

In its simplest form, SHOW EVENTS lists all of the events in the current schema:

mysql> SELECT CURRENT_USER(), SCHEMA();
+----------------+----------+
| CURRENT_USER() | SCHEMA() |
+----------------+----------+
| jon@ghidora    | myschema |
+----------------+----------+
1 row in set (0.00 sec)

mysql> SHOW EVENTS\G
*************************** 1. row ***************************
Db: myschema
Name: e_daily
Definer: jon@ghidora
Time zone: SYSTEM
Type: RECURRING
Execute at: NULL
Interval value: 1
Interval field: DAY
Starts: 2018-08-08 11:06:34
Ends: NULL
Status: ENABLED
Originator: 1
character_set_client: utf8
collation_connection: utf8_general_ci
Database Collation: latin1_swedish_ci

To see events for a specific schema, use the `FROM` clause. For example, to see events for the `test` schema, use the following statement:

```sql
SHOW EVENTS FROM test;
```

The `LIKE` clause, if present, indicates which event names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

SHOW EVENTS output has these columns:

- **Db**

  The name of the schema (database) to which the event belongs.
SHOW Statements

• **Name**
  The name of the event.

• **Definer**
  The account of the user who created the event, in `'user_name'@'host_name'` format.

• **Time zone**
  The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is `SYSTEM`.

• **Type**
  The event repetition type, either **ONE TIME** (transient) or **RECURRING** (repeating).

• **Execute At**
  For a one-time event, this is the **DATETIME** value specified in the **AT** clause of the **CREATE EVENT** statement used to create the event, or of the last **ALTER EVENT** statement that modified the event. The value shown in this column reflects the addition or subtraction of any **INTERVAL** value included in the event's **AT** clause. For example, if an event is created using **ON SCHEDULE AT CURRENT_TIMESTAMP + '1:6' DAY_HOUR**, and the event was created at 2018-02-09 14:05:30, the value shown in this column would be `'2018-02-10 20:05:30'`. If the event's timing is determined by a **EVERY** clause instead of an **AT** clause (that is, if the event is recurring), the value of this column is **NULL**.

• **Interval Value**
  For a recurring event, the number of intervals to wait between event executions. For a transient event, the value of this column is always **NULL**.

• **Interval Field**
  The time units used for the interval which a recurring event waits before repeating. For a transient event, the value of this column is always **NULL**.

• **Starts**
  The start date and time for a recurring event. This is displayed as a **DATETIME** value, and is **NULL** if no start date and time are defined for the event. For a transient event, this column is always **NULL**. For a recurring event whose definition includes a **STARTS** clause, this column contains the corresponding **DATETIME** value. As with the **Execute At** column, this value resolves any expressions used. If there is no **STARTS** clause affecting the timing of the event, this column is **NULL**.

• **Ends**
  For a recurring event whose definition includes a **ENDS** clause, this column contains the corresponding **DATETIME** value. As with the **Execute At** column, this value resolves any expressions used. If there is no **ENDS** clause affecting the timing of the event, this column is **NULL**.

• **Status**
  The event status. One of **ENABLED**, **DISABLED**, or **SLAVESIDE_DISABLED**. **SLAVESIDE_DISABLED** indicates that the creation of the event occurred on another MySQL server acting as a replication master and replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave. For more information, see Section 17.4.1.15, "Replication of Invoked Features". information.
• **Originator**
  
  The server ID of the MySQL server on which the event was created; used in replication. The default value is 0.

• **character_set_client**
  
  The session value of the `character_set_client` system variable when the event was created.

• **collation_connection**
  
  The session value of the `collation_connection` system variable when the event was created.

• **Database Collation**
  
  The collation of the database with which the event is associated.

For more information about `SLAVESIDE_DISABLED` and the `Originator` column, see Section 17.4.1.15, “Replication of Invoked Features”.

Times displayed by `SHOW EVENTS` are given in the event time zone, as discussed in Section 20.4.4, “Event Metadata”.

Event information is also available from the `INFORMATION_SCHEMA EVENTS` table. See Section 21.8, “The `INFORMATION_SCHEMA EVENTS` Table”.

The event action statement is not shown in the output of `SHOW EVENTS`. Use `SHOW CREATE EVENT` or the `INFORMATION_SCHEMA EVENTS` table.

### 13.7.5.20 SHOW FUNCTION CODE Statement

```
SHOW FUNCTION CODE func_name
```

This statement is similar to `SHOW PROCEDURE CODE` but for stored functions. See Section 13.7.5.28, “SHOW PROCEDURE CODE Statement”.

### 13.7.5.21 SHOW FUNCTION STATUS Statement

```
SHOW FUNCTION STATUS
[LIKE 'pattern' | WHERE expr]
```

This statement is similar to `SHOW PROCEDURE STATUS` but for stored functions. See Section 13.7.5.29, “SHOW PROCEDURE STATUS Statement”.

### 13.7.5.22 SHOW GRANTS Statement

```
SHOW GRANTS [FOR user]
```

This statement displays the privileges that are assigned to a MySQL user account, in the form of `GRANT` statements that must be executed to duplicate the privilege assignments.

`SHOW GRANTS` requires the `SELECT` privilege for the `mysql` system database, except to display privileges for the current user. For output that includes an `IDENTIFIED BY PASSWORD` clause displaying an account password hash value, the `SUPER` privilege is required to see the actual hash value. Otherwise, the value displays as `<secret>`.

To name the account for `SHOW GRANTS`, use the same format as for the `GRANT` statement (for example, `'jeffrey'@'localhost'`):

```
mysql> SHOW GRANTS FOR 'jeffrey'@'localhost';
```
SHOW Statements

<table>
<thead>
<tr>
<th>Grants for jeffrey@localhost</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRANT USAGE ON <em>.</em> TO <code>jeffrey</code>@<code>localhost</code></td>
</tr>
<tr>
<td>GRANT SELECT, INSERT, UPDATE ON <code>db1</code>.* TO <code>jeffrey</code>@<code>localhost</code></td>
</tr>
</tbody>
</table>

The host part, if omitted, defaults to '%'. For additional information about specifying account names, see Section 6.2.4, “Specifying Account Names”.

To display the privileges granted to the current user (the account you are using to connect to the server), you can use any of the following statements:

SHOW GRANTS;
SHOW GRANTS FOR CURRENT_USER;
SHOW GRANTS FOR CURRENT_USER();

If SHOW GRANTS FOR CURRENT_USER (or any equivalent syntax) is used in definer context, such as within a stored procedure that executes with definer rather than invoker privileges, the grants displayed are those of the definer and not the invoker.

SHOW GRANTS does not display privileges that are available to the named account but are granted to a different account. For example, if an anonymous account exists, the named account might be able to use its privileges, but SHOW GRANTS does not display them.

13.7.5.23 SHOW INDEX Statement

SHOW {INDEX | INDEXES | KEYS}
{FROM | IN} tbl_name
[{{FROM | IN} db_name}
[WHERE expr]

SHOW INDEX returns table index information. The format resembles that of the SQLStatistics call in ODBC. This statement requires some privilege for any column in the table.

mysql> SHOW INDEX FROM City\G
*************************** 1. row ***************************
Table: city
  Non_unique: 0
  Key_name: PRIMARY
  Seq_in_index: 1
  Column_name: ID
  Collation: A
  Cardinality: 4321
  Sub_part: NULL
  Packed: NULL
  Null: 0
  Index_type: BTREE
  Comment: 
Index_comment: 
*************************** 2. row ***************************
Table: city
  Non_unique: 1
  Key_name: CountryCode
  Seq_in_index: 1
  Column_name: CountryCode
  Collation: A
  Cardinality: 4321
  Sub_part: NULL
  Packed: NULL
  Null: 0
  Index_type: BTREE
  Comment: 

SHOW Statements

Index_comment:

An alternative to `tbl_name` FROM `db_name` syntax is `db_name.tbl_name`. These two statements are equivalent:

```
SHOW INDEX FROM mytable FROM mydb;
SHOW INDEX FROM mydb.mytable;
```

The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

SHOW INDEX returns the following fields:

- **Table**
  The name of the table.

- **Non_unique**
  0 if the index cannot contain duplicates, 1 if it can.

- **Key_name**
  The name of the index. If the index is the primary key, the name is always PRIMARY.

- **Seq_in_index**
  The column sequence number in the index, starting with 1.

- **Column_name**
  The name of the column.

- **Collation**
  How the column is sorted in the index. This can have values A (ascending) or NULL (not sorted).

- **Cardinality**
  An estimate of the number of unique values in the index. To update this number, run ANALYZE TABLE or (for MyISAM tables) myisamchk -a.

  Cardinality is counted based on statistics stored as integers, so the value is not necessarily exact even for small tables. The higher the cardinality, the greater the chance that MySQL uses the index when doing joins.

- **Sub_part**
  The index prefix. That is, the number of indexed characters if the column is only partly indexed, NULL if the entire column is indexed.

**Note**

Prefix limits are measured in bytes. However, prefix lengths for index specifications in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements are interpreted as number of characters for nonbinary string types (CHAR, VARCHAR, TEXT) and number of bytes for binary string types (BINARY, VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.
SHOW Statements

For additional information about index prefixes, see Section 8.3.4, “Column Indexes”, and Section 13.1.13, “CREATE INDEX Statement”.

- **Packed**
  Indicates how the key is packed. NULL if it is not.

- **Null**
  Contains YES if the column may contain NULL values and '' if not.

- **Index_type**
  The index method used (BTREE, FULLTEXT, HASH, RTREE).

- **Comment**
  Information about the index not described in its own column, such as disabled if the index is disabled.

- **Index_comment**
  Any comment provided for the index with a COMMENT attribute when the index was created.

Information about table indexes is also available from the INFORMATION_SCHEMA STATISTICS table. See Section 21.21, “The INFORMATION_SCHEMA STATISTICS Table”.

You can list a table’s indexes with the mysqlshow -k db_name tbl_name command.

### 13.7.5.24 SHOW MASTER STATUS Statement

SHOW MASTER STATUS

This statement provides status information about the binary log files of the master. It requires either the SUPER or REPLICATION CLIENT privilege.

Example:

```sql
mysql> SHOW MASTER STATUS;
+---------------+----------+--------------+------------------+
| File          | Position | Binlog_Do_DB | Binlog_Ignore_DB |
+---------------+----------+--------------+------------------+
| mysql-bin.003 | 73       | test         | manual,mysql     |
+---------------+----------+--------------+------------------+
```

### 13.7.5.25 SHOW OPEN TABLES Statement

SHOW OPEN TABLES

SHOW OPEN TABLES lists the non-TEMPORARY tables that are currently open in the table cache. See Section 8.4.3.1, “How MySQL Opens and Closes Tables”. The FROM clause, if present, restricts the tables shown to those present in the db_name database. The LIKE clause, if present, indicates which table names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

SHOW OPEN TABLES output has these columns:

- **Database**
SHOW Statements

The database containing the table.

- **Table**
  The table name.

- **In_use**
  The number of table locks or lock requests there are for the table. For example, if one client acquires a lock for a table using `LOCK TABLE t1 WRITE`, `In_use` will be 1. If another client issues `LOCK TABLE t1 WRITE` while the table remains locked, the client will block waiting for the lock, but the lock request causes `In_use` to be 2. If the count is zero, the table is open but not currently being used. `In_use` is also increased by the `HANDLER ... OPEN` statement and decreased by `HANDLER ... CLOSE`.

- **Name_locked**
  Whether the table name is locked. Name locking is used for operations such as dropping or renaming tables.

If you have no privileges for a table, it does not show up in the output from `SHOW OPEN TABLES`.

13.7.5.26 SHOW PLUGINS Statement

`SHOW PLUGINS` displays information about server plugins.

Example of `SHOW PLUGINS` output:

```sql
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
Name: binlog
Status: ACTIVE
Type: STORAGE ENGINE
Library: NULL
License: GPL

*************************** 2. row ***************************
Name: CSV
Status: ACTIVE
Type: STORAGE ENGINE
Library: NULL
License: GPL

*************************** 3. row ***************************
Name: MEMORY
Status: ACTIVE
Type: STORAGE ENGINE
Library: NULL
License: GPL

*************************** 4. row ***************************
Name: MyISAM
Status: ACTIVE
Type: STORAGE ENGINE
Library: NULL
License: GPL
...
```

`SHOW PLUGINS` output has these columns:

- **Name**
  The name used to refer to the plugin in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`. 
SHOW Statements

• **Status**
  The plugin status, one of **ACTIVE, INACTIVE, DISABLED, or DELETED**.

• **Type**
  The type of plugin, such as **STORAGE ENGINE, INFORMATION_SCHEMA, or AUTHENTICATION**.

• **Library**
  The name of the plugin shared library file. This is the name used to refer to the plugin file in statements such as **INSTALL PLUGIN** and **UNINSTALL PLUGIN**. This file is located in the directory named by the **plugin_dir** system variable. If the library name is **NULL**, the plugin is compiled in and cannot be uninstalled with **UNINSTALL PLUGIN**.

• **License**
  How the plugin is licensed (for example, **GPL**).

For plugins installed with **INSTALL PLUGIN**, the **Name** and **Library** values are also registered in the **mysql.plugin** system table.

For information about plugin data structures that form the basis of the information displayed by **SHOW PLUGINS**, see **Section 24.2, “The MySQL Plugin API”**.

Plugin information is also available from the **INFORMATION_SCHEMA.PLUGINS** table. See **Section 21.14, “The INFORMATION_SCHEMA PLUGINS Table”**.

**13.7.5.27 SHOW PRIVILEGES Statement**

**SHOW PRIVILEGES**

**SHOW PRIVILEGES** shows the list of system privileges that the MySQL server supports. The exact list of privileges depends on the version of your server.

```plaintext
mysql> SHOW PRIVILEGES
+-----------------+-----------------+-----------------+-----------------+-------------------+-------------------+-------------------+-------------------+-------------------+
| Privilege        | Context         | Comment         |
|------------------|-----------------|-----------------|-----------------|-------------------|-------------------|-------------------|-------------------|
| Alter            | Tables          | To alter the table |
| Alter routine    | Functions,Procedures | To alter or drop stored functions/procedures |
| Create           | Databases,Tables,Indexes | To create new databases and tables |
| Create routine   | Databases       | To use CREATE FUNCTION/PROCEDURE |
| Create temporary tables | Databases | To use CREATE TEMPORARY TABLE |
...```

Privileges belonging to a specific user are displayed by the **SHOW GRANTS** statement. See **Section 13.7.5.22, “SHOW GRANTS Statement”,** for more information.

**13.7.5.28 SHOW PROCEDURE CODE Statement**
SHOW PROCEDURE CODE proc_name

This statement is a MySQL extension that is available only for servers that have been built with debugging support. It displays a representation of the internal implementation of the named stored procedure. A similar statement, SHOW FUNCTION CODE, displays information about stored functions (see Section 13.7.5.20, “SHOW FUNCTION CODE Statement”).

To use either statement, you must be the owner of the routine or have SELECT access to the mysql.proc table.

If the named routine is available, each statement produces a result set. Each row in the result set corresponds to one “instruction” in the routine. The first column is Pos, which is an ordinal number beginning with 0. The second column is Instruction, which contains an SQL statement (usually changed from the original source), or a directive which has meaning only to the stored-routine handler.

```
mysql> DELIMITER //
mysql> CREATE PROCEDURE p1 ()
    -> BEGIN
    -> DECLARE fanta INT DEFAULT 55;
    -> DROP TABLE t2;
    -> LOOP
    -> INSERT INTO t3 VALUES (fanta);
    -> END LOOP;
    -> END //
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SHOW PROCEDURE CODE p1 //
+-----+----------------------------------------+
| Pos | Instruction                            |
+-----+----------------------------------------+
|   0 | set fanta@0 55                         |
|   1 | stmt 9 "DROP TABLE t2"                 |
|   2 | stmt 5 "INSERT INTO t3 VALUES (fanta)" |
|   3 | jump 2                                 |
+-----+----------------------------------------+
4 rows in set (0.00 sec)
```

In this example, the nonexecutable BEGIN and END statements have disappeared, and for the DECLARE variable_name statement, only the executable part appears (the part where the default is assigned). For each statement that is taken from source, there is a code word stmt followed by a type (9 means DROP, 5 means INSERT, and so on). The final row contains an instruction jump 2, meaning GOTO instruction #2.

13.7.5.29 SHOW PROCEDURE STATUS Statement

```
SHOW PROCEDURE STATUS
    [LIKE 'pattern' | WHERE expr]
```

This statement is a MySQL extension. It returns characteristics of a stored procedure, such as the database, name, type, creator, creation and modification dates, and character set information. A similar statement, SHOW FUNCTION STATUS, displays information about stored functions (see Section 13.7.5.21, “SHOW FUNCTION STATUS Statement”).

The LIKE clause, if present, indicates which procedure or function names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

```
mysql> SHOW PROCEDURE STATUS LIKE 'sp1' \G
*************************** 1. row ***************************
  Db: test
  Name: sp1
  Type: PROCEDURE
```

1660
SHOW Statements

---

character_set_client is the session value of the character_set_client system variable when the routine was created. collation_connection is the session value of the collation_connection system variable when the routine was created. Database Collation is the collation of the database with which the routine is associated.

Stored routine information is also available from the INFORMATION_SCHEMA PARAMETERS and ROUTINES tables. See Section 21.12, “The INFORMATION_SCHEMA PARAMETERS Table”, and Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”.

13.7.5.30 SHOW PROCESSLIST Statement

SHOW [FULL] PROCESSLIST

SHOW PROCESSLIST shows which threads are running. If you have the PROCESS privilege, you can see all threads. Otherwise, you can see only your own threads (that is, threads associated with the MySQL account that you are using). If you do not use the FULL keyword, only the first 100 characters of each statement are shown in the Info field.

The SHOW PROCESSLIST statement is very useful if you get the “too many connections” error message and want to find out what is going on. MySQL reserves one extra connection to be used by accounts that have the SUPER privilege, to ensure that administrators should always be able to connect and check the system (assuming that you are not giving this privilege to all your users).

Threads can be killed with the KILL statement. See Section 13.7.6.4, “KILL Statement”.

Example of SHOW PROCESSLIST output:

```sql
mysql> SHOW FULL PROCESSLIST\G
*************************** 1. row ***************************
Id: 1
User: system user
Host: 
db: NULL
Command: Connect
Time: 1030455
State: Waiting for master to send event
Info: NULL
*************************** 2. row ***************************
Id: 2
User: system user
Host: 
db: NULL
Command: Connect
Time: 1004
State: Has read all relay log; waiting for the slave I/O thread to update it
Info: NULL
*************************** 3. row ***************************
Id: 3112
User: replikator
Host: artemis:2204
db: NULL
Command: Binlog Dump
Time: 2144
```
SHOW Statements

State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 4. row ***************************
Id: 3113
User: replikator
Host:'iconnect2:45781'
db: NULL
Command: Binlog Dump
Time: 2086
State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 5. row ***************************
Id: 3123
User: stefan
Host: localhost
db: apollon
Command: Query
Time: 0
State: NULL
Info: SHOW FULL PROCESSLIST
5 rows in set (0.00 sec)

SHOW PROCESSLIST output has these columns:

• **Id**
  The connection identifier. This is the same type of value displayed in the **Id** column of the INFORMATION_SCHEMA.PROCESSLIST table and returned by the CONNECTION_ID() function.

• **User**
  The MySQL user who issued the statement. A value of **system user** refers to a nonclient thread spawned by the server to handle tasks internally. This could be the I/O or SQL thread used on replication slaves or a delayed-row handler. For **system user**, there is no host specified in the **Host** column. **unauthenticated user** refers to a thread that has become associated with a client connection but for which authentication of the client user has not yet been done. **event_scheduler** refers to the thread that monitors scheduled events (see Section 20.4, “Using the Event Scheduler”).

• **Host**
  The host name of the client issuing the statement (except for **system user**, for which there is no host). The host name for TCP/IP connections is reported in **host_name:client_port** format to make it easier to determine which client is doing what.

• **db**
  The default database, if one is selected; otherwise **NULL**.

• **Command**
  The type of command the thread is executing. For descriptions for thread commands, see Section 8.14, “Examining Thread Information”. The value of this column corresponds to the **COM_*** commands of the client/server protocol and **Com_*** status variables. See Section 5.1.9, “Server Status Variables”.

• **Time**
  The time in seconds that the thread has been in its current state. For a slave SQL thread, the value is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. See Section 17.2.1, “Replication Implementation Details”.

• **State**
SHOW Statements

An action, event, or state that indicates what the thread is doing. Descriptions for State values can be found at Section 8.14, “Examining Thread Information”.

Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

For the SHOW PROCESSLIST statement, the value of State is NULL.

• Info

The statement the thread is executing, or NULL if it is not executing any statement. The statement might be the one sent to the server, or an innermost statement if the statement executes other statements. For example, if a CALL statement executes a stored procedure that is executing a SELECT statement, the Info value shows the SELECT statement.

Process information is also available from the mysqladmin processlist command and the INFORMATION_SCHEMA PROCESSLIST table (see Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server” and Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”).

13.7.5.31 SHOW PROFILE Statement

SHOW PROFILE [type [, type] ... ]
[FOR QUERY n]
[LIMIT row_count [OFFSET offset]]

type: {
   ALL
   | BLOCK IO
   | CONTEXT SWITCHES
   | CPU
   | IPC
   | MEMORY
   | PAGE FAULTS
   | SOURCE
   | SWAPS
}

The SHOW PROFILE and SHOW PROFILES statements display profiling information that indicates resource usage for statements executed during the course of the current session.

To control profiling, use the profiling session variable, which has a default value of 0 (OFF). Enable profiling by setting profiling to 1 or ON:

mysql> SET profiling = 1;

SHOW PROFILES displays a list of the most recent statements sent to the server. The size of the list is controlled by the profiling_history_size session variable, which has a default value of 15. The maximum value is 100. Setting the value to 0 has the practical effect of disabling profiling.

All statements are profiled except SHOW PROFILE and SHOW PROFILES, so you will find neither of those statements in the profile list. Malformed statements are profiled. For example, SHOW PROFILING is an illegal statement, and a syntax error occurs if you try to execute it, but it will show up in the profiling list.

SHOW PROFILE displays detailed information about a single statement. Without the FOR QUERY n clause, the output pertains to the most recently executed statement. If FOR QUERY n is included, SHOW PROFILE displays information for statement n. The values of n correspond to the Query_ID values displayed by SHOW PROFILES.

The LIMIT row_count clause may be given to limit the output to row_count rows. If LIMIT is given, OFFSET offset may be added to begin the output offset rows into the full set of rows.
By default, `SHOW PROFILE` displays `Status` and `Duration` columns. The `Status` values are like the `State` values displayed by `SHOW PROCESSLIST`, although there might be some minor differences in interpretation for the two statements for some status values (see Section 8.14, “Examining Thread Information”).

Optional `type` values may be specified to display specific additional types of information:

- **ALL** displays all information
- **BLOCK IO** displays counts for block input and output operations
- **CONTEXT SWITCHES** displays counts for voluntary and involuntary context switches
- **CPU** displays user and system CPU usage times
- **IPC** displays counts for messages sent and received
- **MEMORY** is not currently implemented
- **PAGE FAULTS** displays counts for major and minor page faults
- **SOURCE** displays the names of functions from the source code, together with the name and line number of the file in which the function occurs
- **SWAPS** displays swap counts

Profiling is enabled per session. When a session ends, its profiling information is lost.

```
mysql> SELECT @@profiling;
+-------------+
| @@profiling |
+-------------+
|           0 |
+-------------+
1 row in set (0.00 sec)

mysql> SET profiling = 1;
Query OK, 0 rows affected (0.00 sec)

mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> CREATE TABLE t1 (id INT);
Query OK, 0 rows affected (0.01 sec)

mysql> SHOW PROFILES;
+----------+----------+--------------------------+
<table>
<thead>
<tr>
<th>Query_ID</th>
<th>Duration</th>
<th>Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.000088</td>
<td>SET PROFILING = 1</td>
</tr>
<tr>
<td>1</td>
<td>0.000136</td>
<td>DROP TABLE IF EXISTS t1</td>
</tr>
<tr>
<td>2</td>
<td>0.011947</td>
<td>CREATE TABLE t1 (id INT)</td>
</tr>
</tbody>
</table>
+----------+----------+--------------------------+
3 rows in set (0.00 sec)

mysql> SHOW PROFILE;
+----------------------+----------+
<table>
<thead>
<tr>
<th>Status</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>checking permissions</td>
<td>0.000040</td>
</tr>
<tr>
<td>creating table</td>
<td>0.000056</td>
</tr>
<tr>
<td>After create</td>
<td>0.011363</td>
</tr>
<tr>
<td>query end</td>
<td>0.000375</td>
</tr>
</tbody>
</table>
```
SHOW Statements

| freeing items        | 0.000089 |
| logging slow query   | 0.000019 |
| cleaning up          | 0.000005 |
+----------------------+----------+
7 rows in set (0.00 sec)

mysql> SHOW PROFILE FOR QUERY 1;
+--------------------+----------+
| Status             | Duration |
+--------------------+----------+
| query end          | 0.000107 |
| freeing items      | 0.000008 |
| logging slow query | 0.000015 |
| cleaning up        | 0.000006 |
+--------------------+----------+
4 rows in set (0.00 sec)

mysql> SHOW PROFILE FOR QUERY 2;
+--------------------+----------+----------+------------+
| Status               | Duration | CPU_user | CPU_system |
+--------------------+----------+----------+------------+
| checking permissions | 0.000040 | 0.000038 |   0.000002 |
| creating table       | 0.000056 | 0.000028 |   0.000028 |
| After create         | 0.011363 | 0.000217 |   0.001571 |
| query end            | 0.000375 | 0.000013 |   0.000028 |
| freeing items        | 0.000089 | 0.000010 |   0.000014 |
| logging slow query   | 0.000019 | 0.000009 |   0.000010 |
| cleaning up          | 0.000005 | 0.000003 |   0.000002 |
+--------------------+----------+----------+------------+
7 rows in set (0.00 sec)

Note
Profiling is only partially functional on some architectures. For values that depend on the `getrusage()` system call, `NULL` is returned on systems such as Windows that do not support the call. In addition, profiling is per process and not per thread. This means that activity on threads within the server other than your own may affect the timing information that you see.

Profiling information is also available from the `INFORMATION_SCHEMA.PROFILING` table. See Section 21.16, “The INFORMATION_SCHEMA PROFILING Table”. For example, the following queries are equivalent:

SHOW PROFILE FOR QUERY 2;

SELECT STATE, FORMAT(DURATION, 6) AS DURATION
FROM INFORMATION_SCHEMA.PROFILING
WHERE QUERY_ID = 2 ORDER BY SEQ;

13.7.5.32 SHOW PROFILES Statement

SHOW PROFILES

The `SHOW PROFILES` statement, together with `SHOW PROFILE`, displays profiling information that indicates resource usage for statements executed during the course of the current session. For more information, see Section 13.7.5.31, “SHOW PROFILE Statement”.

13.7.5.33 SHOW RELAYLOG EVENTS Statement

SHOW RELAYLOG EVENTS
  [IN 'log_name']
  [FROM pos]
  [LIMIT [offset,] row_count]
SHOW Statements

Shows the events in the relay log of a replication slave. If you do not specify `log_name`, the first relay log is displayed. This statement has no effect on the master.

The `LIMIT` clause has the same syntax as for the `SELECT` statement. See Section 13.2.9, “SELECT Statement”.

Note
Issuing a `SHOW RELAYLOG EVENTS` with no `LIMIT` clause could start a very time- and resource-consuming process because the server returns to the client the complete contents of the relay log (including all statements modifying data that have been received by the slave).

`SHOW RELAYLOG EVENTS` displays the following fields for each event in the relay log:

- **Log_name**
  The name of the file that is being listed.

- **Pos**
  The position at which the event occurs.

- **Event_type**
  An identifier that describes the event type.

- **Server_id**
  The server ID of the server on which the event originated.

- **End_log_pos**
  The value of `End_log_pos` for this event in the master's binary log.

- **Info**
  More detailed information about the event type. The format of this information depends on the event type.

Note
Some events relating to the setting of user and system variables are not included in the output from `SHOW RELAYLOG EVENTS`. To get complete coverage of events within a relay log, use `mysqlbinlog`.

13.7.5.34 SHOW SLAVE HOSTS Statement

`SHOW SLAVE HOSTS` displays a list of replication slaves currently registered with the master.

`SHOW SLAVE HOSTS` should be executed on a server that acts as a replication master. The statement displays information about servers that are or have been connected as replication slaves, with each row of the result corresponding to one slave server, as shown here:

```
mysql> SHOW SLAVE HOSTS;
+------------+-----------+------+-----------+
<table>
<thead>
<tr>
<th>Server_id</th>
<th>Host</th>
<th>Port</th>
<th>Master_id</th>
</tr>
</thead>
</table>
+------------+-----------+------+-----------+
```
### SHOW Statements

<table>
<thead>
<tr>
<th>192168010</th>
<th>iconnect2</th>
<th>3306</th>
<th>192168011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921680101</td>
<td>athena</td>
<td>3306</td>
<td>192168011</td>
</tr>
</tbody>
</table>

- **Server_id**: The unique server ID of the slave server, as configured in the slave server's option file, or on the command line with `--server-id=value`.

- **Host**: The host name of the slave server as specified on the slave with the `--report-host` option. This can differ from the machine name as configured in the operating system.

- **User**: The slave server user name as specified on the slave with the `--report-user` option. Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.

- **Password**: The slave server password as specified on the slave with the `--report-password` option. Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.

- **Port**: The port on the master to which the slave server is listening, as specified on the slave with the `--report-port` option.

In MySQL 5.5.23 and later, a zero in this column means that the slave port (`--report-port`) was not set. Prior to MySQL 5.5.23, 3306 was used as the default in such cases (Bug #13333431).

- **Master_id**: The unique server ID of the master server that the slave server is replicating from. This is the server ID of the server on which `SHOW SLAVE HOSTS` is executed, so this same value is listed for each row in the result.

### 13.7.5.35 SHOW SLAVE STATUS Statement

#### SHOW SLAVE STATUS

This statement provides status information on essential parameters of the slave threads. It requires either the SUPER or REPLICATION CLIENT privilege.

If you issue this statement using the `mysql` client, you can use a `\G` statement terminator rather than a semicolon to obtain a more readable vertical layout:

```sql
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
  Slave_IO_State: Waiting for master to send event
  Master_Host: localhost
  Master_User: root
  Master_Port: 3306
  Connect_Retry: 3
  Master_Log_File: gbichot-bin.005
  Read_Master_Log_Pos: 79
  Relay_Log_File: gbichot-relay-bin.005
  Relay_Log_Pos: 548
  Relay_Master_Log_File: gbichot-bin.005
  Slave_IO_Running: Yes
  Slave_SQL_Running: Yes
  Replicate_Do_DB:
  Replicate_Ignore_DB:
  Replicate_Do_Table:
  Replicate_Ignore_Table:
  Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
  Last_Errno: 0
  Last_Error:
  Skip_Counter: 0
  Exec_Master_Log_Pos: 79
```
SHOW Statements

The following list describes the fields returned by `SHOW SLAVE STATUS`. For additional information about interpreting their meanings, see Section 8.14.6, “Replication Slave I/O Thread States”.

- **Slave_IO_State**

  A copy of the `State` field of the `SHOW PROCESSLIST` output for the slave I/O thread. This tells you what the thread is doing: trying to connect to the master, waiting for events from the master, reconnecting to the master, and so on. For a listing of possible states, see Section 8.14.6, “Replication Slave I/O Thread States”.

- **Master_Host**

  The master host that the slave is connected to.

- **Master_User**

  The user name of the account used to connect to the master.

- **Master_Port**

  The port used to connect to the master.

- **Connect_Retry**

  The number of seconds between connect retries (default 60). This can be set with the `CHANGE MASTER TO` statement.

- **Master_Log_File**

  The name of the master binary log file from which the I/O thread is currently reading.

- **Read_Master_Log_Pos**

  The position in the current master binary log file up to which the I/O thread has read.

- **Relay_Log_File**

  The name of the relay log file from which the SQL thread is currently reading and executing.

- **Relay_Log_Pos**

  The position in the current relay log file up to which the SQL thread has read and executed.

- **Relay_Log_Space**

- **Until_Condition**

- **Until_Log_File**

- **Until_Log_Pos**

- **Master_SSL_Allowed**

- **Master_SSL_CA_File**

- **Master_SSL_CA_Path**

- **Master_SSL_Cert**

- **Master_SSL_Cipher**

- **Master_SSL_Key**

- **Seconds_Behind_Master**

- **Master_SSL_Verify_Server_Cert**

- **Last_IO_Errno**

- **Last_IO_Error**

- **Last_SQL_Errno**

- **Last_SQL_Error**

- **Replicate_Ignore_Server_Ids**

- **Master_Server_Id**
• **Relay_Master_Log_File**

The name of the master binary log file containing the most recent event executed by the SQL thread.

• **Slave_IO_Running**

Whether the I/O thread is started and has connected successfully to the master. Internally, the state of this thread is represented by one of the following three values:

- **MYSQL_SLAVE_NOT_RUN.** The slave I/O thread is not running. For this state, `Slave_IO_Running` is `No`.

- **MYSQL_SLAVE_RUN_NOT_CONNECT.** The slave I/O thread is running, but is not connected to a replication master. For this state, `Slave_IO_Running` is `Connecting`.

- **MYSQL_SLAVE_RUN_CONNECT.** The slave I/O thread is running, and is connected to a replication master. For this state, `Slave_IO_Running` is `Yes`.

The value of the `Slave_running` system status variable corresponds with this value.

• **Slave_SQL_Running**

Whether the SQL thread is started.

• **Replicate_Do_DB, Replicate_Ignore_DB**

The lists of databases that were specified with the `--replicate-do-db` and `--replicate-ignore-db` options, if any.

• **Replicate_Do_Table, Replicate_Ignore_Table, Replicate_Wild_Do_Table, Replicate_Wild_Ignore_Table**

The lists of tables that were specified with the `--replicate-do-table`, `--replicate-ignore-table`, `--replicate-wild-do-table`, and `--replicate-wild-ignore-table` options, if any.

• **Last_Errno, Last_Error**

These columns are aliases for `Last_SQL_Errno` and `Last_SQL_Error`.

Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns.

**Note**

When the slave SQL thread receives an error, it reports the error first, then stops the SQL thread. This means that there is a small window of time during which `SHOW SLAVE STATUS` shows a nonzero value for `Last_SQL_Errno` even though `Slave_SQL_Running` still displays `Yes`.

• **Skip_Counter**

The current value of the `sql_slave_skip_counter` system variable. See Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Statement”.

• **Exec_Master_Log_Pos**

The position in the current master binary log file to which the SQL thread has read and executed, marking the start of the next transaction or event to be processed. You can use this value with the `CHANGE MASTER TO` statement's `MASTER_LOG_POS` option when starting a new slave.
from an existing slave, so that the new slave reads from this point. The coordinates given by
(\texttt{Relay\_Master\_Log\_File, Exec\_Master\_Log\_Pos}) in the master's binary log correspond to the
coordinates given by (\texttt{Relay\_Log\_File, Relay\_Log\_Pos}) in the relay log.

- \texttt{Relay\_Log\_Space}
  The total combined size of all existing relay log files.

- \texttt{Until\_Condition, Until\_Log\_File, Until\_Log\_Pos}
  The values specified in the \texttt{UNTIL} clause of the \texttt{START SLAVE} statement.

  \texttt{Until\_Condition} has these values:
  - \texttt{None} if no \texttt{UNTIL} clause was specified
  - \texttt{Master} if the slave is reading until a given position in the master's binary log
  - \texttt{Relay} if the slave is reading until a given position in its relay log

  \texttt{Until\_Log\_File} and \texttt{Until\_Log\_Pos} indicate the log file name and position that define the
coordinates at which the SQL thread stops executing.

- \texttt{Master\_SSL\_Allowed, Master\_SSL\_CA\_File, Master\_SSL\_CA\_Path, Master\_SSL\_Cert,}
  \texttt{Master\_SSL\_Cipher, Master\_SSL\_Key, Master\_SSL\_Verify\_Server\_Cert}

  These fields show the SSL parameters used by the slave to connect to the master, if any.

  \texttt{Master\_SSL\_Allowed} has these values:
  - \texttt{Yes} if an SSL connection to the master is permitted
  - \texttt{No} if an SSL connection to the master is not permitted
  - \texttt{Ignored} if an SSL connection is permitted but the slave server does not have SSL support enabled

  The values of the other SSL-related fields correspond to the values of the \texttt{MASTER\_SSL\_CA,}
  \texttt{MASTER\_SSL\_CAPATH, MASTER\_SSL\_CERT, MASTER\_SSL\_CIPHER, MASTER\_SSL\_KEY, and}
  \texttt{MASTER\_SSL\_VERIFY\_SERVER\_CERT} options to the \texttt{CHANGE MASTER TO} statement. See
  Section 13.4.2.1, "CHANGE MASTER TO Statement".

- \texttt{Seconds\_Behind\_Master}
  This field is an indication of how “late” the slave is:
  - When the slave is actively processing updates, this field shows the difference between the current
timestamp on the slave and the original timestamp logged on the master for the event currently being
processed on the slave.
  - When no event is currently being processed on the slave, this value is 0.

In essence, this field measures the time difference in seconds between the slave SQL thread and the
slave I/O thread. If the network connection between master and slave is fast, the slave I/O thread is very
close to the master, so this field is a good approximation of how late the slave SQL thread is compared
to the master. If the network is slow, this is \textit{not} a good approximation; the slave SQL thread may quite
often be caught up with the slow-reading slave I/O thread, so \texttt{Seconds\_Behind\_Master} often shows
a value of 0, even if the I/O thread is late compared to the master. In other words, \textit{this column is useful only for fast networks}. 

1670
SHOW Statements

This time difference computation works even if the master and slave do not have identical clock times, provided that the difference, computed when the slave I/O thread starts, remains constant from then on. Any changes—including NTP updates—can lead to clock skews that can make calculation of Seconds_Behind_Master less reliable.

This field is **NULL** (undefined or unknown) if the slave SQL thread is not running, or if the slave I/O thread is not running or is not connected to the master. For example, if the slave I/O thread is running but is not connected to the master and is sleeping for the number of seconds given by the CHANGE MASTER TO statement or --master-connect-retry option (default 60) before reconnecting, the value is **NULL**. This is because the slave cannot know what the master is doing, and so cannot say reliably how late it is.

The value of Seconds_Behind_Master is based on the timestamps stored in events, which are preserved through replication. This means that if a master M1 is itself a slave of M0, any event from M1’s binary log that originates from M0’s binary log has M0’s timestamp for that event. This enables MySQL to replicate **TIMESTAMP** successfully. However, the problem for Seconds_Behind_Master is that if M1 also receives direct updates from clients, the Seconds_Behind_Master value randomly fluctuates because sometimes the last event from M1 originates from M0 and sometimes is the result of a direct update on M1.

• **Last_IO_Errno, Last_IO_Error**

  The error number and error message of the most recent error that caused the I/O thread to stop. An error number of 0 and message of the empty string mean “no error.” If the **Last_IO_Error** value is not empty, the error values also appear in the slave’s error log.

  Issuing **RESET MASTER** or **RESET SLAVE** resets the values shown in these columns.

• **Last_SQL_Errno, Last_SQL_Error**

  The error number and error message of the most recent error that caused the SQL thread to stop. An error number of 0 and message of the empty string mean “no error.” If the **Last_SQL_Error** value is not empty, the error values also appear in the slave’s error log.

  Example:

  ```
  Last_SQL_Errno: 1051
  Last_SQL_Error: error 'Unknown table 'z'' on query 'drop table z'
  ```

  The message indicates that the table *z* existed on the master and was dropped there, but it did not exist on the slave, so DROP TABLE failed on the slave. (This might occur, for example, if you forget to copy the table to the slave when setting up replication.)

  Issuing **RESET MASTER** or **RESET SLAVE** resets the values shown in these columns.

• **Replicate_Ignore_Server_Ids**

  You can tell a slave to ignore events from 0 or more masters using the **IGNORE_SERVER_IDS** option of the **CHANGE MASTER TO** statement. This is normally of interest only when using a circular or other multi-master replication setup.

  The message shown for **Replicate_Ignore_Server_Ids** consists of a space-delimited list of one or more numbers, the first value indicating the number of servers to be ignored; if not 0 (the default), this server-count value is followed by the actual server IDs. For example, if a **CHANGE MASTER TO** statement containing the **IGNORE_SERVER_IDS = (2, 6, 9)** option has been issued to tell a slave to ignore masters having the server ID 2, 6, or 9, that information appears as shown here:
SHOW Statements

```
Replicate_Ignore_Server_Ids: 3 2 6 9
```

**Replicate_Ignore_Server_Ids** filtering is performed by the I/O thread, rather than by the SQL thread, which means that events which are filtered out are not written to the relay log. This differs from the filtering actions taken by server options such `--replicate-do-table`, which apply to the SQL thread.

* Master_Server_Id

The `server_id` value from the master.

### 13.7.5.36 SHOW STATUS Statement

```
SHOW [GLOBAL | SESSION] STATUS
    [LIKE 'pattern' | WHERE expr]
```

**SHOW STATUS** provides server status information (see Section 5.1.9, “Server Status Variables”). This statement does not require any privilege. It requires only the ability to connect to the server.

Status variable information is also available from these sources:

- The **GLOBAL_STATUS** and **SESSION_STATUS** tables. See Section 21.9, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”.

- The **mysqladmin extended-status** command. See Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”.

For **SHOW STATUS**, a **LIKE** clause, if present, indicates which variable names to match. A **WHERE** clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

**SHOW STATUS** accepts an optional **GLOBAL** or **SESSION** variable scope modifier:

- With a **GLOBAL** modifier, the statement displays the global status values. A global status variable may represent status for some aspect of the server itself (for example, **Aborted_connects**), or the aggregated status over all connections to MySQL (for example, **Bytes_received** and **Bytes_sent**). If a variable has no global value, the session value is displayed.

- With a **SESSION** modifier, the statement displays the status variable values for the current connection. If a variable has no session value, the global value is displayed. **LOCAL** is a synonym for **SESSION**.

- If no modifier is present, the default is **SESSION**.

The scope for each status variable is listed at Section 5.1.9, “Server Status Variables”.

Each invocation of the **SHOW STATUS** statement uses an internal temporary table and increments the global **Created_tmp_tables** value.

Partial output is shown here. The list of names and values may differ for your server. The meaning of each variable is given in Section 5.1.9, “Server Status Variables”.

```sql
mysql> SHOW STATUS;
+--------------------------+------------+
| Variable_name            | Value      |
+--------------------------+------------+
| Aborted_clients          | 0          |
| Aborted_connects         | 0          |
| Bytes_received           | 155372598  |
```
SHOW Statements

<table>
<thead>
<tr>
<th>Bytes_sent</th>
<th>1176560426</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connections</td>
<td>30023</td>
</tr>
<tr>
<td>Created_tmp_disk_tables</td>
<td>0</td>
</tr>
<tr>
<td>Created_tmp_tables</td>
<td>8340</td>
</tr>
<tr>
<td>Created_tmp_files</td>
<td>60</td>
</tr>
<tr>
<td>Open_tables</td>
<td>1</td>
</tr>
<tr>
<td>Open_files</td>
<td>2</td>
</tr>
<tr>
<td>Open_streams</td>
<td>0</td>
</tr>
<tr>
<td>Opened_tables</td>
<td>44600</td>
</tr>
<tr>
<td>Questions</td>
<td>2026873</td>
</tr>
<tr>
<td>Table_locks_immediate</td>
<td>1920382</td>
</tr>
<tr>
<td>Table_locks_waited</td>
<td>0</td>
</tr>
<tr>
<td>Threads_cached</td>
<td>0</td>
</tr>
<tr>
<td>Threads_created</td>
<td>30022</td>
</tr>
<tr>
<td>Threads_connected</td>
<td>1</td>
</tr>
<tr>
<td>Threads_running</td>
<td>1</td>
</tr>
<tr>
<td>Uptime</td>
<td>80380</td>
</tr>
</tbody>
</table>

With a LIKE clause, the statement displays only rows for those variables with names that match the pattern:

```sql
mysql> SHOW STATUS LIKE 'Key%';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key_blocks_used</td>
<td>14955</td>
</tr>
<tr>
<td>Key_read_requests</td>
<td>96854827</td>
</tr>
<tr>
<td>Key_reads</td>
<td>162040</td>
</tr>
<tr>
<td>Key_write_requests</td>
<td>7589728</td>
</tr>
<tr>
<td>Key_writes</td>
<td>3813196</td>
</tr>
</tbody>
</table>

13.7.5.37 SHOW TABLE STATUS Statement

SHOW TABLE STATUS

SHOW TABLE STATUS works like SHOW TABLES, but provides a lot of information about each non-TEMPORARY table. You can also get this list using the mysqlshow --status db_name command. The LIKE clause, if present, indicates which table names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

This statement also displays information about views.

SHOW TABLE STATUS output has these columns:

- **Name**
  
  The name of the table.

- **Engine**
  

  For partitioned tables, Engine shows the name of the storage engine used by all partitions.

- **Version**
The version number of the table's .frm file.

- **Row_format**

  The row-storage format (**Fixed**, **Dynamic**, **Compressed**, **Redundant**, **Compact**). For **MyISAM** tables, **Dynamic** corresponds to what **mysamchk -dvv** reports as **Packed**. **InnoDB** table format is either **Redundant** or **Compact** when using the **Antelope** file format, or **Compressed** or **Dynamic** when using the **Barracuda** file format.

- **Rows**

  The number of rows. Some storage engines, such as **MyISAM**, store the exact count. For other storage engines, such as **InnoDB**, this value is an approximation, and may vary from the actual value by as much as 40% to 50%. In such cases, use **SELECT COUNT(*)** to obtain an accurate count.

  The **Rows** value is **NULL** for **INFORMATION_SCHEMA** tables.

  For **InnoDB** tables, the row count is only a rough estimate used in SQL optimization. (This is also true if the **InnoDB** table is partitioned.)

- **Avg_row_length**

  The average row length.

  Refer to the notes at the end of this section for related information.

- **Data_length**

  For **MyISAM**, **Data_length** is the length of the data file, in bytes.

  For **InnoDB**, **Data_length** is the approximate amount of space allocated for the clustered index, in bytes. Specifically, it is the clustered index size, in pages, multiplied by the **InnoDB** page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- **Max_data_length**

  For **MyISAM**, **Max_data_length** is maximum length of the data file. This is the total number of bytes of data that can be stored in the table, given the data pointer size used.

  Unused for **InnoDB**.

  Refer to the notes at the end of this section for information regarding other storage engines.

- **Index_length**

  For **MyISAM**, **Index_length** is the length of the index file, in bytes.

  For **InnoDB**, **Index_length** is the approximate amount of space allocated for non-clustered indexes, in bytes. Specifically, it is the sum of non-clustered index sizes, in pages, multiplied by the **InnoDB** page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- **Data_free**

  The number of allocated but unused bytes.
SHOW Statements

**InnoDB** tables report the free space of the tablespace to which the table belongs. For a table located in the shared tablespace, this is the free space of the shared tablespace. If you are using multiple tablespaces and the table has its own tablespace, the free space is for only that table. Free space means the number of bytes in completely free extents minus a safety margin. Even if free space displays as 0, it may be possible to insert rows as long as new extents need not be allocated.

For NDB Cluster, **Data_free** shows the space allocated on disk for, but not used by, a Disk Data table or fragment on disk. (In-memory data resource usage is reported by the **Data_length** column.)

For partitioned tables, this value is only an estimate and may not be absolutely correct. A more accurate method of obtaining this information in such cases is to query the **INFORMATION_SCHEMA PARTITIONS** table, as shown in this example:

```sql
SELECT SUM(DATA_FREE) 
FROM INFORMATION_SCHEMA.PARTITIONS 
WHERE TABLE_SCHEMA = 'mydb' 
AND TABLE_NAME   = 'mytable';
```

For more information, see Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”.

- **Auto_increment**
  
The next **AUTO_INCREMENT** value.

- **Create_time**
  
When the table was created.
  
Prior to MySQL 5.5.44, for partitioned **InnoDB** tables, the **Create_time** column shows **NULL**. This column shows the correct table creation time for such tables in MySQL 5.5.44 and later. (Bug #17299181, Bug #69990)

- **Update_time**
  
When the data file was last updated. For some storage engines, this value is **NULL**. For example, **InnoDB** stores multiple tables in its **system tablespace** and the data file timestamp does not apply. Even with **file-per-table** mode with each **InnoDB** table in a separate .ibd file, **change buffering** can delay the write to the data file, so the file modification time is different from the time of the last insert, update, or delete. For **MyISAM**, the data file timestamp is used; however, on Windows the timestamp is not updated by updates, so the value is inaccurate.

For partitioned **InnoDB** tables, **Update_time** is always **NULL**.

- **Check_time**
  
When the table was last checked. Not all storage engines update this time, in which case, the value is always **NULL**.

For partitioned **InnoDB** tables, **Check_time** is always **NULL**.

- **Collation**
  
The table default collation. The output does not explicitly list the table default character set, but the collation name begins with the character set name.

- **Checksum**
  
The live checksum value, if any.
SHOW Statements

- **Create_options**
  Extra options used with `CREATE TABLE`. The original options from when `CREATE TABLE` was executed are retained and the options reported here may differ from the active table settings and options.

  `- Create_options` shows `partitioned` if the table is partitioned.

- **Comment**
  The comment used when creating the table (or information as to why MySQL could not access the table information).

**Notes**

- For **InnoDB tables**, `SHOW TABLE STATUS` does not give accurate statistics except for the physical size reserved by the table. The row count is only a rough estimate used in SQL optimization.

- For **NDB tables**, the output of this statement shows appropriate values for the `Avg_row_length` and `Data_length` columns, with the exception that `BLOB` columns are not taken into account.

- For **NDB tables**, `Data_length` includes data stored in main memory only; the `Max_data_length` and `Data_free` columns apply to Disk Data.

- For **NDB Cluster Disk Data tables**, `Max_data_length` shows the space allocated for the disk part of a Disk Data table or fragment. (In-memory data resource usage is reported by the `Data_length` column.)

- For **MEMORY tables**, the `Data_length`, `Max_data_length`, and `Index_length` values approximate the actual amount of allocated memory. The allocation algorithm reserves memory in large amounts to reduce the number of allocation operations.

- For views, all columns displayed by `SHOW TABLE STATUS` are `NULL` except that `Name` indicates the view name and `Comment` says `VIEW`.

Table information is also available from the `INFORMATION_SCHEMA TABLES` table. See Section 21.22, “The INFORMATION_SCHEMA TABLES Table”.

13.7.5.38 **SHOW TABLES Statement**

```sql
SHOW [FULL] TABLES
   [[FROM | IN] db_name]
   [LIKE 'pattern' | WHERE expr]
```

`SHOW TABLES` lists the non-TEMPORARY tables in a given database. You can also get this list using the `mysqlshow db_name` command. The `LIKE` clause, if present, indicates which table names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

Matching performed by the `LIKE` clause is dependent on the setting of the `lower_case_table_names` system variable.

This statement also lists any views in the database. The optional `FULL` modifier causes `SHOW TABLES` to display a second output column with values of `BASE TABLE` for a table, `VIEW` for a view, or `SYSTEM VIEW` for an `INFORMATION_SCHEMA` table.

If you have no privileges for a base table or view, it does not show up in the output from `SHOW TABLES` or `mysqlshow db_name`.

Table information is also available from the `INFORMATION_SCHEMA TABLES` table. See Section 21.22, “The INFORMATION_SCHEMA TABLES Table”.

1676
SHOW Statements

13.7.5.39 SHOW TRIGGERS Statement

SHOW TRIGGERS

- {FROM | IN} db_name
- [LIKE 'pattern' | WHERE expr]

SHOW TRIGGERS lists the triggers currently defined for tables in a database (the default database unless a FROM clause is given). This statement returns results only for databases and tables for which you have the TRIGGER privilege. The LIKE clause, if present, indicates which table names (not trigger names) to match and causes the statement to display triggers for those tables. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 21.32, "Extensions to SHOW Statements".

For the ins_sum trigger defined in Section 20.3, “Using Triggers”, the output of SHOW TRIGGERS is as shown here:

```sql
c MATLAB> SHOW TRIGGERS LIKE 'acc%'
G
*************************** 1. row ***************************
Trigger: ins_sum
Event: INSERT
Table: account
Statement: SET @sum = @sum + NEW.amount
Timing: BEFORE
Created: NULL
sql_mode:
  Definer: me@localhost
character_set_client: utf8
collation_connection: utf8_general_ci
Database Collation: latin1_swedish_ci
```

SHOW TRIGGERS output has these columns:

- **Trigger**
  The name of the trigger.

- **Event**
  The trigger event. This is the type of operation on the associated table for which the trigger activates. The value is INSERT (a row was inserted), DELETE (a row was deleted), or UPDATE (a row was modified).

- **Table**
  The table for which the trigger is defined.

- **Statement**
  The trigger body; that is, the statement executed when the trigger activates.

- **Timing**
  Whether the trigger activates before or after the triggering event. The value is BEFORE or AFTER.

- **Created**
  The value of this column is always NULL.

- **sql_mode**
  The SQL mode in effect when the trigger was created, and under which the trigger executes. For the permitted values, see Section 5.1.10, “Server SQL Modes”.

---

1677
SHOW Statements

• **Definer**
  The account of the user who created the trigger, in 'user_name'@'host_name' format.

• **character_set_client**
  The session value of the `character_set_client` system variable when the trigger was created.

• **collation_connection**
  The session value of the `collation_connection` system variable when the trigger was created.

• **Database Collation**
  The collation of the database with which the trigger is associated.

Trigger information is also available from the `INFORMATION_SCHEMA TRIGGERS` table. See Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”.

### 13.7.5.40 SHOW VARIABLES Statement

```sql
SHOW [GLOBAL | SESSION] VARIABLES
  [LIKE 'pattern' | WHERE expr]
```

**SHOW VARIABLES** shows the values of MySQL system variables (see Section 5.1.7, “Server System Variables”). This statement does not require any privilege. It requires only the ability to connect to the server.

System variable information is also available from these sources:

- The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables. See Section 21.10, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”.

- The `mysqladmin variables` command. See Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”.

For **SHOW VARIABLES**, a **LIKE** clause, if present, indicates which variable names to match. A **WHERE** clause can be given to select rows using more general conditions, as discussed in Section 21.32, “Extensions to SHOW Statements”.

**SHOW VARIABLES** accepts an optional **GLOBAL** or **SESSION** variable scope modifier:

- With a **GLOBAL** modifier, the statement displays global system variable values. These are the values used to initialize the corresponding session variables for new connections to MySQL. If a variable has no global value, no value is displayed.

- With a **SESSION** modifier, the statement displays the system variable values that are in effect for the current connection. If a variable has no session value, the global value is displayed. **LOCAL** is a synonym for **SESSION**.

- If no modifier is present, the default is **SESSION**.

The scope for each system variable is listed at Section 5.1.7, “Server System Variables”.

**SHOW VARIABLES** is subject to a version-dependent display-width limit. For variables with very long values that are not completely displayed, use **SELECT** as a workaround. For example:
SHOW Statements

```sql
SELECT @@GLOBAL.innodb_data_file_path;
```

Most system variables can be set at server startup (read-only variables such as `version_comment` are exceptions). Many can be changed at runtime with the `SET` statement. See Section 5.1.8, "Using System Variables", and Section 13.7.4.1, "SET Syntax for Variable Assignment".

Partial output is shown here. The list of names and values may differ for your server. Section 5.1.7, "Server System Variables", describes the meaning of each variable, and Section 5.1.1, "Configuring the Server", provides information about tuning them.

```sql
mysql> SHOW VARIABLES;
+-----------------------------------------+---------------------------+
| Variable_name                           | Value                     |
+-----------------------------------------+---------------------------+
| auto_increment_increment                | 1                         |
| auto_increment_offset                   | 1                         |
| autocommit                              | ON                        |
| automatic_sp_privileges                 | ON                        |
| back_log                                | 50                        |
| basedir                                 | /home/jon/bin/mysql-5.5   |
| big_tables                              | OFF                       |
| binlog_cache_size                       | 32768                     |
| binlog_direct_non_transactional_updates | OFF                       |
| binlog_format                           | STATEMENT                 |
| binlog_stmt_cache_size                  | 32768                     |
| bulk_insert_buffer_size                 | 8388608                   |
| max_allowed_packet                      | 1048576                   |
| max_binlog_cache_size                   | 18446744073709547520      |
| max_binlog_size                         | 1073741824                |
| max_binlog_stmt_cache_size              | 18446744073709547520      |
| max_connect_errors                      | 10                        |
| max_connections                         | 151                       |
| max_delayed_threads                     | 20                        |
| max_error_count                         | 64                        |
| max_heap_table_size                     | 16777216                  |
| max_insert_delayed_threads              | 20                        |
| max_join_size                           | 18446744073709551615      |
| thread_handling                         | one-thread-per-connection |
| thread_stack                            | 262144                    |
| time_format                             | %H:%i:%s                  |
| time_zone                               | SYSTEM                    |
| timed_mutexes                           | OFF                       |
| timestamp                               | 1316689732                |
| tmpdir                                  | /tmp                      |
| transaction_alloc_block_size            | 8192                      |
| transaction_prealloc_size               | 4096                      |
| tx_isolation                            | REPEATABLE-READ           |
| unique_checks                           | ON                        |
| updatable_views_with_limit              | YES                       |
| version                                 | 5.5.17-log                |
| version_comment                         | Source distribution       |
| version_compile_machine                 | x86_64                    |
| version_compile_os                      | Linux                     |
| wait_timeout                            | 28800                     |
| warning_count                           | 0                         |
+-----------------------------------------+---------------------------+

With a `LIKE` clause, the statement displays only rows for those variables with names that match the pattern. To obtain the row for a specific variable, use a `LIKE` clause as shown:

```sql
SHOW VARIABLES LIKE 'max_join_size';
```
SHOW SESSION VARIABLES LIKE 'max_join_size';

To get a list of variables whose name match a pattern, use the % wildcard character in a LIKE clause:

SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because _ is a wildcard that matches any single character, you should escape it as \_ to match it literally. In practice, this is rarely necessary.

### 13.7.5.41 SHOW WARNINGS Statement

SHOW WARNINGS [LIMIT [offset,] row_count]
SHOW COUNT(*) WARNINGS

SHOW WARNINGS is a diagnostic statement that displays information about the conditions (errors, warnings, and notes) resulting from executing a statement in the current session. Warnings are generated for DML statements such as INSERT, UPDATE, and LOAD DATA as well as DDL statements such as CREATE TABLE and ALTER TABLE.

The LIMIT clause has the same syntax as for the SELECT statement. See Section 13.2.9, “SELECT Statement”.

SHOW WARNINGS is also used following EXPLAIN EXTENDED, to display the extra information generated by EXPLAIN when the EXTENDED keyword is used. See Section 8.8.3, “Extended EXPLAIN Output Format”.

SHOW WARNINGS displays information about the conditions resulting from the most recent statement in the current session that generated messages. It shows nothing if the most recent statement used a table and generated no messages. (That is, statements that use a table but generate no messages clear the message list.) Statements that do not use tables and do not generate messages have no effect on the message list.

The SHOW COUNT(*) WARNINGS diagnostic statement displays the total number of errors, warnings, and notes. You can also retrieve this number from the warning_count system variable:

SHOW COUNT(*) WARNINGS;
SELECT @@warning_count;

A related diagnostic statement, SHOW ERRORS, shows only error conditions (it excludes warnings and notes), and SHOW COUNT(*) ERRORS statement displays the total number of errors. See Section 13.7.5.18, “SHOW ERRORS Statement”.

Here is a simple example that shows data-conversion warnings for INSERT. The example assumes that strict SQL mode is disabled. With strict mode enabled, the warnings would become errors and terminate the INSERT.

```sql
mysql> CREATE TABLE t1 (a TINYINT NOT NULL, b CHAR(4));
Query OK, 0 rows affected (0.05 sec)
mysql> INSERT INTO t1 VALUES(10,'mysql'), (NULL,'test'), (300,'xyz');
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
Level: Warning
Code: 1265
Message: Data truncated for column 'b' at row 1
```

1680
The `max_error_count` system variable controls the maximum number of error, warning, and note messages for which the server stores information, and thus the number of messages that `SHOW WARNINGS` displays. To change the number of messages the server can store, change the value of `max_error_count`. The default is 64.

`max_error_count` controls only how many messages are stored, not how many are counted. The value of `warning_count` is not limited by `max_error_count`, even if the number of messages generated exceeds `max_error_count`. The following example demonstrates this. The `ALTER TABLE` statement produces three warning messages (strict SQL mode is disabled for the example to prevent an error from occurring after a single conversion issue). Only one message is stored and displayed because `max_error_count` has been set to 1, but all three are counted (as shown by the value of `warning_count`):

```
mysql> SHOW VARIABLES LIKE 'max_error_count';
+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| max_error_count | 64    |
+-----------------+-------+
1 row in set (0.00 sec)
```

```
mysql> SET max_error_count=1, sql_mode = '';
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> ALTER TABLE t1 MODIFY b CHAR;
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3
```

```
mysql> SHOW WARNINGS;
+---------+----------------------------------------------+
| Level   | Code | Message                                |
+---------+----------------------------------------------+
| Warning | 1263 | Data truncated for column 'b' at row 1 |
+---------+----------------------------------------------+
1 row in set (0.00 sec)
```

```
mysql> SELECT @@warning_count;
+-----------------+
| @@warning_count |
+-----------------+
| 3               |
+-----------------+
1 row in set (0.01 sec)
```

To disable message storage, set `max_error_count` to 0. In this case, `warning_count` still indicates how many warnings occurred, but messages are not stored and cannot be displayed.

The `sql_notes` system variable controls whether note messages increment `warning_count` and whether the server stores them. By default, `sql_notes` is 1, but if set to 0, notes do not increment `warning_count` and the server does not store them:

```
mysql> SET sql_notes = 1;
mysql> DROP TABLE IF EXISTS test.no_such_table;
```
Other Administrative Statements

The MySQL server sends to each client a count indicating the total number of errors, warnings, and notes resulting from the most recent statement executed by that client. From the C API, this value can be obtained by calling `mysql_warning_count()`. See Section 23.7.6.72, "mysql_warning_count()".

In the `mysql` client, you can enable and disable automatic warnings display using the `warnings` and `nowarning` commands, respectively, or their shortcuts, \W and \w (see Section 4.5.1.2, "mysql Client Commands"). For example:

```
mysql> \w
Show warnings enabled.
mysql> SELECT 1/0;
+------+
| 1/0  |
+------+
| NULL |
+------+
1 row in set, 1 warning (0.03 sec)
Warning (Code 1365): Division by 0
mysql> \w
Show warnings disabled.
```

13.7.6 Other Administrative Statements

13.7.6.1 BINLOG Statement

```
BINLOG 'str'
```

`BINLOG` is an internal-use statement. It is generated by the `mysqlbinlog` program as the printable representation of certain events in binary log files. (See Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"). The 'str' value is a base 64-encoded string that the server decodes to determine the data change indicated by the corresponding event. This statement requires the `SUPER` privilege.

13.7.6.2 CACHE INDEX Statement

```
CACHE INDEX {
    tbl_index_list [, tbl_index_list] ... 
    | tbl_name PARTITION (partition_list)
}
IN key_cache_name
```

`tbl_index_list`: `tbl_name [{INDEX|KEY} (index_name[, index_name] ...)]`

`partition_list`: `partition_name[, partition_name] ...` | ALL
The **CACHE INDEX** statement assigns table indexes to a specific key cache. It applies only to **MyISAM** tables, including partitioned **MyISAM** tables. After the indexes have been assigned, they can be preloaded into the cache if desired with **LOAD INDEX INTO CACHE**.

The following statement assigns indexes from the tables **t1**, **t2**, and **t3** to the key cache named **hot_cache**:

```sql
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
```

<table>
<thead>
<tr>
<th>Table</th>
<th>Op</th>
<th>Msg_type</th>
<th>Msg_text</th>
</tr>
</thead>
<tbody>
<tr>
<td>test.t1</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
<tr>
<td>test.t2</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
<tr>
<td>test.t3</td>
<td>assign_to_keycache</td>
<td>status</td>
<td>OK</td>
</tr>
</tbody>
</table>

The syntax of **CACHE INDEX** enables you to specify that only particular indexes from a table should be assigned to the cache. However, the implementation assigns all the table’s indexes to the cache, so there is no reason to specify anything other than the table name.

The key cache referred to in a **CACHE INDEX** statement can be created by setting its size with a parameter setting statement or in the server parameter settings. For example:

```sql
SET GLOBAL keycache1.key_buffer_size=128*1024;
```

Key cache parameters are accessed as members of a structured system variable. See Section 5.1.8.3, “Structured System Variables”.

A key cache must exist before you assign indexes to it, or an error occurs:

```sql
mysql> CACHE INDEX t1 IN non_existent_cache;
ERROR 1284 (HY000): Unknown key cache 'non_existent_cache'
```

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it are reassigned to the default key cache.

Index assignment affects the server globally: If one client assigns an index to a given cache, this cache is used for all queries involving the index, no matter which client issues the queries.

**CACHE INDEX** is supported for partitioned **MyISAM** tables. You can assign one or more indexes for one, several, or all partitions to a given key cache. For example, you can do the following:

```sql
CREATE TABLE pt (c1 INT, c2 VARCHAR(50), INDEX i(c1))
ENGINE=MyISAM
PARTITION BY HASH(c1)
PARTITIONS 4;
SET GLOBAL kc_fast.key_buffer_size = 128 * 1024;
SET GLOBAL kc_slow.key_buffer_size = 128 * 1024;
CACHE INDEX pt PARTITION (p0) IN kc_fast;
CACHE INDEX pt PARTITION (p1, p3) IN kc_slow;
```

The previous set of statements performs the following actions:

- Creates a partitioned table with 4 partitions; these partitions are automatically named **p0**, **,..., p3**; this table has an index named **i** on column **c1**.
- Creates 2 key caches named **kc_fast** and **kc_slow**
• Assigns the index for partition p0 to the kc_fast key cache and the index for partitions p1 and p3 to the kc_slow key cache; the index for the remaining partition (p2) uses the server's default key cache.

If you wish instead to assign the indexes for all partitions in table pt to a single key cache named kc_all, you can use either of the following two statements:

```
CACHE INDEX pt PARTITION (ALL) IN kc_all;
CACHE INDEX pt IN kc_all;
```

The two statements just shown are equivalent, and issuing either one has exactly the same effect. In other words, if you wish to assign indexes for all partitions of a partitioned table to the same key cache, the PARTITION (ALL) clause is optional.

When assigning indexes for multiple partitions to a key cache, the partitions need not be contiguous, and you need not list their names in any particular order. Indexes for any partitions not explicitly assigned to a key cache automatically use the server default key cache.

Index preloading is also supported for partitioned MyISAM tables. For more information, see Section 13.7.6.5, “LOAD INDEX INTO CACHE Statement”.

### 13.7.6.3 FLUSH Statement

```
FLUSH [NO_WRITE_TO_BINLOG | LOCAL] {  
  flush_option [, flush_option] ...  
  | tables_option  
}

flush_option: {  
  BINARY LOGS  
  | DES_KEY_FILE  
  | ENGINE LOGS  
  | ERROR LOGS  
  | GENERAL LOGS  
  | HOSTS  
  | LOGS  
  | MASTER  
  | PRIVILEGES  
  | QUERY CACHE  
  | RELAY LOGS  
  | SLAVE  
  | SLOW LOGS  
  | STATUS  
  | USER_RESOURCES  
}

tables_option: {  
  TABLES  
  | TABLES tbl_name [, tbl_name] ...  
  | TABLES WITH READ LOCK  
  | TABLES tbl_name [, tbl_name] ... WITH READ LOCK  
}
```

The **FLUSH** statement has several variant forms that clear or reload various internal caches, flush tables, or acquire locks. To execute **FLUSH**, you must have the **RELOAD** privilege. Specific flush options might require additional privileges, as described later.

**Note**

It is not possible to issue **FLUSH** statements within stored functions or triggers. However, you may use **FLUSH** in stored procedures, so long as these are not called from stored functions or triggers. See Section 20.8, “Restrictions on Stored Programs”.

1684
By default, the server writes `FLUSH` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

**Note**

`FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK` (with or without a table list) are not written to the binary log in any case because they would cause problems if replicated to a slave.

The `FLUSH` statement causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

The `mysqladmin` utility provides a command-line interface to some flush operations, using commands such as `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status`, and `flush-tables`. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

Sending a `SIGHUP` signal to the server causes several flush operations to occur that are similar to various forms of the `FLUSH` statement. Signals can be sent by `root` or the account that owns the server process. They enable the applicable flush operations to be performed without having to connect to the server (which for these operations requires an account that has the `RELOAD` privilege). See Section 4.10, “Unix Signal Handling in MySQL”.

The `RESET` statement is similar to `FLUSH`. See Section 13.7.6.6, “RESET Statement”, for information about using the `RESET` statement with replication.

The following list describes the permitted `FLUSH` statement `flush_option` values. For descriptions of `FLUSH TABLES` variants, see `FLUSH TABLES Syntax`.

- **FLUSH_BINARY_LOGS**
  Closes and reopens any binary log file to which the server is writing. If binary logging is enabled, the sequence number of the binary log file is incremented by one relative to the previous file.

- **FLUSH_DES_KEY_FILE**
  Reloads the DES keys from the file that was specified with the `--des-key-file` option at server startup time.

- **FLUSH_ENGINE_LOGS**
  Closes and reopens any flushable logs for installed storage engines. This causes `InnoDB` to flush its logs to disk.

- **FLUSH_ERROR_LOGS**
  Closes and reopens any error log file to which the server is writing.

- **FLUSH_GENERAL_LOGS**
  Closes and reopens any general query log file to which the server is writing.

- **FLUSH_HOSTS**
  Empties the host cache and unblocks any blocked hosts (see Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”). Flush the host cache if some of your hosts change IP address or if the error message `Host 'host_name' is blocked` occurs for connections from legitimate hosts. (See Section B.4.2.6, “Host 'host_name' is blocked”.) When more than `max_connect_errors`...
Other Administrative Statements

Errors occur successively for a given host while connecting to the MySQL server, MySQL assumes that something is wrong and blocks the host from further connection requests. Flushing the host cache enables further connection attempts from the host. The default value of `max_connect_errors` is 10. To avoid this error message, start the server with `max_connect_errors` set to a large value.

- **FLUSH LOGS**

  Closes and reopens any log file to which the server is writing. If binary logging is enabled, the sequence number of the binary log file is incremented by one relative to the previous file. If relay logging is enabled, the sequence number of the relay log file is incremented by one relative to the previous file.

  `FLUSH LOGS` has no effect on tables used for the general query log or for the slow query log (see Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”).

- **FLUSH MASTER**

  Deletes all binary logs, resets the binary log index file and creates a new binary log. `FLUSH MASTER` is deprecated in favor of `RESET MASTER`. `FLUSH MASTER` is still accepted in MySQL 5.5 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.1.2, “RESET MASTER Statement”.

- **FLUSH PRIVILEGES**

  Reloads the privileges from the grant tables in the `mysql` system database.

  If the `--skip-grant-tables` option was specified at server startup to disable the MySQL privilege system, `FLUSH PRIVILEGES` provides a way to enable the privilege system at runtime.

  Frees memory cached by the server as a result of `GRANT`, `CREATE USER`, `CREATE SERVER`, and `INSTALL PLUGIN` statements. This memory is not released by the corresponding `REVOKE`, `DROP USER`, `DROP SERVER`, and `UNINSTALL PLUGIN` statements, so for a server that executes many instances of the statements that cause caching, there will be an increase in cached memory use unless it is freed with `FLUSH PRIVILEGES`.

- **FLUSH QUERY CACHE**

  Defragment the query cache to better utilize its memory. `FLUSH QUERY CACHE` does not remove any queries from the cache, unlike `FLUSH TABLES` or `RESET QUERY CACHE`.

- **FLUSH RELAY LOGS**

  Closes and reopens any relay log file to which the server is writing. If relay logging is enabled, the sequence number of the relay log file is incremented by one relative to the previous file.

- **FLUSH SLAVE**

  Resets all replication slave parameters, including relay log files and replication position in the master's binary logs. `FLUSH SLAVE` is deprecated in favor of `RESET SLAVE`. `FLUSH SLAVE` is still accepted in MySQL 5.5 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.2.3, “RESET SLAVE Statement”.

- **FLUSH SLOW LOGS**

  Closes and reopens any slow query log file to which the server is writing.

- **FLUSH STATUS**

  This option adds the current thread's session status variable values to the global values and resets the session values to zero. Some global variables may be reset to zero as well. It also resets the counters.
for key caches (default and named) to zero and sets \texttt{Max\_used\_connections} to the current number of open connections. This information may be of use when debugging a query. See Section 1.6, “How to Report Bugs or Problems”.

- **FLUSH USER\_RESOURCES**
  
  Resets all per-hour user resources to zero. This enables clients that have reached their hourly connection, query, or update limits to resume activity immediately. **FLUSH USER\_RESOURCES** does not apply to the limit on maximum simultaneous connections that is controlled by the \texttt{max\_user\_connections} system variable. See Section 6.2.12, “Setting Account Resource Limits”.

**FLUSH TABLES Syntax**

**FLUSH TABLES** flushes tables, and, depending on the variant used, acquires locks. Any \texttt{TABLES} variant used in a **FLUSH** statement must be the only option used. **FLUSH TABLE** is a synonym for **FLUSH TABLES**.

\textbf{Note}

The descriptions here that indicate tables are flushed by closing them apply differently for InnoDB, which flushes table contents to disk but leaves them open. This still permits table files to be copied while the tables are open, as long as other activity does not modify them.

- **FLUSH TABLES**
  
  Closes all open tables, forces all tables in use to be closed, and flushes the query cache. **FLUSH TABLES** also removes all query results from the query cache, like the **RESET QUERY CACHE** statement.

  **FLUSH TABLES** is not permitted when there is an active **LOCK TABLES \ldots READ**. To flush and lock tables, use **FLUSH TABLES tbl\_name \ldots WITH READ LOCK** instead.

- **FLUSH TABLES tbl\_name [, tbl\_name] \ldots**
  
  With a list of one or more comma-separated table names, this statement is like **FLUSH TABLES** with no names except that the server flushes only the named tables. If a named table does not exist, no error occurs.

- **FLUSH TABLES WITH READ LOCK**
  
  Closes all open tables and locks all tables for all databases with a global read lock. This is a very convenient way to get backups if you have a file system such as Veritas or ZFS that can take snapshots in time. Use **UNLOCK TABLES** to release the lock.

  **FLUSH TABLES WITH READ LOCK** acquires a global read lock rather than table locks, so it is not subject to the same behavior as **LOCK TABLES** and **UNLOCK TABLES** with respect to table locking and implicit commits:

  - **UNLOCK TABLES** implicitly commits any active transaction only if any tables currently have been locked with **LOCK TABLES**. The commit does not occur for **UNLOCK TABLES** following **FLUSH TABLES WITH READ LOCK** because the latter statement does not acquire table locks.

  - Beginning a transaction causes table locks acquired with **LOCK TABLES** to be released, as though you had executed **UNLOCK TABLES**. Beginning a transaction does not release a global read lock acquired with **FLUSH TABLES WITH READ LOCK**.

  **FLUSH TABLES WITH READ LOCK** is not compatible with XA transactions.
**FLUSH TABLES** with **read lock** does not prevent the server from inserting rows into the log tables (see Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”).

- **FLUSH TABLES** *tbl_name* [, *tbl_name*] ... WITH **read lock**

  This statement flushes and acquires read locks for the named tables. The statement first acquires exclusive metadata locks for the tables, so it waits for transactions that have those tables open to complete. Then the statement flushes the tables from the table cache, reopens the tables, acquires table locks (like *LOCK TABLES ... READ*), and downgrades the metadata locks from exclusive to shared. After the statement acquires locks and downgrades the metadata locks, other sessions can read but not modify the tables.

  Because this statement acquires table locks, you must have the **LOCK TABLES** privilege for each table, in addition to the **RELOAD** privilege that is required to use any **FLUSH** statement.

  This statement applies only to existing base (non-**TEMPORARY**) tables. If a name refers to a base table, that table is used. If it refers to a **TEMPORARY** table, it is ignored. If a name applies to a view, an **ER_WRONG_OBJECT** error occurs. Otherwise, an **ER_NO_SUCH_TABLE** error occurs.

  Use **UNLOCK TABLES** to release the locks, **LOCK TABLES** to release the locks and acquire other locks, or **START TRANSACTION** to release the locks and begin a new transaction.

  This **FLUSH TABLES** variant enables tables to be flushed and locked in a single operation. It provides a workaround for the restriction that **FLUSH TABLES** is not permitted when there is an active **LOCK TABLES**.

  This statement does not perform an implicit **UNLOCK TABLES**, so an error results if you use the statement while there is any active **LOCK TABLES** or use it a second time without first releasing the locks acquired.

  If a flushed table was opened with **HANDLER**, the handler is implicitly flushed and loses its position.

### 13.7.6.4 KILL Statement

**KILL** with modifiers:

- **KILL** **CONNECTION** or **QUERY** *processlist_id*

  Each connection to *mysqld* runs in a separate thread. You can kill a thread with the **KILL** statement.

  Thread processlist identifiers can be determined from the **ID** column of the **INFORMATION_SCHEMA** **PROCESSLIST** table, the **Id** column of **SHOW PROCESSLIST** output, and the **PROCESSLIST_ID** column of the Performance Schema **threads** table. The value for the current thread is returned by the **CONNECTION_ID()** function.

  **KILL** permits an optional **CONNECTION** or **QUERY** modifier:

  - **KILL** **CONNECTION** is the same as **KILL** with no modifier: It terminates the connection associated with the given *processlist_id*, after terminating any statement the connection is executing.

  - **KILL** **QUERY** terminates the statement the connection is currently executing, but leaves the connection itself intact.

  The ability to see which threads are available to be killed depends on the **PROCESS** privilege:

     - Without **PROCESS**, you can see only your own threads.

     - With **PROCESS**, you can see all threads.
The ability to kill threads and statements depends on the `SUPER` privilege:

- Without `SUPER`, you can kill only your own threads and statements.
- With `SUPER`, you can kill all threads and statements.

You can also use the `mysqladmin processlist` and `mysqladmin kill` commands to examine and kill threads.

**Note**

You cannot use `KILL` with the Embedded MySQL Server library because the embedded server merely runs inside the threads of the host application. It does not create any connection threads of its own.

When you use `KILL`, a thread-specific kill flag is set for the thread. In most cases, it might take some time for the thread to die because the kill flag is checked only at specific intervals:

- During `SELECT` operations, for `ORDER BY` and `GROUP BY` loops, the flag is checked after reading a block of rows. If the kill flag is set, the statement is aborted.
- `ALTER TABLE` operations that make a table copy check the kill flag periodically for each few copied rows read from the original table. If the kill flag was set, the statement is aborted and the temporary table is deleted.

The `KILL` statement returns without waiting for confirmation, but the kill flag check aborts the operation within a reasonably small amount of time. Aborting the operation to perform any necessary cleanup also takes some time.

- During `UPDATE` or `DELETE` operations, the kill flag is checked after each block read and after each updated or deleted row. If the kill flag is set, the statement is aborted. If you are not using transactions, the changes are not rolled back.
- `GET_LOCK()` aborts and returns `NULL`.
- An `INSERT DELAYED` thread quickly flushes (inserts) all rows it has in memory and then terminates.
- If the thread is in the table lock handler (state: Locked), the table lock is quickly aborted.
- If the thread is waiting for free disk space in a write call, the write is aborted with a “disk full” error message.

**Warning**

Killing a `REPAIR TABLE` or `OPTIMIZE TABLE` operation on a `MyISAM` table results in a table that is corrupted and unusable. Any reads or writes to such a table fail until you optimize or repair it again (without interruption).

### 13.7.6.5 LOAD INDEX INTO CACHE Statement

```
LOAD INDEX INTO CACHE
  tbl_index_list [, tbl_index_list] ... 

tbl_index_list:
  tbl_name
    {PARTITION (partition_list)]
    [{(INDEX|KEY} (index_name[, index_name] ...)]
    [IGNORE LEAVES]
```
The `LOAD INDEX INTO CACHE` statement preloads a table index into the key cache to which it has been assigned by an explicit `CACHE INDEX` statement, or into the default key cache otherwise.

`LOAD INDEX INTO CACHE` applies only to `MyISAM` tables, including partitioned `MyISAM` tables. In addition, indexes on partitioned tables can be preloaded for one, several, or all partitions.

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded.

`IGNORE LEAVES` is also supported for partitioned `MyISAM` tables.

The following statement preloads nodes (index blocks) of indexes for the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
```

```
+---------+--------------+----------+----------+
<table>
<thead>
<tr>
<th>Table</th>
<th>Op</th>
<th>Msg_type</th>
<th>Msg_text</th>
</tr>
</thead>
<tbody>
<tr>
<td>test.t1</td>
<td>preload_keys</td>
<td>status</td>
<td>OK</td>
</tr>
<tr>
<td>test.t2</td>
<td>preload_keys</td>
<td>status</td>
<td>OK</td>
</tr>
</tbody>
</table>
+---------+--------------+----------+----------+
```

This statement preloads all index blocks from `t1`. It preloads only blocks for the nonleaf nodes from `t2`.

The syntax of `LOAD INDEX INTO CACHE` enables you to specify that only particular indexes from a table should be preloaded. However, the implementation preloads all the table's indexes into the cache, so there is no reason to specify anything other than the table name.

It is possible to preload indexes on specific partitions of partitioned `MyISAM` tables. For example, of the following 2 statements, the first preloads indexes for partition `p0` of a partitioned table `pt`, while the second preloads the indexes for partitions `p1` and `p3` of the same table:

```
LOAD INDEX INTO CACHE pt PARTITION (p0);
LOAD INDEX INTO CACHE pt PARTITION (p1, p3);
```

To preload the indexes for all partitions in table `pt`, you can use either of the following two statements:

```
LOAD INDEX INTO CACHE pt PARTITION (ALL);
LOAD INDEX INTO CACHE pt;
```

The two statements just shown are equivalent, and issuing either one has exactly the same effect. In other words, if you wish to preload indexes for all partitions of a partitioned table, the `PARTITION (ALL)` clause is optional.

When preloading indexes for multiple partitions, the partitions need not be contiguous, and you need not list their names in any particular order.

`LOAD INDEX INTO CACHE ... IGNORE LEAVES` fails unless all indexes in a table have the same block size. To determine index block sizes for a table, use `myisamchk -dv` and check the `Blocksize` column.

### 13.7.6.6 RESET Statement

```
reset_option: {
    reset_option [, reset_option] ...
}
```
The `RESET` statement is used to clear the state of various server operations. You must have the `RELOAD` privilege to execute `RESET`.

`RESET` acts as a stronger version of the `FLUSH` statement. See Section 13.7.6.3, “FLUSH Statement”.

The `RESET` statement causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

The following list describes the permitted `RESET` statement `reset_option` values:

- **RESET MASTER**
  
  Deletes all binary logs listed in the index file, resets the binary log index file to be empty, and creates a new binary log file.

- **RESET QUERY CACHE**
  
  Removes all query results from the query cache.

- **RESET SLAVE**
  
  Makes the slave forget its replication position in the master binary logs. Also resets the relay log by deleting any existing relay log files and beginning a new one.

### 13.8 Utility Statements

#### 13.8.1 DESCRIBE Statement

The `DESCRIBE` and `EXPLAIN` statements are synonyms, used either to obtain information about table structure or query execution plans. For more information, see Section 13.7.5.6, “SHOW COLUMNS Statement”, and Section 13.8.2, “EXPLAIN Statement”.

#### 13.8.2 EXPLAIN Statement

```
{EXPLAIN | DESCRIBE | DESC} [select_options]
```

```
{EXPLAIN | DESCRIBE | DESC} [explain_type] SELECT select_options
```

The `DESCRIBE` and `EXPLAIN` statements are synonyms. In practice, the `DESCRIBE` keyword is more often used to obtain information about table structure, whereas `EXPLAIN` is used to obtain a query execution plan (that is, an explanation of how MySQL would execute a query).

The following discussion uses the `DESCRIBE` and `EXPLAIN` keywords in accordance with those uses, but the MySQL parser treats them as completely synonymous.

- **Obtaining Table Structure Information**

- **Obtaining Execution Plan Information**
EXPLAIN Statement

Obtaining Table Structure Information

DESCRIBE provides information about the columns in a table:

```
mysql> DESCRIBE City;
+------------+----------+------+-----+---------+----------------+
| Field      | Type     | Null | Key | Default | Extra          |
+------------+----------+------+-----+---------+----------------+
| Id         | int(11)  | NO   | PRI | NULL    | auto_increment |
| Name       | char(35) | NO   |     |         |                |
| Country    | char(3)  | NO   | UNI |         |                |
| District   | char(20) | YES  | MUL |         |                |
| Population | int(11)  | NO   |     | 0       |                |
+------------+----------+------+-----+---------+----------------+
```

DESCRIBE is a shortcut for SHOW COLUMNS. These statements also display information for views. The description for SHOW COLUMNS provides more information about the output columns. See Section 13.7.5.6, “SHOW COLUMNS Statement”.

By default, DESCRIBE displays information about all columns in the table. col_name, if given, is the name of a column in the table. In this case, the statement displays information only for the named column. wild, if given, is a pattern string. It can contain the SQL % and _ wildcard characters. In this case, the statement displays output only for the columns with names matching the string. There is no need to enclose the string within quotation marks unless it contains spaces or other special characters.

The DESCRIBE statement is provided for compatibility with Oracle.

The SHOW CREATE TABLE, SHOW TABLE STATUS, and SHOW INDEX statements also provide information about tables. See Section 13.7.5, “SHOW Statements”.

Obtaining Execution Plan Information

The EXPLAIN statement provides information about how MySQL executes statements:

- When you precede a SELECT statement with the keyword EXPLAIN, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using EXPLAIN to obtain execution plan information, see Section 8.8.2, “EXPLAIN Output Format”.

- EXPLAIN EXTENDED produces additional execution plan information that can be displayed using SHOW WARNINGS. See Section 8.8.3, “Extended EXPLAIN Output Format”.

- EXPLAIN PARTITIONS is useful for examining queries involving partitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

EXPLAIN requires the SELECT privilege for any tables or views accessed, including any underlying tables of views. For views, EXPLAIN also requires the SHOW VIEW privilege.

With the help of EXPLAIN, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use EXPLAIN to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a SELECT statement, begin the statement with SELECT STRAIGHT_JOIN rather than just SELECT. (See Section 13.2.9, “SELECT Statement”.)

If you have a problem with indexes not being used when you believe that they should be, run ANALYZE TABLE to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, “ANALYZE TABLE Statement”.
13.8.3 HELP Statement

HELP 'search_string'

The HELP statement returns online information from the MySQL Reference Manual. Its proper operation requires that the help tables in the mysql database be initialized with help topic information (see Section 5.1.13, “Server-Side Help Support”).

The HELP statement searches the help tables for the given search string and displays the result of the search. The search string is not case-sensitive.

The search string can contain the wildcard characters % and _. These have the same meaning as for pattern-matching operations performed with the LIKE operator. For example, HELP 'rep%' returns a list of topics that begin with rep.

The HELP statement understands several types of search strings:

- At the most general level, use contents to retrieve a list of the top-level help categories:
  HELP 'contents'

- For a list of topics in a given help category, such as Data Types, use the category name:
  HELP 'data types'

- For help on a specific help topic, such as the ASCII() function or the CREATE TABLE statement, use the associated keyword or keywords:
  HELP 'ascii'
  HELP 'create table'

In other words, the search string matches a category, many topics, or a single topic. You cannot necessarily tell in advance whether a given search string will return a list of items or the help information for a single help topic. However, you can tell what kind of response HELP returned by examining the number of rows and columns in the result set.

The following descriptions indicate the forms that the result set can take. Output for the example statements is shown using the familiar “tabular” or “vertical” format that you see when using the mysql client, but note that mysql itself reformats HELP result sets in a different way.

- Empty result set
  No match could be found for the search string.

- Result set containing a single row with three columns
  This means that the search string yielded a hit for the help topic. The result has three columns:
    - name: The topic name.
    - description: Descriptive help text for the topic.
    - example: Usage example or examples. This column might be blank.
Example: HELP 'replace'

Yields:

```
name: REPLACE
description: Syntax: REPLACE(str,from_str,to_str)

Returns the string str with all occurrences of the string from_str replaced by the string to_str. REPLACE() performs a case-sensitive match when searching for from_str.
example: mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
-> 'WwWwWw.mysql.com'
```

• Result set containing multiple rows with two columns

This means that the search string matched many help topics. The result set indicates the help topic names:

• name: The help topic name.

• is_it_category: Y if the name represents a help category, N if it does not. If it does not, the name value when specified as the argument to the HELP statement should yield a single-row result set containing a description for the named item.

Example: HELP 'status'

Yields:

```
+-----------------------+----------------+
| name                  | is_it_category |
+-----------------------+----------------+
| SHOW                  | N              |
| SHOW ENGINE           | N              |
| SHOW MASTER STATUS    | N              |
| SHOW PROCEDURE STATUS | N              |
| SHOW SLAVE STATUS     | N              |
| SHOW STATUS           | N              |
| SHOW TABLE STATUS     | N              |
+-----------------------+----------------+
```

• Result set containing multiple rows with three columns

This means the search string matched a category. The result set contains category entries:

• source_category_name: The help category name.

• name: The category or topic name

• is_it_category: Y if the name represents a help category, N if it does not. If it does not, the name value when specified as the argument to the HELP statement should yield a single-row result set containing a description for the named item.

Example: HELP 'functions'

Yields:

```
+----------------------|-----------------|----------------+
| source_category_name | name             | is_it_category |
|----------------------|-----------------|----------------+
| Functions            | CREATE FUNCTION | N              |
```

1694
## 13.8.4 USE Statement

The **USE** statement tells MySQL to use the named database as the default (current) database for subsequent statements. This statement requires some privilege for the database or some object within it.

The named database remains the default until the end of the session or another **USE** statement is issued:

```
USE db1;
SELECT COUNT(*) FROM mytable;   # selects from db1.mytable
USE db2;
SELECT COUNT(*) FROM mytable;   # selects from db2.mytable
```

The database name must be specified on a single line. Newlines in database names are not supported.

Making a particular database the default by means of the **USE** statement does not preclude accessing tables in other databases. The following example accesses the `author` table from the `db1` database and the `editor` table from the `db2` database:

```
USE db1;
SELECT author_name,editor_name FROM author,db2.editor
WHERE author.editor_id = db2.editor.editor_id;
```
Chapter 14 The InnoDB Storage Engine

Table of Contents

14.1 Introduction to InnoDB ................................................................. 1698
  14.1.1 Benefits of Using InnoDB Tables ........................................ 1700
  14.1.2 Best Practices for InnoDB Tables ...................................... 1701
  14.1.3 Checking InnoDB Availability ........................................ 1702
  14.1.4 Upward and Downward Compatibility ................................. 1702
  14.1.5 Testing and Benchmarking with InnoDB ............................. 1703
  14.1.6 Turning Off InnoDB .................................................... 1703
  14.1.7 Third-Party Software Contributions .................................. 1704
14.2 Installing the InnoDB Storage Engine .................................. 1706
14.3 Upgrading the InnoDB Storage Engine .................................. 1706
14.4 Downgrading the InnoDB Storage Engine .............................. 1707
14.5 InnoDB and the ACID Model ................................................. 1707
14.6 InnoDB Multi-Versioning ................................................... 1708
14.7 InnoDB Architecture ......................................................... 1709
14.8 InnoDB In-Memory Structures .............................................. 1710
  14.8.1 Buffer Pool ................................................................. 1710
  14.8.2 Change Buffer ............................................................ 1715
  14.8.3 Adaptive Hash Index .................................................. 1718
  14.8.4 Log Buffer ................................................................. 1719
14.9 InnoDB On-Disk Structures .................................................. 1719
  14.9.1 Tables ........................................................................ 1719
  14.9.2 Indexes ..................................................................... 1733
  14.9.3 Tablespaces ............................................................... 1734
  14.9.4 InnoDB Data Dictionary ............................................... 1739
  14.9.5 Doublewrite Buffer ...................................................... 1739
  14.9.6 Redo Log ................................................................. 1740
  14.9.7 Undo Logs ................................................................. 1740
14.10 InnoDB Locking and Transaction Model ............................ 1741
  14.10.1 InnoDB Locking ......................................................... 1742
  14.10.2 InnoDB Transaction Model ......................................... 1746
  14.10.3 Locks Set by Different SQL Statements in InnoDB ............ 1754
  14.10.4 Phantom Rows ......................................................... 1757
  14.10.5 Deadlocks in InnoDB ................................................. 1758
14.11 InnoDB Configuration ........................................................... 1761
  14.11.1 InnoDB Startup Configuration ..................................... 1761
  14.11.2 InnoDB Buffer Pool Configuration ................................ 1766
  14.11.3 Configuring the Memory Allocator for InnoDB ............... 1769
  14.11.4 Configuring Thread Concurrency for InnoDB .................. 1770
  14.11.5 Configuring the Number of Background InnoDB I/O Threads .. 1771
  14.11.6 Using Asynchronous I/O on Linux ................................ 1772
  14.11.7 Configuring InnoDB I/O Capacity ................................ 1772
  14.11.8 Configuring Spin Lock Polling .................................... 1773
  14.11.9 Purge Configuration ................................................ 1774
  14.11.10 Configuring Optimizer Statistics for InnoDB .................. 1775
14.12 InnoDB Table Compression ................................................. 1776
  14.12.1 Overview of Table Compression ................................... 1777
  14.12.2 Enabling Compression for a Table ............................... 1777
  14.12.3 Tuning Compression for InnoDB Tables ......................... 1778
14.1 Introduction to InnoDB

InnoDB is a general-purpose storage engine that balances high reliability and high performance. Starting from MySQL 5.5.5, the default storage engine for new tables is InnoDB rather than MyISAM. Unless you have configured a different default storage engine, issuing a CREATE TABLE statement without an ENGINE= clause creates an InnoDB table. Given this change of default behavior, MySQL 5.5 might be a logical point to evaluate whether tables that use MyISAM could benefit from switching to InnoDB.
Key Advantages of InnoDB

InnoDB includes all the features that were part of the InnoDB Plugin for MySQL 5.1, plus new features specific to MySQL 5.5 and higher.

**Note**
The `mysql` and `INFORMATION_SCHEMA` databases that implement some of the MySQL internals still use MyISAM. In particular, you cannot switch the grant tables to use InnoDB.

**Key Advantages of InnoDB**

- Its DML operations follow the ACID model, with transactions featuring commit, rollback, and crash-recovery capabilities to protect user data. See Section 14.5, “InnoDB and the ACID Model” for more information.


- InnoDB tables arrange your data on disk to optimize queries based on primary keys. Each InnoDB table has a primary key index called the clustered index that organizes the data to minimize I/O for primary key lookups. See Section 14.9.2.1, “Clustered and Secondary Indexes” for more information.

- To maintain data integrity, InnoDB supports FOREIGN KEY constraints. With foreign keys, inserts, updates, and deletes are checked to ensure they do not result in inconsistencies across different tables. See Section 13.1.17.6, “FOREIGN KEY Constraints” for more information.

**Table 14.1 InnoDB Storage Engine Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-tree indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backup/point-in-time recovery (Implemented in the server, rather than in the storage engine.)</td>
<td>Yes</td>
</tr>
<tr>
<td>Cluster database support</td>
<td>No</td>
</tr>
<tr>
<td>Clustered indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Compressed data</td>
<td>Yes</td>
</tr>
<tr>
<td>Data caches</td>
<td>Yes</td>
</tr>
<tr>
<td>Encrypted data</td>
<td>Yes (Implemented in the server via encryption functions; In MySQL 5.7 and later, data-at-rest tablespace encryption is supported.)</td>
</tr>
<tr>
<td>Foreign key support</td>
<td>Yes</td>
</tr>
<tr>
<td>Full-text search indexes</td>
<td>Yes (InnoDB support for FULLTEXT indexes is available in MySQL 5.6 and later.)</td>
</tr>
<tr>
<td>Geospatial data type support</td>
<td>Yes</td>
</tr>
<tr>
<td>Geospatial indexing support</td>
<td>Yes (InnoDB support for geospatial indexing is available in MySQL 5.7 and later.)</td>
</tr>
<tr>
<td>Hash indexes</td>
<td>No (InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.)</td>
</tr>
</tbody>
</table>
InnoDB Enhancements and New Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index caches</td>
<td>Yes</td>
</tr>
<tr>
<td>Locking granularity</td>
<td>Row</td>
</tr>
<tr>
<td>MVCC</td>
<td>Yes</td>
</tr>
<tr>
<td>Replication support (Implemented in the server, rather than in the storage engine.)</td>
<td>Yes</td>
</tr>
<tr>
<td>Storage limits</td>
<td>64TB</td>
</tr>
<tr>
<td>T-tree indexes</td>
<td>No</td>
</tr>
<tr>
<td>Transactions</td>
<td>Yes</td>
</tr>
<tr>
<td>Update statistics for data dictionary</td>
<td>Yes</td>
</tr>
</tbody>
</table>

To compare the features of InnoDB with other storage engines provided with MySQL, see the Storage Engine Features table in Chapter 15, Alternative Storage Engines.

InnoDB Enhancements and New Features

The InnoDB storage engine in MySQL 5.5 releases includes a number of performance improvements that in MySQL 5.1 were only available by installing the InnoDB Plugin. This latest InnoDB offers new features, improved performance and scalability, enhanced reliability and new capabilities for flexibility and ease of use.

For information about InnoDB enhancements and new features, refer to:

- The InnoDB enhancements list in Section 1.4, “What Is New in MySQL 5.5”.
- The Release Notes.

Additional InnoDB Information and Resources

- For InnoDB-related terms and definitions, see the MySQL Glossary.
- For a forum dedicated to the InnoDB storage engine, see MySQL Forums::InnoDB.
- InnoDB is published under the same GNU GPL License Version 2 (of June 1991) as MySQL. For more information on MySQL licensing, see http://www.mysql.com/company/legal/licensing/.

14.1.1 Benefits of Using InnoDB Tables

You may find InnoDB tables beneficial for the following reasons:

- If your server crashes because of a hardware or software issue, regardless of what was happening in the database at the time, you don't need to do anything special after restarting the database. InnoDB crash recovery automatically finalizes any changes that were committed before the time of the crash, and undoes any changes that were in process but not committed. Just restart and continue where you left off. This process is now much faster than in MySQL 5.1 and earlier.

- The InnoDB storage engine maintains its own buffer pool that caches table and index data in main memory as data is accessed. Frequently used data is processed directly from memory. This cache applies to many types of information and speeds up processing. On dedicated database servers, up to 80% of physical memory is often assigned to the buffer pool.

- If you split up related data into different tables, you can set up foreign keys that enforce referential integrity. Update or delete data, and the related data in other tables is updated or deleted automatically.
Best Practices for InnoDB Tables

Try to insert data into a secondary table without corresponding data in the primary table, and the bad data gets kicked out automatically.

- If data becomes corrupted on disk or in memory, a checksum mechanism alerts you to the bogus data before you use it.

- When you design your database with appropriate primary key columns for each table, operations involving those columns are automatically optimized. It is very fast to reference the primary key columns in WHERE clauses, ORDER BY clauses, GROUP BY clauses, and join operations.

- Inserts, updates, deletes are optimized by an automatic mechanism called change buffering. InnoDB not only allows concurrent read and write access to the same table, it caches changed data to streamline disk I/O.

- Performance benefits are not limited to giant tables with long-running queries. When the same rows are accessed over and over from a table, a feature called the Adaptive Hash Index takes over to make these lookups even faster, as if they came out of a hash table.

- You can freely mix InnoDB tables with tables from other MySQL storage engines, even within the same statement. For example, you can use a join operation to combine data from InnoDB and MEMORY tables in a single query.

- InnoDB has been designed for CPU efficiency and maximum performance when processing large data volumes.

- InnoDB tables can handle large quantities of data, even on operating systems where file size is limited to 2GB.

For InnoDB-specific tuning techniques you can apply in your application code, see Section 8.5, “Optimizing for InnoDB Tables”.

14.1.2 Best Practices for InnoDB Tables

This section describes best practices when using InnoDB tables.

- Specify a primary key for every table using the most frequently queried column or columns, or an autoincrement value if there is no obvious primary key.

- Using joins wherever data is pulled from multiple tables based on identical ID values from those tables. For fast join performance, define foreign keys on the join columns, and declare those columns with the same data type in each table. Adding foreign keys ensures that referenced columns are indexed, which can improve performance. Foreign keys also propagate deletes or updates to all affected tables, and prevent insertion of data in a child table if the corresponding IDs are not present in the parent table.

- Turning off autocommit. Committing hundreds of times a second puts a cap on performance (limited by the write speed of your storage device).

- Grouping sets of related DML operations into transactions, by bracketing them with START TRANSACTION and COMMIT statements. While you don't want to commit too often, you also don't want to issue huge batches of INSERT, UPDATE, or DELETE statements that run for hours without committing.

- Not using LOCK TABLES statements. InnoDB can handle multiple sessions all reading and writing to the same table at once, without sacrificing reliability or high performance. To get exclusive write access to a set of rows, use the SELECT ... FOR UPDATE syntax to lock just the rows you intend to update.

- Enabling the innodb_file_per_table option to put the data and indexes for individual tables into separate files, instead of the system tablespace. This setting is required to use some of the other features, such as table compression.
• Evaluating whether your data and access patterns benefit from the InnoDB table compression feature. You can compress InnoDB tables without sacrificing read/write capability.

• Running your server with the option `--sql_mode=NO_ENGINE_SUBSTITUTION` to prevent tables being created with a different storage engine if there is an issue with the engine specified in the ENGINE= clause of CREATE TABLE.

14.1.3 Checking InnoDB Availability

To determine whether your server supports InnoDB:

• Issue the `SHOW ENGINES` statement to view the available MySQL storage engines. Look for DEFAULT in the InnoDB line.

  ```
  mysql> SHOW ENGINES;
  ```

  Alternatively, query the INFORMATION_SCHEMA.ENGINES table.

  ```
  mysql> SELECT * FROM INFORMATION_SCHEMA.ENGINES;
  ```

  (Now that InnoDB is the default MySQL storage engine, only very specialized environments might not support it.)

• Issue a `SHOW VARIABLES` statement to confirm that InnoDB is available.

  ```
  mysql> SHOW VARIABLES LIKE 'have_innodb';
  ```

• If InnoDB is not present, you have a mysqld binary that was compiled without InnoDB support and you need to get a different one.

• If InnoDB is present but disabled, go back through your startup options and configuration file and get rid of any `--skip-innodb` option.

14.1.4 Upward and Downward Compatibility

The ability to use the InnoDB table compression feature introduced in MySQL 5.5 and the new row format require the use of a new InnoDB file format called Barracuda. The previous file format, used by the built-in InnoDB in MySQL 5.1 and earlier, is now called Antelope and does not support these features, but does support the other features introduced with the InnoDB storage engine.

The InnoDB storage engine is upward compatible from standard InnoDB as built in to, and distributed with, MySQL. Existing databases can be used with the InnoDB Storage Engine for MySQL. The new parameter `innodb_file_format` can help protect upward and downward compatibility between InnoDB versions and database files, allowing users to enable or disable use of new features that can only be used with certain versions of InnoDB.

InnoDB since version 5.0.21 has a safety feature that prevents it from opening tables that are in an unknown format. However, the system tablespace may contain references to new-format tables that confuse the built-in InnoDB in MySQL 5.1 and earlier. These references are cleared in a slow shutdown.

With previous versions of InnoDB, no error would be returned until you try to access a table that is in a format “too new” for the software. To provide early feedback, InnoDB now checks the system tablespace before startup to ensure that the file format used in the database is supported by the storage engine. See Section 14.13.2.1, “Compatibility Check When InnoDB Is Started” for the details.
14.1.5 Testing and Benchmarking with InnoDB

If InnoDB is not your default storage engine, you can determine if your database server or applications work correctly with InnoDB by restarting the server with `--default-storage-engine=InnoDB` defined on the command line or with `default-storage-engine=innodb` defined in the [mysqld] section of your MySQL server option file.

Since changing the default storage engine only affects new tables as they are created, run all your application installation and setup steps to confirm that everything installs properly. Then exercise all the application features to make sure all the data loading, editing, and querying features work. If a table relies on a feature that is specific to another storage engine, you will receive an error; add the `ENGINE=other_engine_name` clause to the CREATE TABLE statement to avoid the error.

If you did not make a deliberate decision about the storage engine, and you want to preview how certain tables work when created using InnoDB, issue the command `ALTER TABLE table_name ENGINE=InnoDB;` for each table. Or, to run test queries and other statements without disturbing the original table, make a copy:

```sql
CREATE TABLE InnoDB_Table (...) ENGINE=InnoDB AS SELECT * FROM other_engine_table;
```

To assess performance with a full application under a realistic workload, install the latest MySQL server and run benchmarks.

Test the full application lifecycle, from installation, through heavy usage, and server restart. Kill the server process while the database is busy to simulate a power failure, and verify that the data is recovered successfully when you restart the server.

Test any replication configurations, especially if you use different MySQL versions and options on the master and slaves.

14.1.6 Turning Off InnoDB

Oracle recommends InnoDB as the preferred storage engine for typical database applications, from single-user wikis and blogs running on a local system, to high-end applications pushing the limits of performance. As of MySQL 5.5, InnoDB is the default storage engine for new tables.

If you do not want to use InnoDB tables:

• Start the server with the `--innodb=OFF` or `--skip-innodb` option to disable the InnoDB storage engine.

• Because the default storage engine is InnoDB, the server will not start unless you also change the `default_storage_engine` system variable to set the default to some other available engine.

• To prevent the server from crashing when the InnoDB-related information_schema tables are queried, also disable the plugins associated with those tables. Specify in the [mysqld] section of the MySQL configuration file:

```
loose-innodb-trx=0
loose-innodb-locks=0
loose-innodb-lock-waits=0
loose-innodb-cmp=0
loose-innodb-cmp-per-index=0
loose-innodb-cmp-per-index-reset=0
loose-innodb-cmp-reset=0
loose-innodb-cmpmem=0
loose-innodb-cmpmem-reset=0
loose-innodb-buffer-page=0
loose-innodb-buffer-page-lru=0
loose-innodb-buffer-pool-stats=0
```
14.1.7 Third-Party Software Contributions

Oracle acknowledges that certain Third Party and Open Source software has been used to develop or is incorporated in the InnoDB storage engine. This appendix includes required third-party license information.

14.1.7.1 Performance Patches from Google

Oracle gratefully acknowledges the following contributions from Google, Inc. to improve InnoDB performance:

- Replacing InnoDB's use of Pthreads mutexes with calls to GCC atomic builtins. This change means that InnoDB mutex and rw-lock operations take less CPU time, and improves throughput on those platforms where the atomic operations are available.

- Controlling InnoDB I/O capacity, as discussed in Section 14.11.7, “Configuring InnoDB I/O Capacity”. InnoDB performs various tasks in the background. Historically, InnoDB has used a hard coded value as the total I/O capacity of the server. With this change, user can control the number of I/O operations that can be performed per second based on their own workload.

Changes from the Google contributions were incorporated in the following source code files: `btr0cur.c`, `btr0sea.c`, `buf0buf.c`, `buf0buf.ic`, `ha_innodb.cc`, `log0log.c`, `log0log.h`, `os0sync.h`, `row0sel.c`, `srv0srv.c`, `srv0srv.h`, `srv0start.c`, `sync0arr.c`, `sync0rw.c`, `sync0rw.h`, `sync0rw.ic`, `sync0sync.c`, `sync0sync.h`, `sync0sync.ic`, and `univ.i`.

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14.1.7.2 Multiple Background I/O Threads Patch from Percona

Oracle gratefully acknowledges the contribution of Percona, Inc. to improve InnoDB performance by implementing configurable background threads, as discussed in Section 14.11.5, “Configuring the Number
Third-Party Software Contributions

of Background InnoDB I/O Threads". InnoDB uses background threads to service various types of I/O requests. The change provides another way to make InnoDB more scalable on high end systems.

Changes from the Percona, Inc. contribution were incorporated in the following source code files: ha_innodb.cc, os0file.c, os0file.h, srv0srv.c, srv0srv.h, and srv0start.c.

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14.1.7.3 Performance Patches from Sun Microsystems

Oracle gratefully acknowledges the following contributions from Sun Microsystems, Inc. to improve InnoDB performance:

• Introducing the PAUSE instruction inside spin loops. This change increases performance in high concurrency, CPU-bound workloads.

• Enabling inlining of functions and prefetch with Sun Studio.

Changes from the Sun Microsystems, Inc. contribution were incorporated in the following source code files: univ.i, ut0ut.c, and ut0ut.h.

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14.2 Installing the InnoDB Storage Engine

When you use the InnoDB storage engine 1.1 and above, with MySQL 5.5 and above, you do not need to do anything special to install: everything comes configured as part of the MySQL source and binary distributions. This is a change from earlier releases of the InnoDB Plugin, where you were required to match up MySQL and InnoDB version numbers and update your build and configuration processes.

The InnoDB storage engine is included in the MySQL distribution, starting from MySQL 5.1.38. From MySQL 5.1.46 and up, this is the only download location for the InnoDB storage engine; it is not available from the InnoDB website.

If you used any scripts or configuration files with the earlier InnoDB storage engine from the InnoDB website, be aware that the filename of the shared library as supplied by MySQL is `ha_innodb_plugin.so` or `ha_innodb_plugin.dll`, as opposed to `ha_innodb.so` or `ha_innodb.dll` in the older Plugin downloaded from the InnoDB website. You might need to change the applicable file names in your startup or configuration scripts.

Because the InnoDB storage engine has now replaced the built-in InnoDB, you no longer need to specify options like `--ignore-built-in-innodb` and `--plugin-load` during startup.

To take best advantage of current InnoDB features, we recommend specifying the following options in your configuration file:

```
innoDb_file_per_table=1
innoDb_file_format=barracuda
innoDb_strict_mode=1
```

For information about these features, see Section 14.17, “InnoDB Startup Options and System Variables”, Section 14.13, “InnoDB File-Format Management”, and `innodb_strict_mode`. You might need to continue to use the previous values for these parameters in some replication and similar configurations involving both new and older versions of MySQL.

14.3 Upgrading the InnoDB Storage Engine

Prior to MySQL 5.5, some upgrade scenarios involved upgrading the separate instance of InnoDB known as the InnoDB Plugin. In MySQL 5.5 and higher, the features of the InnoDB Plugin have been folded back into built-in InnoDB, so the upgrade procedure for InnoDB is the same as the one for the MySQL server. For details, see Section 2.11, “Upgrading MySQL”.

1706
14.4 Downgrading the InnoDB Storage Engine

Prior to MySQL 5.5, some downgrade scenarios involved switching the separate instance of InnoDB known as the InnoDB Plugin back to the built-in InnoDB storage engine. In MySQL 5.5 and higher, the features of the InnoDB Plugin have been folded back into built-in InnoDB, so the downgrade procedure for InnoDB is the same as the one for the MySQL server. For details, see Section 2.12, “Downgrading MySQL”.

14.5 InnoDB and the ACID Model

The ACID model is a set of database design principles that emphasize aspects of reliability that are important for business data and mission-critical applications. MySQL includes components such as the InnoDB storage engine that adhere closely to the ACID model, so that data is not corrupted and results are not distorted by exceptional conditions such as software crashes and hardware malfunctions. When you rely on ACID-compliant features, you do not need to reinvent the wheel of consistency checking and crash recovery mechanisms. In cases where you have additional software safeguards, ultra-reliable hardware, or an application that can tolerate a small amount of data loss or inconsistency, you can adjust MySQL settings to trade some of the ACID reliability for greater performance or throughput.

The following sections discuss how MySQL features, in particular the InnoDB storage engine, interact with the categories of the ACID model:

• A: atomicity.
• C: consistency.
• I: isolation.
• D: durability.

Atomicity

The atomicity aspect of the ACID model mainly involves InnoDB transactions. Related MySQL features include:

• Autocommit setting.
• COMMIT statement.
• ROLLBACK statement.
• Operational data from the INFORMATION_SCHEMA tables.

Consistency

The consistency aspect of the ACID model mainly involves internal InnoDB processing to protect data from crashes. Related MySQL features include:

• InnoDB doublewrite buffer.
• InnoDB crash recovery.

Isolation

The isolation aspect of the ACID model mainly involves InnoDB transactions, in particular the isolation level that applies to each transaction. Related MySQL features include:
Durability

The **durability** aspect of the ACID model involves MySQL software features interacting with your particular hardware configuration. Because of the many possibilities depending on the capabilities of your CPU, network, and storage devices, this aspect is the most complicated to provide concrete guidelines for. (And those guidelines might take the form of buy “new hardware”.) Related MySQL features include:

- **InnoDB doublewrite buffer**, turned on and off by the `innodb_doublewrite` configuration option.
- Configuration option `innodb_flush_log_at_trx_commit`.
- Configuration option `sync_binlog`.
- Configuration option `innodb_file_per_table`.
- Write buffer in a storage device, such as a disk drive, SSD, or RAID array.
- Battery-backed cache in a storage device.
- The operating system used to run MySQL, in particular its support for the `fsync()` system call.
- Uninterruptible power supply (UPS) protecting the electrical power to all computer servers and storage devices that run MySQL servers and store MySQL data.
- Your backup strategy, such as frequency and types of backups, and backup retention periods.
- For distributed or hosted data applications, the particular characteristics of the data centers where the hardware for the MySQL servers is located, and network connections between the data centers.

### 14.6 InnoDB Multi-Versioning

**InnoDB** is a multi-versioned storage engine: it keeps information about old versions of changed rows, to support transactional features such as concurrency and rollback. This information is stored in the tablespace in a data structure called a rollback segment (after an analogous data structure in Oracle). InnoDB uses the information in the rollback segment to perform the undo operations needed in a transaction rollback. It also uses the information to build earlier versions of a row for a consistent read.

Internally, InnoDB adds three fields to each row stored in the database. A 6-byte `DB_TRX_ID` field indicates the transaction identifier for the last transaction that inserted or updated the row. Also, a deletion is treated internally as an update where a special bit in the row is set to mark it as deleted. Each row also contains a 7-byte `DB_ROLL_PTR` field called the roll pointer. The roll pointer points to an undo log record written to the rollback segment. If the row was updated, the undo log record contains the information necessary to rebuild the content of the row before it was updated. A 6-byte `DB_ROW_ID` field contains a row ID that increases monotonically as new rows are inserted. If InnoDB generates a clustered index automatically, the index contains row ID values. Otherwise, the `DB_ROW_ID` column does not appear in any index.

Undo logs in the rollback segment are divided into insert and update undo logs. Insert undo logs are needed only in transaction rollback and can be discarded as soon as the transaction commits. Update
undo logs are used also in consistent reads, but they can be discarded only after there is no transaction present for which InnoDB has assigned a snapshot that in a consistent read could need the information in the update undo log to build an earlier version of a database row.

Commit your transactions regularly, including those transactions that issue only consistent reads. Otherwise, InnoDB cannot discard data from the update undo logs, and the rollback segment may grow too big, filling up your tablespace.

The physical size of an undo log record in the rollback segment is typically smaller than the corresponding inserted or updated row. You can use this information to calculate the space needed for your rollback segment.

In the InnoDB multi-versioning scheme, a row is not physically removed from the database immediately when you delete it with an SQL statement. InnoDB only physically removes the corresponding row and its index records when it discards the update undo log record written for the deletion. This removal operation is called a purge, and it is quite fast, usually taking the same order of time as the SQL statement that did the deletion.

If you insert and delete rows in smallish batches at about the same rate in the table, the purge thread can start to lag behind and the table can grow bigger and bigger because of all the “dead” rows, making everything disk-bound and very slow. In such a case, throttle new row operations, and allocate more resources to the purge thread by tuning the innodb_max_purge_lag system variable. See Section 14.17, “InnoDB Startup Options and System Variables” for more information.

Multi-Versioning and Secondary Indexes

InnoDB multiversion concurrency control (MVCC) treats secondary indexes differently than clustered indexes. Records in a clustered index are updated in-place, and their hidden system columns point undo log entries from which earlier versions of records can be reconstructed. Unlike clustered index records, secondary index records do not contain hidden system columns nor are they updated in-place.

When a secondary index column is updated, old secondary index records are delete-marked, new records are inserted, and delete-marked records are eventually purged. When a secondary index record is delete-marked or the secondary index page is updated by a newer transaction, InnoDB looks up the database record in the clustered index. In the clustered index, the record’s DB_TRX_ID is checked, and the correct version of the record is retrieved from the undo log if the record was modified after the reading transaction was initiated.

If a secondary index record is marked for deletion or the secondary index page is updated by a newer transaction, the covering index technique is not used. Instead of returning values from the index structure, InnoDB looks up the record in the clustered index.

14.7 InnoDB Architecture

The following diagram shows in-memory and on-disk structures that comprise the InnoDB storage engine architecture. For information about each structure, see Section 14.8, “InnoDB In-Memory Structures”, and Section 14.9, “InnoDB On-Disk Structures”.
14.8 InnoDB In-Memory Structures

This section describes InnoDB in-memory structures and related topics.

14.8.1 Buffer Pool

The buffer pool is an area in main memory where InnoDB caches table and index data as it is accessed. The buffer pool permits frequently used data to be processed directly from memory, which speeds up processing. On dedicated servers, up to 80% of physical memory is often assigned to the buffer pool.

For efficiency of high-volume read operations, the buffer pool is divided into pages that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache using a variation of the LRU algorithm.

Knowing how to take advantage of the buffer pool to keep frequently accessed data in memory is an important aspect of MySQL tuning.

Buffer Pool LRU Algorithm

The buffer pool is managed as a list using a variation of the least recently used (LRU) algorithm. When room is needed to add a new page to the buffer pool, the least recently used page is evicted and a new page is added to the middle of the list. This midpoint insertion strategy treats the list as two sublists:
• At the head, a sublist of new (“young”) pages that were accessed recently
• At the tail, a sublist of old pages that were accessed less recently

**Figure 14.2 Buffer Pool List**

The algorithm keeps heavily pages in the new sublist. The old sublist contains less-used pages; these pages are candidates for **eviction**.

By default, the algorithm operates as follows:

• 3/8 of the buffer pool is devoted to the old sublist.

• The midpoint of the list is the boundary where the tail of the new sublist meets the head of the old sublist.
• When InnoDB reads a page into the buffer pool, it initially inserts it at the midpoint (the head of the old sublist). A page can be read because it is required for a user-initiated operation such as an SQL query, or as part of a read-ahead operation performed automatically by InnoDB.

• Accessing a page in the old sublist makes it “young”, moving it to the head of the new sublist. If the page was read because it was required by a user-initiated operation, the first access occurs immediately and the page is made young. If the page was read due to a read-ahead operation, the first access does not occur immediately, and might not occur at all before the page is evicted.

• As the database operates, pages in the buffer pool that are not accessed “age” by moving toward the tail of the list. Pages in both the new and old sublists age as other pages are made new. Pages in the old sublist also age as pages are inserted at the midpoint. Eventually, a page that remains unused reaches the tail of the old sublist and is evicted.

By default, pages read by queries are immediately moved into the new sublist, meaning they stay in the buffer pool longer. A table scan, performed for a mysqldump operation or a SELECT statement with no WHERE clause, for example, can bring a large amount of data into the buffer pool and evict an equivalent amount of older data, even if the new data is never used again. Similarly, pages that are loaded by the read-ahead background thread and accessed only once are moved to the head of the new list. These situations can push frequently used pages to the old sublist where they become subject to eviction. For information about optimizing this behavior, see Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”, and Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

InnoDB Standard Monitor output contains several fields in the BUFFER POOL AND MEMORY section regarding operation of the buffer pool LRU algorithm. For details, see Monitoring the Buffer Pool Using the InnoDB Standard Monitor.

Buffer Pool Configuration

You can configure the various aspects of the buffer pool to improve performance.

• Ideally, you set the size of the buffer pool to as large a value as practical, leaving enough memory for other processes on the server to run without excessive paging. The larger the buffer pool, the more InnoDB acts like an in-memory database, reading data from disk once and then accessing the data from memory during subsequent reads. Buffer pool size is configured using the innodb_buffer_pool_size configuration option.

• On 64-bit systems with sufficient memory, you can split the buffer pool into multiple parts to minimize contention for memory structures among concurrent operations. For details, see Section 14.11.2.1, “Configuring Multiple Buffer Pool Instances”.

• You can keep frequently accessed data in memory regardless of sudden spikes of activity from operations that would bring large amounts of infrequently accessed data into the buffer pool. For details, see Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”.

• You can control when and how to perform read-ahead requests to prefetch pages into the buffer pool asynchronously in anticipation that the pages will be needed soon. For details, see Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

• You can control when background flushing occurs and whether or not the rate of flushing is dynamically adjusted based on workload. For details, see Section 14.11.2.4, “Configuring Buffer Pool Flushing”.

Monitoring the Buffer Pool Using the InnoDB Standard Monitor

InnoDB Standard Monitor output, which can be accessed using SHOW ENGINE INNODB STATUS, provides metrics regarding operation of the buffer pool. Buffer pool metrics are located in the BUFFER POOL AND MEMORY section of InnoDB Standard Monitor output and appear similar to the following:
Buffer Pool

---

**BUFFER POOL AND MEMORY**

Total memory allocated 2217738240; in additional pool allocated 0
Dictionary memory allocated 121719
Buffer pool size 131072
Free buffers 129937
Database pages 1134
Old database pages 211
Modified db pages 187
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 426, created 708, written 768
0.00 reads/s, 40.99 creates/s, 50.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 1134, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]

The following table describes buffer pool metrics reported by the InnoDB Standard Monitor.

---

**Note**

Per second averages provided in InnoDB Standard Monitor output are based on the elapsed time since InnoDB Standard Monitor output was last printed.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total memory allocated</td>
<td>The total memory allocated for the buffer pool in bytes.</td>
</tr>
<tr>
<td>additional pool allocated</td>
<td>The total memory allocated for the additional pool in bytes.</td>
</tr>
<tr>
<td>Dictionary memory allocated</td>
<td>The total memory allocated for the InnoDB data dictionary in bytes.</td>
</tr>
<tr>
<td>Buffer pool size</td>
<td>The total size in pages allocated to the buffer pool.</td>
</tr>
<tr>
<td>Free buffers</td>
<td>The total size in pages of the buffer pool free list.</td>
</tr>
<tr>
<td>Database pages</td>
<td>The total size in pages of the buffer pool LRU list.</td>
</tr>
<tr>
<td>Old database pages</td>
<td>The total size in pages of the buffer pool old LRU sublist.</td>
</tr>
<tr>
<td>Modified db pages</td>
<td>The current number of pages modified in the buffer pool.</td>
</tr>
<tr>
<td>Pending reads</td>
<td>The number of buffer pool pages waiting to be read into the buffer pool.</td>
</tr>
<tr>
<td>Pending writes LRU</td>
<td>The number of old dirty pages within the buffer pool to be written from the bottom of the LRU list.</td>
</tr>
<tr>
<td>Pending writes flush list</td>
<td>The number of buffer pool pages to be flushed during checkpointing.</td>
</tr>
<tr>
<td>Pending writes single page</td>
<td>The number of pending independent page writes within the buffer pool.</td>
</tr>
<tr>
<td>Pages made young</td>
<td>The total number of pages made young in the buffer pool LRU list (moved to the head of sublist of “new” pages).</td>
</tr>
<tr>
<td>Pages made not young</td>
<td>The total number of pages not made young in the buffer pool LRU list (pages that have remained in the “old” sublist without being made young).</td>
</tr>
</tbody>
</table>
Buffer Pool

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>youngs/s</td>
<td>The per second average of accesses to old pages in the buffer pool LRU list that have resulted in making pages young. See the notes that follow this table for more information.</td>
</tr>
<tr>
<td>non-youngs/s</td>
<td>The per second average of accesses to old pages in the buffer pool LRU list that have resulted in not making pages young. See the notes that follow this table for more information.</td>
</tr>
<tr>
<td>Pages read</td>
<td>The total number of pages read from the buffer pool.</td>
</tr>
<tr>
<td>Pages created</td>
<td>The total number of pages created within the buffer pool.</td>
</tr>
<tr>
<td>Pages written</td>
<td>The total number of pages written from the buffer pool.</td>
</tr>
<tr>
<td>reads/s</td>
<td>The per second average number of buffer pool page reads per second.</td>
</tr>
<tr>
<td>creates/s</td>
<td>The per second average number of buffer pool pages created per second.</td>
</tr>
<tr>
<td>writes/s</td>
<td>The per second average number of buffer pool page writes per second.</td>
</tr>
<tr>
<td>Buffer pool hit rate</td>
<td>The buffer pool page hit rate for pages read from the buffer pool memory vs from disk storage.</td>
</tr>
<tr>
<td>young-making rate</td>
<td>The average hit rate at which page accesses have resulted in making pages young. See the notes that follow this table for more information.</td>
</tr>
<tr>
<td>not (young-making rate)</td>
<td>The average hit rate at which page accesses have not resulted in making pages young. See the notes that follow this table for more information.</td>
</tr>
<tr>
<td>Pages read ahead</td>
<td>The per second average of read ahead operations.</td>
</tr>
<tr>
<td>Pages evicted without access</td>
<td>The per second average of the pages evicted without being accessed from the buffer pool.</td>
</tr>
<tr>
<td>Random read ahead</td>
<td>The per second average of random read ahead operations.</td>
</tr>
<tr>
<td>LRU len</td>
<td>The total size in pages of the buffer pool LRU list.</td>
</tr>
<tr>
<td>unzip_LRU len</td>
<td>The total size in pages of the buffer pool unzip_LRU list.</td>
</tr>
<tr>
<td>I/O sum</td>
<td>The total number of buffer pool LRU list pages accessed, for the last 50 seconds.</td>
</tr>
<tr>
<td>I/O cur</td>
<td>The total number of buffer pool LRU list pages accessed.</td>
</tr>
<tr>
<td>I/O unzip sum</td>
<td>The total number of buffer pool unzip_LRU list pages accessed.</td>
</tr>
<tr>
<td>I/O unzip cur</td>
<td>The total number of buffer pool unzip_LRU list pages accessed.</td>
</tr>
</tbody>
</table>

Notes:

- The `youngs/s` metric is applicable only to old pages. It is based on the number of accesses to pages and not the number of pages. There can be multiple accesses to a given page, all of which are counted. If you see very low `youngs/s` values when there are no large scans occurring, you might need to reduce the delay time or increase the percentage of the buffer pool used for the old sublist. Increasing the percentage makes the old sublist larger, so pages in that sublist take longer to move to the tail, which increases the likelihood that those pages will be accessed again and made young.

- The `non-youngs/s` metric is applicable only to old pages. It is based on the number of accesses to pages and not the number of pages. There can be multiple accesses to a given page, all of which are
counted. If you do not see a higher non-youngs/s value when performing large table scans (and a higher youngs/s value), increase the delay value.

- The young-making rate accounts for accesses to all buffer pool pages, not just accesses to pages in the old sublist. The young-making rate and not rate do not normally add up to the overall buffer pool hit rate. Page hits in the old sublist cause pages to move to the new sublist, but page hits in the new sublist cause pages to move to the head of the list only if they are a certain distance from the head.

- not (young-making rate) is the average hit rate at which page accesses have not resulted in making pages young due to the delay defined by `innodb_old_blocks_time` not being met, or due to page hits in the new sublist that did not result in pages being moved to the head. This rate accounts for accesses to all buffer pool pages, not just accesses to pages in the old sublist.

Buffer pool server status variables and the `INNODB_BUFFER_POOL_STATS` table provide many of the same buffer pool metrics found in InnoDB Standard Monitor output. For more information, see Example 14.6, “Querying the INNODB_BUFFER_POOL_STATS Table”.

### 14.8.2 Change Buffer

The change buffer is a special data structure that caches changes to secondary index pages when those pages are not in the buffer pool. The buffered changes, which may result from `INSERT`, `UPDATE`, or `DELETE` operations (DML), are merged later when the pages are loaded into the buffer pool by other read operations.

**Figure 14.3 Change Buffer**

Unlike clustered indexes, secondary indexes are usually nonunique, and inserts into secondary indexes happen in a relatively random order. Similarly, deletes and updates may affect secondary index pages that are not adjacent in an index tree. Merging cached changes at a later time, when affected pages are read into the buffer pool by other operations, avoids substantial random access I/O that would be required to read secondary index pages into the buffer pool from disk.
Change Buffer

Periodically, the purge operation that runs when the system is mostly idle, or during a slow shutdown, writes the updated index pages to disk. The purge operation can write disk blocks for a series of index values more efficiently than if each value were written to disk immediately.

Change buffer merging may take several hours when there are many affected rows and numerous secondary indexes to update. During this time, disk I/O is increased, which can cause a significant slowdown for disk-bound queries. Change buffer merging may also continue to occur after a transaction is committed, and even after a server shutdown and restart (see Section 14.23.2, “Forcing InnoDB Recovery” for more information).

In memory, the change buffer occupies part of the buffer pool. On disk, the change buffer is part of the system tablespace, where index changes are buffered when the database server is shut down.

The type of data cached in the change buffer is governed by the `innodb_change_buffering` variable. For more information, see Configuring Change Buffering.

For answers to frequently asked questions about the change buffer, see Section A.16, “MySQL 5.5 FAQ: InnoDB Change Buffer”.

Configuring Change Buffering

When `INSERT`, `UPDATE`, and `DELETE` operations are performed on a table, the values of indexed columns (particularly the values of secondary keys) are often in an unsorted order, requiring substantial I/O to bring secondary indexes up to date. The change buffer caches changes to secondary index entries when the relevant page is not in the buffer pool, thus avoiding expensive I/O operations by not immediately reading in the page from disk. The buffered changes are merged when the page is loaded into the buffer pool, and the updated page is later flushed to disk. The InnoDB main thread merges buffered changes when the server is nearly idle, and during a slow shutdown.

Because it can result in fewer disk reads and writes, the change buffer feature is most valuable for workloads that are I/O-bound, for example applications with a high volume of DML operations such as bulk inserts.

However, the change buffer occupies a part of the buffer pool, reducing the memory available to cache data pages. If the working set almost fits in the buffer pool, or if your tables have relatively few secondary indexes, it may be useful to disable change buffering. If the working data set fits entirely within the buffer pool, change buffering does not impose extra overhead, because it only applies to pages that are not in the buffer pool.

You can control the extent to which InnoDB performs change buffering using the `innodb_change_buffering` configuration parameter. You can enable or disable buffering for inserts, delete operations (when index records are initially marked for deletion) and purge operations (when index records are physically deleted). An update operation is a combination of an insert and a delete. The default `innodb_change_buffering` value is `all`.

Permitted `innodb_change_buffering` values include:

- `all`
  The default value: buffer inserts, delete-marking operations, and purges.

- `none`
  Do not buffer any operations.

- `inserts`
  Buffer insert operations.
• **deletes**
  Buffer delete-marking operations.

• **changes**
  Buffer both inserts and delete-marking operations.

• **purges**
  Buffer physical deletion operations that happen in the background.

You can set the `innodb_change_buffering` variable in the MySQL option file (`my.cnf` or `my.ini`) or change it dynamically with the `SET GLOBAL` statement, which requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”. Changing the setting affects the buffering of new operations; the merging of existing buffered entries is not affected.

**Monitoring the Change Buffer**

The following options are available for change buffer monitoring:

• **InnoDB** Standard Monitor output includes status information for the change buffer. To view monitor data, issue the `SHOW ENGINE INNODB STATUS` command.

  ```
  mysql> SHOW ENGINE INNODB STATUS\G
  ```

  Change buffer status information is located under the **INSERT BUFFER AND ADAPTIVE HASH INDEX** heading and appears similar to the following:

  ```
  INSERT BUFFER AND ADAPTIVE HASH INDEX
  -------------------------------------
  Ibuf: size 1, free list len 0, seg size 2, 0 merges
  merged operations:
  insert 0, delete mark 0, delete 0
  discarded operations:
  insert 0, delete mark 0, delete 0
  Hash table size 276707, node heap has 1 buffer(s)
  15.81 hash searches/s, 46.33 non-hash searches/s
  ```

  For more information, see Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”.

• **The INFORMATION_SCHEMA.INNODB_BUFFER_PAGE table** provides metadata about each page in the buffer pool, including change buffer index and change buffer bitmap pages. Change buffer pages are identified by `PAGE_TYPE`. `IBUF_INDEX` is the page type for change buffer index pages, and `IBUF_BITMAP` is the page type for change buffer bitmap pages.

  **Warning**

  Querying the `INNODB_BUFFER_PAGE` table can introduce significant performance overhead. To avoid impacting performance, reproduce the issue you want to investigate on a test instance and run your queries on the test instance.

  For example, you can query the `INNODB_BUFFER_PAGE` table to determine the approximate number of `IBUF_INDEX` and `IBUF_BITMAP` pages as a percentage of total buffer pool pages.

  ```
  mysql> SELECT (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE WHERE PAGE_TYPE LIKE 'IBUF\%') AS change_buffer_pages,
         (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE) AS total_pages,
         (SELECT ((change_buffer_pages/total_pages)*100))
  ```
14.8.3 Adaptive Hash Index

The adaptive hash index feature enables InnoDB to perform more like an in-memory database on systems with appropriate combinations of workload and sufficient memory for the buffer pool without sacrificing transactional features or reliability. The adaptive hash index feature is enabled by the `innodb_adaptive_hash_index` variable, or turned off at server startup by `--skip-innodb-adaptive-hash-index`.

Based on the observed pattern of searches, a hash index is built using a prefix of the index key. The prefix can be any length, and it may be that only some values in the B-tree appear in the hash index. Hash indexes are built on demand for the pages of the index that are accessed often.

If a table fits almost entirely in main memory, a hash index can speed up queries by enabling direct lookup of any element, turning the index value into a sort of pointer. InnoDB has a mechanism that monitors index searches. If InnoDB notices that queries could benefit from building a hash index, it does so automatically.

With some workloads, the speedup from hash index lookups greatly outweighs the extra work to monitor index lookups and maintain the hash index structure. Access to the adaptive hash index can sometimes become a source of contention under heavy workloads, such as multiple concurrent joins. Queries with LIKE operators and % wildcards also tend not to benefit. For workloads that do not benefit from the adaptive hash index feature, turning it off reduces unnecessary performance overhead. Because it is difficult to predict in advance whether the adaptive hash index feature is appropriate for a particular system and workload, consider running benchmarks with it enabled and disabled.

You can monitor adaptive hash index use and contention in the SEMAPHORES section of SHOW ENGINE INNODB STATUS output. If there are numerous threads waiting on an RW-latch created in `btr0sea.c`, it might be useful to disable the adaptive hash index feature.

For information about the performance characteristics of hash indexes, see Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

For information about other data provided by the INNODB_BUFFER_PAGE table, see Section 21.29.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”. For related usage information, see Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”.

- Performance Schema provides change buffer mutex wait instrumentation for advanced performance monitoring. To view change buffer instrumentation, issue the following query (Performance Schema must be enabled):

```
mysql> SELECT * FROM performance_schema.setup_instruments
WHERE NAME LIKE '%wait/synch/mutex/innodb/ibuf%';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/innodb/ibuf_bitmap_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

For information about monitoring InnoDB mutex waits, see Section 14.19.1, “Monitoring InnoDB Mutex Waits Using Performance Schema”.
14.8.4 Log Buffer

The log buffer is the memory area that holds data to be written to the log files on disk. Log buffer size is defined by the `innodb_log_buffer_size` variable. The default size is 16MB. The contents of the log buffer are periodically flushed to disk. A large log buffer enables large transactions to run without the need to write redo log data to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, increasing the size of the log buffer saves disk I/O.

The `innodb_flush_log_at_trx_commit` variable controls how the contents of the log buffer are written and flushed to disk. The `innodb_flush_log_at_timeout` variable controls log flushing frequency.

For related information, see Memory Configuration, and Section 8.5.3, “Optimizing InnoDB Redo Logging”.

14.9 InnoDB On-Disk Structures

This section describes InnoDB on-disk structures and related topics.

14.9.1 Tables

This section covers topics related to InnoDB tables.

14.9.1.1 Creating InnoDB Tables

To create an InnoDB table, use the `CREATE TABLE` statement.

```sql
CREATE TABLE t1 (a INT, b CHAR (20), PRIMARY KEY (a)) ENGINE=InnoDB;
```

You do not need to specify the `ENGINE=InnoDB` clause if InnoDB is defined as the default storage engine, which it is by default. To check the default storage engine, issue the following statement:

```sql
mysql> SELECT @@default_storage_engine;
+--------------------------+
| @@default_storage_engine |
+--------------------------+
| InnoDB                   |
+--------------------------+
```

You might still use `ENGINE=InnoDB` clause if you plan to use `mysqldump` or replication to replay the `CREATE TABLE` statement on a server where the default storage engine is not InnoDB.

An InnoDB table and its indexes can be created in the system tablespace or in a file-per-table tablespace. When `innodb_file_per_table` is enabled, an InnoDB table is implicitly created in an individual file-per-table tablespace. Conversely, when `innodb_file_per_table` is disabled, an InnoDB table is implicitly created in the InnoDB system tablespace.

When you create an InnoDB table, MySQL creates a .frm file in the database directory under the MySQL data directory. For more information about .frm files, see InnoDB Tables and .frm Files. For a table created in a file-per-table tablespace, MySQL also creates an .ibd tablespace file in the database directory. A table created in the InnoDB system tablespace is created in an existing ibdata file, which resides in the MySQL data directory.

Internally, InnoDB adds an entry for each table to the InnoDB data dictionary. The entry includes the database name. For example, if table `t1` is created in the `test` database, the data dictionary entry for the database name is 'test/t1'. This means you can create a table of the same name (t1) in a different database, and the table names do not collide inside InnoDB.

InnoDB Tables and .frm Files
MySQL stores data dictionary information for tables in .frm files in database directories. Unlike other MySQL storage engines, InnoDB also encodes information about the table in its own internal data dictionary inside the system tablespace. When MySQL drops a table or a database, it deletes one or more .frm files as well as the corresponding entries inside the InnoDB data dictionary. You cannot move InnoDB tables between databases simply by moving the .frm files. For information about moving InnoDB tables, see Section 14.9.1.2, “Moving or Copying InnoDB Tables”.

**InnoDB Tables and Row Formats**

The default row format of an InnoDB table is **Compact**. Although this row format is fine for basic experimentation, consider using the Dynamic or Compressed row format to take advantage of InnoDB features such as table compression and efficient off-page storage of long column values. Using these row formats requires that `innodb_file_per_table` is enabled and that `innodb_file_format` is set to **Barracuda**:

```sql
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=barracuda;
CREATE TABLE t3 (a INT, b CHAR (20), PRIMARY KEY (a)) ROW_FORMAT=DYNAMIC;
CREATE TABLE t4 (a INT, b CHAR (20), PRIMARY KEY (a)) ROW_FORMAT=COMPRESSED;
```

For more information about InnoDB row formats, see Section 14.14, “InnoDB Row Formats”. For how to determine the row format of an InnoDB table and the physical characteristics of InnoDB row formats, see Section 14.14, “InnoDB Row Formats”.

**InnoDB Tables and Primary Keys**

Always define a **primary key** for an InnoDB table, specifying the column or columns that:

- Are referenced by the most important queries.
- Are never left blank.
- Never have duplicate values.
- Rarely if ever change value once inserted.

For example, in a table containing information about people, you would not create a primary key on `(firstname, lastname)` because more than one person can have the same name, some people have blank last names, and sometimes people change their names. With so many constraints, often there is not an obvious set of columns to use as a primary key, so you create a new column with a numeric ID to serve as all or part of the primary key. You can declare an **auto-increment** column so that ascending values are filled in automatically as rows are inserted:

```sql
# The value of ID can act like a pointer between related items in different tables.
CREATE TABLE t5 (id INT AUTO_INCREMENT, b CHAR (20), PRIMARY KEY (id));

# The primary key can consist of more than one column. Any autoinc column must come first.
CREATE TABLE t6 (id INT AUTO_INCREMENT, a INT, b CHAR (20), PRIMARY KEY (id, a));
```

Although the table works correctly without defining a primary key, the primary key is involved with many aspects of performance and is a crucial design aspect for any large or frequently used table. It is recommended that you always specify a primary key in the `CREATE TABLE` statement. If you create the table, load data, and then run `ALTER TABLE` to add a primary key later, that operation is much slower than defining the primary key when creating the table.

**Viewing InnoDB Table Properties**

To view the properties of an InnoDB table, issue a `SHOW TABLE STATUS` statement:

```sql
SHOW TABLE STATUS WHERE `Name` = 't3';
SHOW TABLE STATUS WHERE `Name` = 't4';
SHOW TABLE STATUS WHERE `Name` = 't5';
SHOW TABLE STATUS WHERE `Name` = 't6';
```
14.9.1.2 Moving or Copying InnoDB Tables

This section describes techniques for moving or copying some or all InnoDB tables to a different server or instance. For example, you might move an entire MySQL instance to a larger, faster server; you might clone an entire MySQL instance to a new replication slave server; you might copy individual tables to another instance to develop and test an application, or to a data warehouse server to produce reports.

On Windows, InnoDB always stores database and table names internally in lowercase. To move databases in a binary format from Unix to Windows or from Windows to Unix, create all databases and tables using lowercase names. A convenient way to accomplish this is to add the following line to the [mysqld] section of your my.cnf or my.ini file before creating any databases or tables:

```
[mysqld]
lower_case_table_names=1
```

Techniques for moving or copying InnoDB tables include:

- Copying Data Files (Cold Backup Method)
- Restoring from a Logical Backup

**Copying Data Files (Cold Backup Method)**

You can move an InnoDB database simply by copying all the relevant files listed under "Cold Backups" in Section 14.21.1, "InnoDB Backup".

InnoDB data and log files are binary-compatible on all platforms having the same floating-point number format. If the floating-point formats differ but you have not used FLOAT or DOUBLE data types in your tables, then the procedure is the same: simply copy the relevant files.

**Restoring from a Logical Backup**

You can use a utility such as mysqldump to perform a logical backup, which produces a set of SQL statements that can be executed to reproduce the original database object definitions and table data for transfer to another SQL server. Using this method, it does not matter whether the formats differ or if your tables contain floating-point data.
To improve the performance of this method, disable `autocommit` when importing data. Perform a commit only after importing an entire table or segment of a table.

### 14.9.1.3 Converting Tables from MyISAM to InnoDB

If you have MyISAM tables that you want to convert to InnoDB for better reliability and scalability, review the following guidelines and tips before converting.

- **Adjusting Memory Usage for MyISAM and InnoDB**
- **Handling Too-Long Or Too-Short Transactions**
- **Handling Deadlocks**
- **Planning the Storage Layout**
- **Converting an Existing Table**
- **Cloning the Structure of a Table**
- **Transferring Existing Data**
- **Storage Requirements**
- **Defining a PRIMARY KEY for Each Table**
- **Application Performance Considerations**
- **Understanding Files Associated with InnoDB Tables**

#### Adjusting Memory Usage for MyISAM and InnoDB

As you transition away from MyISAM tables, lower the value of the `key_buffer_size` configuration option to free memory no longer needed for caching results. Increase the value of the `innodb_buffer_pool_size` configuration option, which performs a similar role of allocating cache memory for InnoDB tables. The InnoDB buffer pool caches both table data and index data, speeding up lookups for queries and keeping query results in memory for reuse. For guidance regarding buffer pool size configuration, see Section 8.12.4.1, “How MySQL Uses Memory”.

On a busy server, run benchmarks with the query cache turned off. The InnoDB buffer pool provides similar benefits, so the query cache might be tying up memory unnecessarily. For information about the query cache, see Section 8.10.3, “The MySQL Query Cache”.

#### Handling Too-Long Or Too-Short Transactions

Because MyISAM tables do not support transactions, you might not have paid much attention to the `autocommit` configuration option and the `COMMIT` and `ROLLBACK` statements. These keywords are important to allow multiple sessions to read and write InnoDB tables concurrently, providing substantial scalability benefits in write-heavy workloads.

While a transaction is open, the system keeps a snapshot of the data as seen at the beginning of the transaction, which can cause substantial overhead if the system inserts, updates, and deletes millions of rows while a stray transaction keeps running. Thus, take care to avoid transactions that run for too long:

- If you are using a mysql session for interactive experiments, always `COMMIT` (to finalize the changes) or `ROLLBACK` (to undo the changes) when finished. Close down interactive sessions rather than leave them open for long periods, to avoid keeping transactions open for long periods by accident.
- Make sure that any error handlers in your application also `ROLLBACK` incomplete changes or `COMMIT` completed changes.
• **ROLLBACK** is a relatively expensive operation, because **INSERT**, **UPDATE**, and **DELETE** operations are written to **InnoDB** tables prior to the **COMMIT**, with the expectation that most changes are committed successfully and rollbacks are rare. When experimenting with large volumes of data, avoid making changes to large numbers of rows and then rolling back those changes.

• When loading large volumes of data with a sequence of **INSERT** statements, periodically **COMMIT** the results to avoid having transactions that last for hours. In typical load operations for data warehousing, if something goes wrong, you truncate the table (using **TRUNCATE TABLE**) and start over from the beginning rather than doing a **ROLLBACK**.

The preceding tips save memory and disk space that can be wasted during too-long transactions. When transactions are shorter than they should be, the problem is excessive I/O. With each **COMMIT**, MySQL makes sure each change is safely recorded to disk, which involves some I/O.

• For most operations on **InnoDB** tables, you should use the setting **autocommit=0**. From an efficiency perspective, this avoids unnecessary I/O when you issue large numbers of consecutive **INSERT**, **UPDATE**, or **DELETE** statements. From a safety perspective, this allows you to issue a **ROLLBACK** statement to recover lost or garbled data if you make a mistake on the **mysql** command line, or in an exception handler in your application.

• The time when **autocommit=1** is suitable for **InnoDB** tables is when running a sequence of queries for generating reports or analyzing statistics. In this situation, there is no I/O penalty related to **COMMIT** or **ROLLBACK**, and **InnoDB** can automatically optimize the read-only workload.

• If you make a series of related changes, finalize all the changes at once with a single **COMMIT** at the end. For example, if you insert related pieces of information into several tables, do a single **COMMIT** after making all the changes. Or if you run many consecutive **INSERT** statements, do a single **COMMIT** after all the data is loaded; if you are doing millions of **INSERT** statements, perhaps split up the huge transaction by issuing a **COMMIT** every ten thousand or hundred thousand records, so the transaction does not grow too large.

• Remember that even a **SELECT** statement opens a transaction, so after running some report or debugging queries in an interactive **mysql** session, either issue a **COMMIT** or close the **mysql** session.

### Handling Deadlocks

You might see warning messages referring to “deadlocks” in the MySQL error log, or the output of **SHOW ENGINE INNODB STATUS**. Despite the scary-sounding name, a **deadlock** is not a serious issue for **InnoDB** tables, and often does not require any corrective action. When two transactions start modifying multiple tables, accessing the tables in a different order, they can reach a state where each transaction is waiting for the other and neither can proceed. MySQL immediately detects this condition and cancels (rolls back) the “smaller” transaction, allowing the other to proceed.

Your applications do need error-handling logic to restart a transaction that is forcibly cancelled like this. When you re-issue the same SQL statements as before, the original timing issue no longer applies. Either the other transaction has already finished and yours can proceed, or the other transaction is still in progress and your transaction waits until it finishes.

If deadlock warnings occur constantly, you might review the application code to reorder the SQL operations in a consistent way, or to shorten the transactions.

For more information, see [Section 14.10.5, “Deadlocks in InnoDB”](#).

### Planning the Storage Layout

To get the best performance from **InnoDB** tables, you can adjust a number of parameters related to storage layout.
When you convert **MyISAM** tables that are large, frequently accessed, and hold vital data, investigate and consider the `innodb_file_per_table` and `innodb_file_format` configuration options, and the `ROW_FORMAT` and `KEY_BLOCK_SIZE` clauses of the `CREATE TABLE` statement.

During your initial experiments, the most important setting is `innodb_file_per_table`. When this setting is enabled, new InnoDB tables are implicitly created in *file-per-table* tablespaces. In contrast with the InnoDB system tablespace, file-per-table tablespaces allow disk space to be reclaimed by the operating system when a table is truncated or dropped. File-per-table tablespaces also support the Barracuda file format and associated features such as table compression and efficient off-page storage for long variable-length columns. For more information, see Section 14.9.3.2, “File-Per-Table Tablespaces”.

### Converting an Existing Table

To convert a non-InnoDB table to use InnoDB use `ALTER TABLE`:

```
ALTER TABLE table_name ENGINE=InnoDB;
```

#### Warning

Do *not* convert MySQL system tables in the `mysql` database from *MyISAM* to InnoDB tables. This is an unsupported operation. If you do this, MySQL does not restart until you restore the old system tables from a backup or regenerate them by reinitializing the data directory (see Section 2.10.1, “Initializing the Data Directory”).

### Cloning the Structure of a Table

You might make an InnoDB table that is a clone of a MyISAM table, rather than using `ALTER TABLE` to perform conversion, to test the old and new table side-by-side before switching.

Create an empty InnoDB table with identical column and index definitions. Use `SHOW CREATE TABLE table_name\G` to see the full `CREATE TABLE` statement to use. Change the `ENGINE` clause to `ENGINE=INNODB`.

### Transferring Existing Data

To transfer a large volume of data into an empty InnoDB table created as shown in the previous section, insert the rows with `INSERT INTO innodb_table SELECT * FROM myisam_table ORDER BY primary_key_columns`.

You can also create the indexes for the InnoDB table after inserting the data. Historically, creating new secondary indexes was a slow operation for InnoDB, but now you can create the indexes after the data is loaded with relatively little overhead from the index creation step.

If you have `UNIQUE` constraints on secondary keys, you can speed up a table import by turning off the uniqueness checks temporarily during the import operation:

```
SET unique_checks=0; ... import operation ... 
SET unique_checks=1; 
```

For big tables, this saves disk I/O because InnoDB can use its change buffer to write secondary index records as a batch. Be certain that the data contains no duplicate keys. `unique_checks` permits but does not require storage engines to ignore duplicate keys.

For better control over the insertion process, you can insert big tables in pieces:

```
INSERT INTO newtable SELECT * FROM oldtable
WHERE yourkey > something AND yourkey <= somethingelse;
```

After all records are inserted, you can rename the tables.
During the conversion of big tables, increase the size of the InnoDB buffer pool to reduce disk I/O, to a maximum of 80% of physical memory. You can also increase the size of InnoDB log files.

**Storage Requirements**

If you intend to make several temporary copies of your data in InnoDB tables during the conversion process, it is recommended that you create the tables in file-per-table tablespaces so that you can reclaim the disk space when you drop the tables. When the `innodb_file_per_table` configuration option is enabled (the default), newly created InnoDB tables are implicitly created in file-per-table tablespaces.

Whether you convert the MyISAM table directly or create a cloned InnoDB table, make sure that you have sufficient disk space to hold both the old and new tables during the process. InnoDB tables require more disk space than MyISAM tables. If an ALTER TABLE operation runs out of space, it starts a rollback, and that can take hours if it is disk-bound. For inserts, InnoDB uses the insert buffer to merge secondary index records to indexes in batches. That saves a lot of disk I/O. For rollback, no such mechanism is used, and the rollback can take 30 times longer than the insertion.

In the case of a runaway rollback, if you do not have valuable data in your database, it may be advisable to kill the database process rather than wait for millions of disk I/O operations to complete. For the complete procedure, see Section 14.23.2, “Forcing InnoDB Recovery”.

**Defining a PRIMARY KEY for Each Table**

The PRIMARY KEY clause is a critical factor affecting the performance of MySQL queries and the space usage for tables and indexes. The primary key uniquely identifies a row in a table. Every row in the table must have a primary key value, and no two rows can have the same primary key value.

These are guidelines for the primary key, followed by more detailed explanations.

- Declare a PRIMARY KEY for each table. Typically, it is the most important column that you refer to in WHERE clauses when looking up a single row.
- Declare the PRIMARY KEY clause in the original CREATE TABLE statement, rather than adding it later through an ALTER TABLE statement.
- Choose the column and its data type carefully. Prefer numeric columns over character or string ones.
- Consider using an auto-increment column if there is no other stable, unique, non-null, numeric column to use.
- An auto-increment column is also a good choice if there is any doubt whether the value of the primary key column could ever change. Changing the value of a primary key column is an expensive operation, possibly involving rearranging data within the table and within each secondary index.

Consider adding a primary key to any table that does not already have one. Use the smallest practical numeric type based on the maximum projected size of the table. This can make each row slightly more compact, which can yield substantial space savings for large tables. The space savings are multiplied if the table has any secondary indexes, because the primary key value is repeated in each secondary index entry. In addition to reducing data size on disk, a small primary key also lets more data fit into the buffer pool, speeding up all kinds of operations and improving concurrency.

If the table already has a primary key on some longer column, such as a VARCHAR, consider adding a new unsigned AUTO_INCREMENT column and switching the primary key to that, even if that column is not referenced in queries. This design change can produce substantial space savings in the secondary indexes. You can designate the former primary key columns as UNIQUE NOT NULL to enforce the same constraints as the PRIMARY KEY clause, that is, to prevent duplicate or null values across all those columns.
If you spread related information across multiple tables, typically each table uses the same column for its primary key. For example, a personnel database might have several tables, each with a primary key of employee number. A sales database might have some tables with a primary key of customer number, and other tables with a primary key of order number. Because lookups using the primary key are very fast, you can construct efficient join queries for such tables.

If you leave the PRIMARY KEY clause out entirely, MySQL creates an invisible one for you. It is a 6-byte value that might be longer than you need, thus wasting space. Because it is hidden, you cannot refer to it in queries.

Application Performance Considerations

The reliability and scalability features of InnoDB require more disk storage than equivalent MyISAM tables. You might change the column and index definitions slightly, for better space utilization, reduced I/O and memory consumption when processing result sets, and better query optimization plans making efficient use of index lookups.

If you do set up a numeric ID column for the primary key, use that value to cross-reference with related values in any other tables, particularly for join queries. For example, rather than accepting a country name as input and doing queries searching for the same name, do one lookup to determine the country ID, then do other queries (or a single join query) to look up relevant information across several tables. Rather than storing a customer or catalog item number as a string of digits, potentially using up several bytes, convert it to a numeric ID for storing and querying. A 4-byte unsigned INT column can index over 4 billion items (with the US meaning of billion: 1000 million). For the ranges of the different integer types, see Section 11.1.2, “Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT”.

Understanding Files Associated with InnoDB Tables

InnoDB files require more care and planning than MyISAM files do.

- You must not delete the ibdata files that represent the InnoDB system tablespace.
- Methods of moving or copying InnoDB tables to a different server are described in Section 14.9.1.2, “Moving or Copying InnoDB Tables”.

14.9.1.4 AUTO_INCREMENT Handling in InnoDB

InnoDB provides a configurable locking mechanism that can significantly improve scalability and performance of SQL statements that add rows to tables with AUTO_INCREMENT columns. To use the AUTO_INCREMENT mechanism with an InnoDB table, an AUTO_INCREMENT column must be defined as part of an index such that it is possible to perform the equivalent of an indexed SELECT MAX(ai_col) lookup on the table to obtain the maximum column value. Typically, this is achieved by making the column the first column of some table index.

This section describes the behavior of AUTO_INCREMENT lock modes, usage implications for different AUTO_INCREMENT lock mode settings, and how InnoDB initializes the AUTO_INCREMENT counter.

- InnoDB AUTO_INCREMENT Lock Modes
- InnoDB AUTO_INCREMENT Lock Mode Usage Implications
- InnoDB AUTO_INCREMENT Counter Initialization
- Notes

InnoDB AUTO_INCREMENT Lock Modes
This section describes the behavior of AUTO_INCREMENT lock modes used to generate auto-increment values, and how each lock mode affects replication. Auto-increment lock modes are configured at startup using the innodb_autoinc_lock_mode configuration parameter.

The following terms are used in describing innodb_autoinc_lock_mode settings:

- **“INSERT-like” statements**
  
  All statements that generate new rows in a table, including INSERT, INSERT ... SELECT, REPLACE, REPLACE ... SELECT, and LOAD DATA. Includes “simple-inserts”, “bulk-inserts”, and “mixed-mode” inserts.

- **“Simple inserts”**
  
  Statements for which the number of rows to be inserted can be determined in advance (when the statement is initially processed). This includes single-row and multiple-row INSERT and REPLACE statements that do not have a nested subquery, but not INSERT ... ON DUPLICATE KEY UPDATE.

- **“Bulk inserts”**
  
  Statements for which the number of rows to be inserted (and the number of required auto-increment values) is not known in advance. This includes INSERT ... SELECT, REPLACE ... SELECT, and LOAD DATA statements, but not plain INSERT. InnoDB assigns new values for the AUTO_INCREMENT column one at a time as each row is processed.

- **“Mixed-mode inserts”**
  
  These are “simple insert” statements that specify the auto-increment value for some (but not all) of the new rows. An example follows, where \( c1 \) is an AUTO_INCREMENT column of table \( t1 \):

  ```sql
  INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
  ```

  Another type of “mixed-mode insert” is INSERT ... ON DUPLICATE KEY UPDATE, which in the worst case is in effect an INSERT followed by a UPDATE, where the allocated value for the AUTO_INCREMENT column may or may not be used during the update phase.

There are three possible settings for the innodb_autoinc_lock_mode configuration parameter. The settings are 0, 1, or 2, for “traditional”, “consecutive”, or “interleaved” lock mode, respectively.

- **innodb_autoinc_lock_mode = 0 (“traditional” lock mode)**
  
  The traditional lock mode provides the same behavior that existed before the innodb_autoinc_lock_mode configuration parameter was introduced in MySQL 5.1. The traditional lock mode option is provided for backward compatibility, performance testing, and working around issues with “mixed-mode inserts”, due to possible differences in semantics.

  In this lock mode, all “INSERT-like” statements obtain a special table-level AUTO_INC lock for inserts into tables with AUTO_INCREMENT columns. This lock is normally held to the end of the statement (not to the end of the transaction) to ensure that auto-increment values are assigned in a predictable and repeatable order for a given sequence of INSERT statements, and to ensure that auto-increment values assigned by any given statement are consecutive.

  In the case of statement-based replication, this means that when an SQL statement is replicated on a slave server, the same values are used for the auto-increment column as on the master server. The result of execution of multiple INSERT statements is deterministic, and the slave reproduces the same data as on the master. If auto-increment values generated by multiple INSERT statements were interleaved, the result of two concurrent INSERT statements would be nondeterministic, and could not reliably be propagated to a slave server using statement-based replication.
Tables

To make this clear, consider an example that uses this table:

```sql
CREATE TABLE t1 (
    c1 INT(11) NOT NULL AUTO_INCREMENT,
    c2 VARCHAR(10) DEFAULT NULL,
    PRIMARY KEY (c1)
) ENGINE=InnoDB;
```

Suppose that there are two transactions running, each inserting rows into a table with an `AUTO_INCREMENT` column. One transaction is using an `INSERT ... SELECT` statement that inserts 1000 rows, and another is using a simple `INSERT` statement that inserts one row:

```sql
Tx1: INSERT INTO t1 (c2) SELECT 1000 rows from another table ...
Tx2: INSERT INTO t1 (c2) VALUES ('xxx');
```

InnoDB cannot tell in advance how many rows are retrieved from the `SELECT` in the `INSERT` statement in Tx1, and it assigns the auto-increment values one at a time as the statement proceeds. With a table-level lock, held to the end of the statement, only one `INSERT` statement referring to table `t1` can execute at a time, and the generation of auto-increment numbers by different statements is not interleaved. The auto-increment value generated by the Tx1 `INSERT ... SELECT` statement is consecutive, and the (single) auto-increment value used by the `INSERT` statement in Tx2 is either be smaller or larger than all those used for Tx1, depending on which statement executes first.

As long as the SQL statements execute in the same order when replayed from the binary log (when using statement-based replication, or in recovery scenarios), the results are the same as they were when Tx1 and Tx2 first ran. Thus, table-level locks held until the end of a statement make `INSERT` statements using auto-increment safe for use with statement-based replication. However, those table-level locks limit concurrency and scalability when multiple transactions are executing insert statements at the same time.

In the preceding example, if there were no table-level lock, the value of the auto-increment column used for the `INSERT` in Tx2 depends on precisely when the statement executes. If the `INSERT` of Tx2 executes while the `INSERT` of Tx1 is running (rather than before it starts or after it completes), the specific auto-increment values assigned by the two `INSERT` statements are nondeterministic, and may vary from run to run.

Under the `consecutive` lock mode, InnoDB can avoid using table-level `AUTO-INC` locks for “simple insert” statements where the number of rows is known in advance, and still preserve deterministic execution and safety for statement-based replication.

If you are not using the binary log to replay SQL statements as part of recovery or replication, the `interleaved` lock mode can be used to eliminate all use of table-level `AUTO-INC` locks for even greater concurrency and performance, at the cost of permitting gaps in auto-increment numbers assigned by a statement and potentially having the numbers assigned by concurrently executing statements interleaved.

- `innodb_autoinc_lock_mode = 1` ("consecutive" lock mode)

This is the default lock mode. In this mode, “bulk inserts” use the special `AUTO-INC` table-level lock and hold it until the end of the statement. This applies to all `INSERT ... SELECT`, `REPLACE ... SELECT`, and `LOAD DATA` statements. Only one statement holding the `AUTO-INC` lock can execute at a time. If the source table of the bulk insert operation is different from the target table, the `AUTO-INC` lock on the target table is taken after a shared lock is taken on the first row selected from the source table. If
the source and target of the bulk insert operation are the same table, the AUTO-INC lock is taken after shared locks are taken on all selected rows.

“Simple inserts” (for which the number of rows to be inserted is known in advance) avoid table-level AUTO-INC locks by obtaining the required number of auto-increment values under the control of a mutex (a light-weight lock) that is only held for the duration of the allocation process, not until the statement completes. No table-level AUTO-INC lock is used unless an AUTO-INC lock is held by another transaction. If another transaction holds an AUTO-INC lock, a “simple insert” waits for the AUTO-INC lock, as if it were a “bulk insert”.

This lock mode ensures that, in the presence of INSERT statements where the number of rows is not known in advance (and where auto-increment numbers are assigned as the statement progresses), all auto-increment values assigned by any “INSERT-like” statement are consecutive, and operations are safe for statement-based replication.

Simply put, this lock mode significantly improves scalability while being safe for use with statement-based replication. Further, as with “traditional” lock mode, auto-increment numbers assigned by any given statement are consecutive. There is no change in semantics compared to “traditional” mode for any statement that uses auto-increment, with one important exception.

The exception is for “mixed-mode inserts”, where the user provides explicit values for an AUTO_INCREMENT column for some, but not all, rows in a multiple-row “simple insert”. For such inserts, InnoDB allocates more auto-increment values than the number of rows to be inserted. However, all values automatically assigned are consecutively generated (and thus higher than) the auto-increment value generated by the most recently executed previous statement. “Excess” numbers are lost.

- **innodb_autoinc_lock_mode = 2 ("interleaved" lock mode)**

  In this lock mode, no "INSERT-like" statements use the table-level AUTO-INC lock, and multiple statements can execute at the same time. This is the fastest and most scalable lock mode, but it is not safe when using statement-based replication or recovery scenarios when SQL statements are replayed from the binary log.

  In this lock mode, auto-increment values are guaranteed to be unique and monotonically increasing across all concurrently executing "INSERT-like" statements. However, because multiple statements can be generating numbers at the same time (that is, allocation of numbers is interleaved across statements), the values generated for the rows inserted by any given statement may not be consecutive.

  If the only statements executing are “simple inserts” where the number of rows to be inserted is known ahead of time, there are no gaps in the numbers generated for a single statement, except for “mixed-mode inserts”. However, when “bulk inserts” are executed, there may be gaps in the auto-increment values assigned by any given statement.

**InnoDB AUTO_INCREMENT Lock Mode Usage Implications**

- **Using auto-increment with replication**

  If you are using statement-based replication, set innodb_autoinc_lock_mode to 0 or 1 and use the same value on the master and its slaves. Auto-increment values are not ensured to be the same on the slaves as on the master if you use innodb_autoinc_lock_mode = 2 ("interleaved") or configurations where the master and slaves do not use the same lock mode.

  If you are using row-based or mixed-format replication, all of the auto-increment lock modes are safe, since row-based replication is not sensitive to the order of execution of the SQL statements (and the mixed format uses row-based replication for any statements that are unsafe for statement-based replication).
• “Lost” auto-increment values and sequence gaps

In all lock modes (0, 1, and 2), if a transaction that generated auto-increment values rolls back, those auto-increment values are “lost”. Once a value is generated for an auto-increment column, it cannot be rolled back, whether or not the “INSERT-like” statement is completed, and whether or not the containing transaction is rolled back. Such lost values are not reused. Thus, there may be gaps in the values stored in an \texttt{AUTO_INCREMENT} column of a table.

• Specifying NULL or 0 for the \texttt{AUTO_INCREMENT} column

In all lock modes (0, 1, and 2), if a user specifies NULL or 0 for the \texttt{AUTO_INCREMENT} column in an \texttt{INSERT}, InnoDB treats the row as if the value was not specified and generates a new value for it.

• Assigning a negative value to the \texttt{AUTO_INCREMENT} column

In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if you assign a negative value to the \texttt{AUTO_INCREMENT} column.

• If the \texttt{AUTO_INCREMENT} value becomes larger than the maximum integer for the specified integer type

In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if the value becomes larger than the maximum integer that can be stored in the specified integer type.

• Gaps in auto-increment values for “bulk inserts”

With \texttt{innodb_autoinc_lock_mode} set to 0 (“traditional”) or 1 (“consecutive”), the auto-increment values generated by any given statement are consecutive, without gaps, because the table-level \texttt{AUTO_INCREMENT} lock is held until the end of the statement, and only one such statement can execute at a time.

With \texttt{innodb_autoinc_lock_mode} set to 2 (“interleaved”), there may be gaps in the auto-increment values generated by “bulk inserts,” but only if there are concurrently executing “INSERT-like” statements.

For lock modes 1 or 2, gaps may occur between successive statements because for bulk inserts the exact number of auto-increment values required by each statement may not be known and overestimation is possible.

• Auto-increment values assigned by “mixed-mode inserts”

Consider a “mixed-mode insert,” where a “simple insert” specifies the auto-increment value for some (but not all) resulting rows. Such a statement behaves differently in lock modes 0, 1, and 2. For example, assume \texttt{c1} is an \texttt{AUTO_INCREMENT} column of table \texttt{t1}, and that the most recent automatically generated sequence number is 100.

```
mysql> CREATE TABLE t1 (  
  > c1 INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,  
  > c2 CHAR(1)  
  > ) ENGINE = INNODB;
```

Now, consider the following “mixed-mode insert” statement:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

With \texttt{innodb_autoinc_lock_mode} set to 0 (“traditional”), the four new rows are:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+----+----+
<table>
<thead>
<tr>
<th>c1</th>
<th>c2</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>b</td>
</tr>
<tr>
<td>101</td>
<td>a</td>
</tr>
</tbody>
</table>
+----+----+
```

1730
The next available auto-increment value is 103 because the auto-increment values are allocated one at a time, not all at once at the beginning of statement execution. This result is true whether or not there are concurrently executing "INSERT-like" statements (of any type).

With `innodb_autoinc_lock_mode` set to 1 ("consecutive"), the four new rows are also:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
```

```
+----+----+
| c1 | c2 |
+----+----+
|   1 | a  |
| 101 | b  |
|   5 | c  |
| 102 | d  |
+----+----+
```

However, in this case, the next available auto-increment value is 105, not 103 because four auto-increment values are allocated at the time the statement is processed, but only two are used. This result is true whether or not there are concurrently executing "INSERT-like" statements (of any type).

With `innodb_autoinc_lock_mode` set to mode 2 ("interleaved"), the four new rows are:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
```

```
+----+----+
| c1 | c2 |
+----+----+
|   1 | a  |
|x   | b  |
|   5 | c  |
| y   | d  |
+----+----+
```

The values of $x$ and $y$ are unique and larger than any previously generated rows. However, the specific values of $x$ and $y$ depend on the number of auto-increment values generated by concurrently executing statements.

Finally, consider the following statement, issued when the most-recently generated sequence number is 100:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (101,'c'), (NULL,'d');
```

With any `innodb_autoinc_lock_mode` setting, this statement generates a duplicate-key error 23000 (Can't write; duplicate key in table) because 101 is allocated for the row (NULL, 'b') and insertion of the row (101, 'c') fails.

• Modifying AUTO_INCREMENT column values in the middle of a sequence of INSERT statements

In all lock modes (0, 1, and 2), modifying an AUTO_INCREMENT column value in the middle of a sequence of INSERT statements could lead to “Duplicate entry” errors. For example, if you perform an UPDATE operation that changes an AUTO_INCREMENT column value to a value larger than the current maximum auto-increment value, subsequent INSERT operations that do not specify an unused auto-increment value could encounter “Duplicate entry” errors. This behavior is demonstrated in the following example.

```
mysql> CREATE TABLE t1 (
    c1 INT NOT NULL AUTO_INCREMENT,
    PRIMARY KEY (c1)
```

```
+----+----+
| 5  | c  |
| 102| d  |
+----+----+
```
InnoDB AUTO_INCREMENT Counter Initialization

This section describes how InnoDB initializes AUTO_INCREMENT counters.

If you specify an AUTO_INCREMENT column for an InnoDB table, the table handle in the InnoDB data dictionary contains a special counter called the auto-increment counter that is used in assigning new values for the column. This counter is stored only in main memory, not on disk.

To initialize an auto-increment counter after a server restart, InnoDB executes the equivalent of the following statement on the first insert into a table containing an AUTO_INCREMENT column.

```sql
SELECT MAX(ai_col) FROM table_name FOR UPDATE;
```

InnoDB increments the value retrieved by the statement and assigns it to the column and to the auto-increment counter for the table. By default, the value is incremented by 1. This default can be overridden by the `auto_increment_increment` configuration setting.

If the table is empty, InnoDB uses the value 1. This default can be overridden by the `auto_increment_offset` configuration setting.

If a SHOW TABLE STATUS statement examines the table before the auto-increment counter is initialized, InnoDB initializes but does not increment the value. The value is stored for use by later inserts. This initialization uses a normal exclusive-locking read on the table and the lock lasts to the end of the transaction. InnoDB follows the same procedure for initializing the auto-increment counter for a newly created table.

After the auto-increment counter has been initialized, if you do not explicitly specify a value for an AUTO_INCREMENT column, InnoDB increments the counter and assigns the new value to the column. If you insert a row that explicitly specifies the column value, and the value is greater than the current counter value, the counter is set to the specified column value.

InnoDB uses the in-memory auto-increment counter as long as the server runs. When the server is stopped and restarted, InnoDB reinitializes the counter for each table for the first INSERT to the table, as described earlier.
A server restart also cancels the effect of the `AUTO_INCREMENT = N` table option in `CREATE TABLE` and `ALTER TABLE` statements, which you can use with InnoDB tables to set the initial counter value or alter the current counter value.

Notes

- When an `AUTO_INCREMENT` integer column runs out of values, a subsequent `INSERT` operation returns a duplicate-key error. This is general MySQL behavior.
- When you restart the MySQL server, InnoDB may reuse an old value that was generated for an `AUTO_INCREMENT` column but never stored (that is, a value that was generated during an old transaction that was rolled back).

14.9.2 Indexes

This section covers topics related to InnoDB indexes.

14.9.2.1 Clustered and Secondary Indexes

Every InnoDB table has a special index called the clustered index where the data for the rows is stored. Typically, the clustered index is synonymous with the primary key. To get the best performance from queries, inserts, and other database operations, you must understand how InnoDB uses the clustered index to optimize the most common lookup and DML operations for each table.

- When you define a `PRIMARY KEY` on your table, InnoDB uses it as the clustered index. Define a primary key for each table that you create. If there is no logical unique and non-null column or set of columns, add a new auto-increment column, whose values are filled in automatically.
- If you do not define a `PRIMARY KEY` for your table, MySQL locates the first `UNIQUE` index where all the key columns are `NOT NULL` and InnoDB uses it as the clustered index.
- If the table has no `PRIMARY KEY` or suitable `UNIQUE` index, InnoDB internally generates a hidden clustered index named `GEN_CLUST_INDEX` on a synthetic column containing row ID values. The rows are ordered by the ID that InnoDB assigns to the rows in such a table. The row ID is a 6-byte field that increases monotonically as new rows are inserted. Thus, the rows ordered by the row ID are physically in insertion order.

How the Clustered Index Speeds Up Queries

Accessing a row through the clustered index is fast because the index search leads directly to the page with all the row data. If a table is large, the clustered index architecture often saves a disk I/O operation when compared to storage organizations that store row data using a different page from the index record.

How Secondary Indexes Relate to the Clustered Index

All indexes other than the clustered index are known as secondary indexes. In InnoDB, each record in a secondary index contains the primary key columns for the row, as well as the columns specified for the secondary index. InnoDB uses this primary key value to search for the row in the clustered index.

If the primary key is long, the secondary indexes use more space, so it is advantageous to have a short primary key.

For guidelines to take advantage of InnoDB clustered and secondary indexes, see Section 8.3, “Optimization and Indexes”.

14.9.2.2 The Physical Structure of an InnoDB Index
All InnoDB indexes are B-trees where the index records are stored in the leaf pages of the tree. The default size of an index page is 16KB.

When new records are inserted into an InnoDB clustered index, InnoDB tries to leave 1/16 of the page free for future insertions and updates of the index records. If index records are inserted in a sequential order (ascending or descending), the resulting index pages are about 15/16 full. If records are inserted in a random order, the pages are from 1/2 to 15/16 full. If the fill factor of an index page drops below 1/2, InnoDB tries to contract the index tree to free the page.

Changing the InnoDB page size is not a supported operation and there is no guarantee that InnoDB functions normally with a page size other than 16KB. Problems compiling or running InnoDB may occur. In particular, ROW_FORMAT=COMPRESSED in the Barracuda file format assumes that the page size is at most 16KB and uses 14-bit pointers.

An instance using a particular InnoDB page size cannot use data files or log files from an instance that uses a different page size.

14.9.3 Tablespace

This section covers topics related to InnoDB tablespace.

14.9.3.1 The System Tablespace

The system tablespace is the storage area for the InnoDB data dictionary, the doublewrite buffer, the change buffer, and undo logs. It may also contain table and index data if tables are created in the system tablespace rather than file-per-table tablespaces.

The system tablespace can have one or more data files. By default, a single system tablespace data file, named ibdata1, is created in the data directory. The size and number of system tablespace data files is defined by the innodb_data_file_path startup option. For configuration information, see System Tablespace Data File Configuration.

Additional information about the system tablespace is provided under the following topics in the section:

- Resizing the System Tablespace
- Using Raw Disk Partitions for the System Tablespace

Resizing the System Tablespace

This section describes how to increase or decrease the size of the system tablespace.

Increasing the Size of the System Tablespace

The easiest way to increase the size of the system tablespace is to configure it to be auto-extending. To do so, specify the autoextend attribute for the last data file in the innodb_data_file_path setting, and restart the server. For example:

```
innodb_data_file_path=ibdata1:10MB:autoextend
```

When the autoextend attribute is specified, the data file automatically increases in size by 8MB increments as space is required. The innodb_autoextend_increment variable controls the increment size.

You can also increase system tablespace size by adding another data file. To do so:

1. Stop the MySQL server.
2. If the last data file in the `innodb_data_file_path` setting is defined with the `autoextend` attribute, remove it, and modify the size attribute to reflect the current data file size. To determine the appropriate data file size to specify, check your file system for the file size, and round that value down to the closest MB value, where a MB is equal to 1024 x 1024.

3. Append a new data file to the `innodb_data_file_path` setting, optionally specifying the `autoextend` attribute. The `autoextend` attribute can be specified only for the last data file in the `innodb_data_file_path` setting.

4. Start the MySQL server.

For example, this tablespace has one auto-extending data file:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:10M:autoextend
```

Suppose that the data file has grown to 988MB over time. This is the `innodb_data_file_path` setting after modifying the size attribute to reflect the current data file size, and after specifying a new 50MB auto-extending data file:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:988M;/disk2/ibdata2:50M:autoextend
```

When adding a new data file, do not specify an existing file name. InnoDB creates and initializes the new data file when you start the server.

**Note**

You cannot increase the size of an existing system tablespace data file by changing its size attribute. For example, changing the `innodb_data_file_path` setting from `ibdata1:10M:autoextend` to `ibdata1:12M:autoextend` produces the following error when starting the server:

```
[ERROR] [MY-012263] [InnoDB] The Auto-extending innodb_system data file './ibdata1' is of a different size 640 pages (rounded down to MB) than specified in the .cnf file: initial 768 pages, max 0 (relevant if non-zero) pages!
```

The error indicates that the existing data file size (expressed in InnoDB pages) is different from the size specified in the configuration file. If you encounter this error, restore the previous `innodb_data_file_path` setting, and refer to the system tablespace resizing instructions.

InnoDB page size is defined by the `innodb_page_size` variable. The default is 16384 bytes.

---

**Decreasing the Size of the InnoDB System Tablespace**

You cannot remove a data file from the system tablespace. To decrease the system tablespace size, use this procedure:

1. Use `mysqldump` to dump all of your InnoDB tables.
2. Stop the server.
3. Remove all of the existing tablespace files, including the `ibdata` and `ib_log` files. If you want to keep a backup copy of the information, then copy all the `ib*` files to another location before the removing the files in your MySQL installation.
4. Remove any `.frm` files for InnoDB tables.
5. Configure the data files for the new system tablespace. See System Tablespace Data File Configuration.

6. Restart the server.

7. Import the dump files.

To avoid large system tablespaces, consider using file-per-table tablespaces for your data. File-per-table tablespaces are the default tablespace type and are used implicitly when creating an InnoDB table. Unlike the system tablespace, disk space is returned to the operating system after truncating or dropping a table created in a file-per-table tablespace. For more information, see Section 14.9.3.2, “File-Per-Table Tablespaces”.

Using Raw Disk Partitions for the System Tablespace

You can use raw disk partitions as data files in the InnoDB system tablespace. This technique enables nonbuffered I/O on Windows and on some Linux and Unix systems without file system overhead. Perform tests with and without raw partitions to verify whether this change actually improves performance on your system.

When you use a raw disk partition, ensure that the user ID that runs the MySQL server has read and write privileges for that partition. For example, if you run the server as the mysql user, the partition must be readable and writeable by mysql. If you run the server with the --memlock option, the server must be run as root, so the partition must be readable and writeable by root.

The procedures described below involve option file modification. For additional information, see Section 4.2.2.2, “Using Option Files”.

Allocating a Raw Disk Partition on Linux and Unix Systems

1. When you create a new data file, specify the keyword newraw immediately after the data file size for the innodb_data_file_path option. The partition must be at least as large as the size that you specify. Note that 1MB in InnoDB is 1024 × 1024 bytes, whereas 1MB in disk specifications usually means 1,000,000 bytes.

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=/dev/hdd1:3Gnewraw;/dev/hdd2:2Gnewraw
   ```

2. Restart the server. InnoDB notices the newraw keyword and initializes the new partition. However, do not create or change any InnoDB tables yet. Otherwise, when you next restart the server, InnoDB reinitializes the partition and your changes are lost. (As a safety measure InnoDB prevents users from modifying data when any partition with newraw is specified.)

3. After InnoDB has initialized the new partition, stop the server, change newraw in the data file specification to raw:

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=/dev/hdd1:3Graw;/dev/hdd2:2Graw
   ```

4. Restart the server. InnoDB now permits changes to be made.

Allocating a Raw Disk Partition on Windows

On Windows systems, the same steps and accompanying guidelines described for Linux and Unix systems apply except that the innodb_data_file_path setting differs slightly on Windows.

1. When you create a new data file, specify the keyword newraw immediately after the data file size for the innodb_data_file_path option:
2. Restart the server. InnoDB notices the newraw keyword and initializes the new partition.

3. After InnoDB has initialized the new partition, stop the server, change newraw in the data file specification to raw:

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=./D::10Graw
   ```

4. Restart the server. InnoDB now permits changes to be made.

### 14.9.3.2 File-Per-Table Tablespaces

A file-per-table tablespace contains data and indexes for a single InnoDB table, and is stored on the file system in its own data file.

File-per-table tablespace characteristics are described under the following topics in this section:

- File-Per-Table Tablespace Configuration
- File-Per-Table Tablespace Data Files
- File-Per-Table Tablespace Advantages
- File-Per-Table Tablespace Disadvantages

#### File-Per-Table Tablespace Configuration

InnoDB creates tables in the shared system tablespace by default. To have InnoDB create tables in file-per-table tablespaces instead, you can enable the `innodb_file_per_table` variable.

An `innodb_file_per_table` setting can be specified in an option file or configured at runtime using a `SET GLOBAL` statement. Changing the setting at runtime requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

Option file:

   ```
   [mysqld]
   innodb_file_per_table=ON
   ```

Using `SET GLOBAL` at runtime:

   ```
   mysql> SET GLOBAL innodb_file_per_table=ON;
   ```

**Warning**

Enabling `innodb_file_per_table` causes a table-copying `ALTER TABLE` operation to implicitly move a table that resides in the system tablespace to a file-per-table tablespace. A table-copying `ALTER TABLE` operation recreates the table using the current `innodb_file_per_table` setting. This behavior does not apply when adding or dropping secondary indexes. To perform a table-copying `ALTER TABLE` operation on a table that resides in the system tablespace without moving...
Tables

the table to a file-per-table tablespace, ensure that innodb_file_per_table is
disabled before executing the operation.

File-Per-Table Tablespace Data Files

A file-per-table tablespace is created in an .idb data file in a schema directory under the MySQL data
directory. The .ibd file is named for the table (table_name.ibd). For example, the data file for table
test.t1 is created in the test directory under the MySQL data directory:

mysql> USE test;

mysql> CREATE TABLE t1 (
    id INT PRIMARY KEY AUTO_INCREMENT,
    name VARCHAR(100)
) ENGINE = InnoDB;

shell> cd /path/to/mysql/data/test
shell> ls
  t1.ibd

File-Per-Table Tablespace Advantages

File-per-table tablespaces have the following advantages over the shared system tablespace.

• Disk space is returned to the operating system after truncating or dropping a table created in a file-
  per-table tablespace. Truncating or dropping a table stored in the system tablespace creates free
  space within the system tablespace, which can only be used for InnoDB data. In other words, a system
  tablespace does not shrink in size after a table is truncated or dropped.

• A table-copying ALTER TABLE operation on a table that resides in the system tablespace can increase
  the amount of disk space occupied by the tablespace. Such operations may require as much additional
  space as the data in the table plus indexes. This space is not released back to the operating system as it
  is for file-per-table tablespaces.

• TRUNCATE TABLE performance is better when executed on tables that reside in file-per-table
  tablespaces.

• Tables created in file-per-table tablespaces use the Barracuda file format. See Section 14.13, “InnoDB
  File-Format Management”. The Barracuda file format enables features associated with DYNAMIC and
  COMPRESSED row formats. See Section 14.14, “InnoDB Row Formats”.

• Tables stored in individual tablespace data files can save time and improve chances for a successful
  recovery when data corruption occurs, when backups or binary logs are unavailable, or when the MySQL
  server instance cannot be restarted.

• You can backup or restore tables created in file-per-table tablespaces quickly using MySQL Enterprise
  Backup, without interrupting the use of other InnoDB tables. This is beneficial for tables on varying
  backup schedules or that require backup less frequently. See Making a Partial Backup for details.

• File-per-table tablespaces permit monitoring table size on the file system by monitoring the size of the
  tablespace data file.

• Common Linux file systems do not permit concurrent writes to a single file such as a system tablespace
  data file when innodb_flush_method is set to O_DIRECT. As a result, there are possible performance
  improvements when using file-per-table tablespaces in conjunction with this setting.

• Tables in the shared system tablespace, which contains other structures such as the InnoDB data
  dictionary and undo logs, are limited in size by the 64TB tablespace size limit. By comparison, each file-
  per-table tablespace has a 64TB size limit, which provides plenty of room for individual tables to grow in
  size.
File-Per-Table Tablespace Disadvantages

File-per-table tablespaces have the following disadvantages compared to the shared system tablespace.

- With file-per-table tablespaces, each table may have unused space that can only be utilized by rows of the same table, which can lead to wasted space if not properly managed.

- `fsync` operations are performed on multiple file-per-table data files instead of a shared system tablespace data file. Because `fsync` operations are per file, write operations for multiple tables cannot be combined, which can result in a higher total number of `fsync` operations.

- `mysqld` must keep an open file handle for each file-per-table tablespace, which may impact performance if you have numerous tables in file-per-table tablespaces.

- More file descriptors are required when each table has its own data file.

- There is potential for more fragmentation, which can impede `DROP TABLE` and table scan performance. However, if fragmentation is managed, file-per-table tablespaces can improve performance for these operations.

- The buffer pool is scanned when dropping a table that resides in a file-per-table tablespace, which can take several seconds for large buffer pools. The scan is performed with a broad internal lock, which may delay other operations.

- The `innodb_autoextend_increment` variable, which defines the increment size for extending the size of an auto-extending system tablespace file when it becomes full, does not apply to file-per-table tablespace files, which are auto-extending regardless of the `innodb_autoextend_increment` setting. Initial file-per-table tablespace extensions are by small amounts, after which extensions occur in increments of 4MB.

14.9.4 InnoDB Data Dictionary

The InnoDB data dictionary is comprised of internal system tables that contain metadata used to keep track of objects such as tables, indexes, and table columns. The metadata is physically located in the InnoDB system tablespace. For historical reasons, data dictionary metadata overlaps to some degree with information stored in InnoDB table metadata files (`.frm` files).

14.9.5 Doublewrite Buffer

The doublewrite buffer is a storage area in the system tablespace where InnoDB writes pages that are flushed from the buffer pool before writing them to their proper positions in the data file. Only after flushing and writing pages to the doublewrite buffer does InnoDB write pages to their proper positions. If there is an operating system, storage subsystem, or `mysqld` process crash in the middle of a page write, InnoDB can find a good copy of the page from the doublewrite buffer during crash recovery.

Although data is always written twice, the doublewrite buffer does not require twice as much I/O overhead or twice as many I/O operations. Data is written to the doublewrite buffer as a large sequential chunk, with a single `fsync()` call to the operating system.

The doublewrite buffer is enabled by default. To disable the doublewrite buffer, set `innodb_doublewrite` to 0.

14.9.6 Redo Log

The redo log is a disk-based data structure used during crash recovery to correct data written by incomplete transactions. During normal operations, the redo log encodes requests to change table data that result from SQL statements or low-level API calls. Modifications that did not finish updating the
data files before an unexpected shutdown are replayed automatically during initialization, and before the connections are accepted. For information about the role of the redo log in crash recovery, see Section 14.21.2, “InnoDB Recovery”.

By default, the redo log is physically represented on disk by two files named `ib_logfile0` and `ib_logfile1`. MySQL writes to the redo log files in a circular fashion. Data in the redo log is encoded in terms of records affected; this data is collectively referred to as redo. The passage of data through the redo log is represented by an ever-increasing LSN value.

For related information, see Redo Log File Configuration, and Section 8.5.3, “Optimizing InnoDB Redo Logging”.

### Changing the Number or Size of Redo Log Files

To change the number or the size of your InnoDB redo log files, perform the following steps:

1. If `innodb_fast_shutdown` is set to 2, set `innodb_fast_shutdown` to 1:
   ```sql
   mysql> SET GLOBAL innodb_fast_shutdown = 1;
   ```

2. After ensuring that `innodb_fast_shutdown` is not set to 2, stop the MySQL server and make sure that it shuts down without errors (to ensure that there is no information for outstanding transactions in the log).

3. Copy the old log files into a safe place in case something went wrong during the shutdown and you need them to recover the tablespace.

4. Delete the old log files from the log file directory.

5. Edit `my.cnf` to change the log file configuration.

6. Start the MySQL server again. `mysqld` sees that no InnoDB log files exist at startup and creates new ones.

### Group Commit for Redo Log Flushing

InnoDB, like any other ACID-compliant database engine, flushes the redo log of a transaction before it is committed. InnoDB uses group commit functionality to group multiple such flush requests together to avoid one flush for each commit. With group commit, InnoDB issues a single write to the redo log file to perform the commit action for multiple user transactions that commit at about the same time, significantly improving throughput.

Group commit in InnoDB worked in earlier releases of MySQL and works once again with MySQL 5.1 with the InnoDB Plugin, and MySQL 5.5 and higher. The introduction of support for the distributed transactions and Two Phase Commit (2PC) in MySQL 5.0 interfered with the InnoDB group commit functionality. This issue is now resolved.

The group commit functionality inside InnoDB works with the Two Phase Commit protocol in MySQL. Re-enabling of the group commit functionality fully ensures that the ordering of commit in the MySQL binary log and the InnoDB logfile is the same as it was before. It means it is safe to use the MySQL Enterprise Backup product with InnoDB 1.0.4 (that is, the InnoDB Plugin with MySQL 5.1) and above.

For more information about performance of COMMIT and other transactional operations, see Section 8.5.2, “Optimizing InnoDB Transaction Management”.

### 14.9.7 Undo Logs

An undo log is a collection of undo log records associated with a single read-write transaction. An undo log record contains information about how to undo the latest change by a transaction to a clustered index...
record. If another transaction needs to see the original data as part of a consistent read operation, the unmodified data is retrieved from undo log records. Undo logs exist within undo log segments, which are contained within rollback segments. Rollback segments are physically part of the system tablespace.

InnoDB supports 128 rollback segments. The innodb.rollback.segments variable defines the number of rollback segments used by InnoDB.

Each rollback segment supports up to 1024 transactions, depending on the number of undo logs assigned to each transaction. (The 1024 value is the number of undo slots in a rollback segment.) A transaction is assigned up to two undo logs, one for each of the following operation types:

1. **INSERT** operations
2. **UPDATE** and **DELETE** operations

Undo logs are assigned as needed. For example, a transaction that performs **INSERT**, **UPDATE**, and **DELETE** operations is assigned two undo logs. A transaction that performs only **INSERT** operations is assigned a single undo log. Undo logs are assigned to a transaction from a single rollback segment that is also assigned to the transaction.

An undo log assigned to a transaction remains tied to the transaction for its duration. For example, an undo log assigned to a transaction for an **INSERT** operation is used for all **INSERT** operations performed by that transaction.

Given the factors described above, the following formulas can be used to estimate the number of concurrent read-write transactions that InnoDB is capable of supporting.

**Note**

A transaction can encounter a concurrent transaction limit error before reaching the number of concurrent read-write transactions that InnoDB is capable of supporting. This occurs when the rollback segment assigned to a transaction runs out of undo slots. In such cases, try rerunning the transaction.

- If each transaction performs either an **INSERT** or an **UPDATE** or **DELETE** operation, the number of concurrent read-write transactions that InnoDB is capable of supporting is:

  \[1024 \times \text{innodb.rollback.segments}\]

- If each transaction performs an **INSERT** and an **UPDATE** or **DELETE** operation, the number of concurrent read-write transactions that InnoDB is capable of supporting is:

  \[\frac{1024}{2} \times \text{innodb.rollback.segments}\]

### 14.10 InnoDB Locking and Transaction Model

To implement a large-scale, busy, or highly reliable database application, to port substantial code from a different database system, or to tune MySQL performance, it is important to understand InnoDB locking and the InnoDB transaction model.

This section discusses several topics related to InnoDB locking and the InnoDB transaction model with which you should be familiar.

- **Section 14.10.1, “InnoDB Locking”** describes lock types used by InnoDB.
- **Section 14.10.2, “InnoDB Transaction Model”** describes transaction isolation levels and the locking strategies used by each. It also discusses the use of **autocommit**, consistent non-locking reads, and locking reads.
InnoDB Locking

- Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB” discusses specific types of locks set in InnoDB for various statements.
- Section 14.10.4, “Phantom Rows” describes how InnoDB uses next-key locking to avoid phantom rows.
- Section 14.10.5, “Deadlocks in InnoDB” provides a deadlock example, discusses deadlock detection and rollback, and provides tips for minimizing and handling deadlocks in InnoDB.

14.10.1 InnoDB Locking

This section describes lock types used by InnoDB.

- Shared and Exclusive Locks
- Intention Locks
- Record Locks
- Gap Locks
- Next-Key Locks
- Insert Intention Locks
- AUTO-INC Locks

Shared and Exclusive Locks

InnoDB implements standard row-level locking where there are two types of locks, shared (S) locks and exclusive (X) locks.

- A shared (S) lock permits the transaction that holds the lock to read a row.
- An exclusive (X) lock permits the transaction that holds the lock to update or delete a row.

If transaction T1 holds a shared (S) lock on row r, then requests from some distinct transaction T2 for a lock on row r are handled as follows:

- A request by T2 for an S lock can be granted immediately. As a result, both T1 and T2 hold an S lock on r.
- A request by T2 for an X lock cannot be granted immediately.

If a transaction T1 holds an exclusive (X) lock on row r, a request from some distinct transaction T2 for a lock of either type on r cannot be granted immediately. Instead, transaction T2 has to wait for transaction T1 to release its lock on row r.

Intention Locks

InnoDB supports multiple granularity locking which permits coexistence of row locks and table locks. For example, a statement such as LOCK TABLES ... WRITE takes an exclusive lock (an X lock) on the specified table. To make locking at multiple granularity levels practical, InnoDB uses intention locks. Intention locks are table-level locks that indicate which type of lock (shared or exclusive) a transaction requires later for a row in a table. There are two types of intention locks:

- An intention shared lock (IS) indicates that a transaction intends to set a shared lock on individual rows in a table.
- An intention exclusive lock (IX) indicates that a transaction intends to set an exclusive lock on individual rows in a table.
InnoDB Locking

For example, SELECT ... LOCK IN SHARE MODE sets an IS lock, and SELECT ... FOR UPDATE sets an IX lock.

The intention locking protocol is as follows:

• Before a transaction can acquire a shared lock on a row in a table, it must first acquire an IS lock or stronger on the table.

• Before a transaction can acquire an exclusive lock on a row in a table, it must first acquire an IX lock on the table.

Table-level lock type compatibility is summarized in the following matrix.

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>IX</th>
<th>S</th>
<th>IS</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Conflict</td>
<td>Conflict</td>
<td>Conflict</td>
<td>Conflict</td>
</tr>
<tr>
<td>IX</td>
<td>Conflict</td>
<td>Compatible</td>
<td>Conflict</td>
<td>Compatible</td>
</tr>
<tr>
<td>S</td>
<td>Conflict</td>
<td>Conflict</td>
<td>Compatible</td>
<td>Compatible</td>
</tr>
<tr>
<td>IS</td>
<td>Conflict</td>
<td>Compatible</td>
<td>Compatible</td>
<td>Compatible</td>
</tr>
</tbody>
</table>

A lock is granted to a requesting transaction if it is compatible with existing locks, but not if it conflicts with existing locks. A transaction waits until the conflicting existing lock is released. If a lock request conflicts with an existing lock and cannot be granted because it would cause deadlock, an error occurs.

Intention locks do not block anything except full table requests (for example, LOCK TABLES ... WRITE). The main purpose of intention locks is to show that someone is locking a row, or going to lock a row in the table.

Transaction data for an intention lock appears similar to the following in SHOW ENGINE INNODB STATUS and InnoDB monitor output:

```
TABLE LOCK table `test`.`t` trx id 10080 lock mode IX
```

Record Locks

A record lock is a lock on an index record. For example, SELECT c1 FROM t WHERE c1 = 10 FOR UPDATE; prevents any other transaction from inserting, updating, or deleting rows where the value of t.c1 is 10.

Record locks always lock index records, even if a table is defined with no indexes. For such cases, InnoDB creates a hidden clustered index and uses this index for record locking. See Section 14.9.2.1, "Clustered and Secondary Indexes".

Transaction data for a record lock appears similar to the following in SHOW ENGINE INNODB STATUS and InnoDB monitor output:

```
RECORD LOCKS space id 58 page no 3 n bits 72 index `PRIMARY` of table `test`.`t`
trx id 10078 lock_mode X locks rec but not gap
Record lock, heap no 2 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
  0: len 4; hex 8000000a; asc ;
  1: len 6; hex 0000000274f; asc O;
  2: len 7; hex b6000019d0110; asc ;
```

Gap Locks

A gap lock is a lock on a gap between index records, or a lock on the gap before the first or after the last index record. For example, SELECT c1 FROM t WHERE c1 BETWEEN 10 and 20 FOR UPDATE;
InnoDB Locking

prevents other transactions from inserting a value of 15 into column \texttt{t.c1}, whether or not there was already any such value in the column, because the gaps between all existing values in the range are locked.

A gap might span a single index value, multiple index values, or even be empty.

Gap locks are part of the tradeoff between performance and concurrency, and are used in some transaction isolation levels and not others.

Gap locking is not needed for statements that lock rows using a unique index to search for a unique row. (This does not include the case that the search condition includes only some columns of a multiple-column unique index; in that case, gap locking does occur.) For example, if the \texttt{id} column has a unique index, the following statement uses only an index-record lock for the row having \texttt{id} value 100 and it does not matter whether other sessions insert rows in the preceding gap:

\begin{verbatim}
SELECT * FROM child WHERE id = 100;
\end{verbatim}

If \texttt{id} is not indexed or has a nonunique index, the statement does lock the preceding gap.

It is also worth noting here that conflicting locks can be held on a gap by different transactions. For example, transaction A can hold a shared gap lock (gap S-lock) on a gap while transaction B holds an exclusive gap lock (gap X-lock) on the same gap. The reason conflicting gap locks are allowed is that if a record is purged from an index, the gap locks held on the record by different transactions must be merged.

Gap locks in \textit{InnoDB} are “purely inhibitive”, which means that their only purpose is to prevent other transactions from inserting to the gap. Gap locks can co-exist. A gap lock taken by one transaction does not prevent another transaction from taking a gap lock on the same gap. There is no difference between shared and exclusive gap locks. They do not conflict with each other, and they perform the same function.

Gap locking can be disabled explicitly. This occurs if you change the transaction isolation level to \textit{READ COMMITTED} or enable the \texttt{innodb_locks_unsafe_for_binlog} system variable. Under these circumstances, gap locking is disabled for searches and index scans and is used only for foreign-key constraint checking and duplicate-key checking.

There are also other effects of using the \textit{READ COMMITTED} isolation level or enabling \texttt{innodb_locks_unsafe_for_binlog}. Record locks for nonmatching rows are released after MySQL has evaluated the \texttt{WHERE} condition. For \texttt{UPDATE} statements, \textit{InnoDB} does a “semi-consistent” read, such that it returns the latest committed version to MySQL so that MySQL can determine whether the row matches the \texttt{WHERE} condition of the \texttt{UPDATE}.

\textbf{Next-Key Locks}

A next-key lock is a combination of a record lock on the index record and a gap lock on the gap before the index record.

\textit{InnoDB} performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. A next-key lock on an index record also affects the “gap” before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record \texttt{R} in an index, another session cannot insert a new index record in the gap immediately before \texttt{R} in the index order.

Suppose that an index contains the values 10, 11, 13, and 20. The possible next-key locks for this index cover the following intervals, where a round bracket denotes exclusion of the interval endpoint and a square bracket denotes inclusion of the endpoint:
For the last interval, the next-key lock locks the gap above the largest value in the index and the "supremum" pseudo-record having a value higher than any value actually in the index. The supremum is not a real index record, so, in effect, this next-key lock locks only the gap following the largest index value.

By default, InnoDB operates in REPEATABLE READ transaction isolation level and with the innodb_locks_unsafe_for_binlog system variable disabled. In this case, InnoDB uses next-key locks for searches and index scans, which prevents phantom rows (see Section 14.10.4, "Phantom Rows").

Transaction data for a next-key lock appears similar to the following in SHOW ENGINE INNODB STATUS and InnoDB monitor output:

```
RECORD LOCKS space id 58 page no 3 n bits 72 index `PRIMARY` of table `test`.`t`
trx id 10080 lock_mode X
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
  0: len 8; hex 73757072656d756d; asc supremum;;
Record lock, heap no 2 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
  0: len 4; hex 8000000a; asc ;;
  1: len 6; hex 0000000274f; asc 'O;;
  2: len 7; hex b60000019d0110; asc ;;
```

### Insert Intention Locks

An insert intention lock is a type of gap lock set by INSERT operations prior to row insertion. This lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6, respectively, each lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

The following example demonstrates a transaction taking an insert intention lock prior to obtaining an exclusive lock on the inserted record. The example involves two clients, A and B.

Client A creates a table containing two index records (90 and 102) and then starts a transaction that places an exclusive lock on index records with an ID greater than 100. The exclusive lock includes a gap lock before record 102:

```
mysql> CREATE TABLE child (id int(11) NOT NULL, PRIMARY KEY(id)) ENGINE=InnoDB;
mysql> INSERT INTO child (id) values (90),(102);
mysql> START TRANSACTION;
mysql> SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

```
+-----+
| id  |
+-----+
| 102 |
```

Client B begins a transaction to insert a record into the gap. The transaction takes an insert intention lock while it waits to obtain an exclusive lock.

```
mysql> START TRANSACTION;
mysql> INSERT INTO child (id) VALUES (101);
```
InnoDB Transaction Model

Transaction data for an insert intention lock appears similar to the following in `SHOW ENGINE INNODB STATUS` and `InnoDB monitor` output:

```
RECORD LOCKS space id 31 page no 3 n bits 72 index `PRIMARY` of table `test`.`child`
trx id 8731 lock_mode X locks gap before rec insert intention waiting
0: len 4; hex 80000066; asc  |
1: len 6; hex 000000022215; asc  |
2: len 7; hex 900000172011c; asc  |
```

AUTO-INC Locks

An AUTO-INC lock is a special table-level lock taken by transactions inserting into tables with AUTO_INCREMENT columns. In the simplest case, if one transaction is inserting values into the table, any other transactions must wait to do their own inserts into that table, so that rows inserted by the first transaction receive consecutive primary key values.

The `innodb_autoinc_lock_mode` configuration option controls the algorithm used for auto-increment locking. It allows you to choose how to trade off between predictable sequences of auto-increment values and maximum concurrency for insert operations.

For more information, see Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”.

14.10.2 InnoDB Transaction Model

In the InnoDB transaction model, the goal is to combine the best properties of a multi-versioning database with traditional two-phase locking. InnoDB performs locking at the row level and runs queries as nonlocking consistent reads by default, in the style of Oracle. The lock information in InnoDB is stored space-efficiently so that lock escalation is not needed. Typically, several users are permitted to lock every row in InnoDB tables, or any random subset of the rows, without causing InnoDB memory exhaustion.

14.10.2.1 Transaction Isolation Levels

Transaction isolation is one of the foundations of database processing. Isolation is the I in the acronym ACID; the isolation level is the setting that fine-tunes the balance between performance and reliability, consistency, and reproducibility of results when multiple transactions are making changes and performing queries at the same time.

InnoDB offers all four transaction isolation levels described by the SQL:1992 standard: READ UNCOMMITTED, READ COMMITTED, REPEATABLE READ, and SERIALIZABLE. The default isolation level for InnoDB is REPEATABLE READ.

A user can change the isolation level for a single session or for all subsequent connections with the `SET TRANSACTION` statement. To set the server's default isolation level for all connections, use the `--transaction-isolation` option on the command line or in an option file. For detailed information about isolation levels and level-setting syntax, see Section 13.3.6, “SET TRANSACTION Statement”.

InnoDB supports each of the transaction isolation levels described here using different locking strategies. You can enforce a high degree of consistency with the default REPEATABLE READ level, for operations on crucial data where ACID compliance is important. Or you can relax the consistency rules with READ COMMITTED or even READ UNCOMMITTED, in situations such as bulk reporting where precise consistency and repeatable results are less important than minimizing the amount of overhead for locking. SERIALIZABLE enforces even stricter rules than REPEATABLE READ, and is used mainly in specialized situations, such as with XA transactions and for troubleshooting issues with concurrency and deadlocks.

The following list describes how MySQL supports the different transaction levels. The list goes from the most commonly used level to the least used.
InnoDB Transaction Model

• **REPEATABLE READ**

This is the default isolation level for InnoDB. Consistent reads within the same transaction read the snapshot established by the first read. This means that if you issue several plain (nonlocking) SELECT statements within the same transaction, these SELECT statements are consistent also with respect to each other. See Section 14.10.2.3, “Consistent Nonlocking Reads”.

For locking reads (SELECT with FOR UPDATE or LOCK IN SHARE MODE), UPDATE, and DELETE statements, locking depends on whether the statement uses a unique index with a unique search condition, or a range-type search condition.

• For a unique index with a unique search condition, InnoDB locks only the index record found, not the gap before it.

• For other search conditions, InnoDB locks the index range scanned, using gap locks or next-key locks to block insertions by other sessions into the gaps covered by the range. For information about gap locks and next-key locks, see Section 14.10.1, “InnoDB Locking”.

• **READ COMMITTED**

Each consistent read, even within the same transaction, sets and reads its own fresh snapshot. For information about consistent reads, see Section 14.10.2.3, “Consistent Nonlocking Reads”.

For locking reads (SELECT with FOR UPDATE or LOCK IN SHARE MODE), UPDATE statements, and DELETE statements, InnoDB locks only index records, not the gaps before them, and thus permits the free insertion of new records next to locked records. Gap locking is only used for foreign-key constraint checking and duplicate-key checking.

Because gap locking is disabled, phantom problems may occur, as other sessions can insert new rows into the gaps. For information about phantoms, see Section 14.10.4, “Phantom Rows”.

Only row-based binary logging is supported with the READ COMMITTED isolation level. If you use READ COMMITTED with binlog_format=MIXED, the server automatically uses row-based logging.

Using **READ COMMITTED** has additional effects:

• For UPDATE or DELETE statements, InnoDB holds locks only for rows that it updates or deletes. Record locks for nonmatching rows are released after MySQL has evaluated the WHERE condition. This greatly reduces the probability of deadlocks, but they can still happen.

• For UPDATE statements, if a row is already locked, InnoDB performs a “semi-consistent” read, returning the latest committed version to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE. If the row matches (must be updated), MySQL reads the row again and this time InnoDB either locks it or waits for a lock on it.

Consider the following example, beginning with this table:

```sql
CREATE TABLE t (a INT NOT NULL, b INT) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2),(2,3),(3,2),(4,3),(5,2);
COMMIT;
```

In this case, the table has no indexes, so searches and index scans use the hidden clustered index for record locking (see Section 14.9.2.1, “Clustered and Secondary Indexes”) rather than indexed columns.

Suppose that one session performs an UPDATE using these statements:

```sql
# Session A
START TRANSACTION;
```
UPDATE t SET b = 5 WHERE b = 3;

Suppose also that a second session performs an `UPDATE` by executing this statement following those of the first session:

```sql
# Session B
UPDATE t SET b = 4 WHERE b = 2;
```

As InnoDB executes each `UPDATE`, it first acquires an exclusive lock for each row that it reads, and then determines whether to modify it. If InnoDB does not modify the row, it releases the lock. Otherwise, InnoDB retains the lock until the end of the transaction. This affects transaction processing as follows.

When using the default `REPEATABLE READ` isolation level, the first `UPDATE` acquires an x-lock on each row that it reads and does not release any of them:

<table>
<thead>
<tr>
<th>x-lock(1,2); retain x-lock</th>
<th>x-lock(2,3); update(2,3) to (2,5); retain x-lock</th>
<th>x-lock(3,2); retain x-lock</th>
<th>x-lock(4,3); update(4,3) to (4,5); retain x-lock</th>
<th>x-lock(5,2); retain x-lock</th>
</tr>
</thead>
</table>

The second `UPDATE` blocks as soon as it tries to acquire any locks (because first update has retained locks on all rows), and does not proceed until the first `UPDATE` commits or rolls back:

<table>
<thead>
<tr>
<th>x-lock(1,2); block and wait for first UPDATE to commit or roll back</th>
</tr>
</thead>
</table>

If `READ COMMITTED` is used instead, the first `UPDATE` acquires an x-lock on each row that it reads and releases those for rows that it does not modify:

<table>
<thead>
<tr>
<th>x-lock(1,2); unlock(1,2)</th>
<th>x-lock(2,3); update(2,3) to (2,5); retain x-lock</th>
<th>x-lock(3,2); unlock(3,2)</th>
<th>x-lock(4,3); update(4,3) to (4,5); retain x-lock</th>
<th>x-lock(5,2); unlock(5,2)</th>
</tr>
</thead>
</table>

For the second `UPDATE`, InnoDB does a “semi-consistent” read, returning the latest committed version of each row that it reads to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`:

<table>
<thead>
<tr>
<th>x-lock(1,2); update(1,2) to (1,4); retain x-lock</th>
<th>x-lock(2,3); unlock(2,3)</th>
<th>x-lock(3,2); update(3,2) to (3,4); retain x-lock</th>
<th>x-lock(4,3); unlock(4,3)</th>
<th>x-lock(5,2); update(5,2) to (5,4); retain x-lock</th>
</tr>
</thead>
</table>

However, if the `WHERE` condition includes an indexed column, and InnoDB uses the index, only the indexed column is considered when taking and retaining record locks. In the following example, the first `UPDATE` takes and retains an x-lock on each row where `b = 2`. The second `UPDATE` blocks when it tries to acquire x-locks on the same records, as it also uses the index defined on column `b`.

```sql
CREATE TABLE t (a INT NOT NULL, b INT, c INT, INDEX (b)) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2,3),(2,2,4);
COMMIT;
# Session A
START TRANSACTION;
UPDATE t SET b = 3 WHERE b = 2 AND c = 3;
# Session B
```
**UPDATE t SET b = 4 WHERE b = 2 AND c = 4;**

The effects of using the `READ COMMITTED` isolation level are the same as enabling the `innodb_locks_unsafe_for_binlog` configuration option, with these exceptions:

- Enabling `innodb_locks_unsafe_for_binlog` is a global setting and affects all sessions, whereas the isolation level can be set globally for all sessions, or individually per session.

- `innodb_locks_unsafe_for_binlog` can be set only at server startup, whereas the isolation level can be set at startup or changed at runtime.

`READ COMMITTED` therefore offers finer and more flexible control than `innodb_locks_unsafe_for_binlog`.

- **READ UNCOMMITTED**

  `SELECT` statements are performed in a nonlocking fashion, but a possible earlier version of a row might be used. Thus, using this isolation level, such reads are not consistent. This is also called a “dirty read.” Otherwise, this isolation level works like `READ COMMITTED`.

- **SERIALIZABLE**

  This level is like `REPEATABLE READ`, but InnoDB implicitly converts all plain `SELECT` statements to `SELECT ... LOCK IN SHARE MODE` if autocommit is disabled. If autocommit is enabled, the `SELECT` is its own transaction. It therefore is known to be read only and can be serialized if performed as a consistent (nonlocking) read and need not block for other transactions. (To force a plain `SELECT` to block if other transactions have modified the selected rows, disable autocommit.)

### 14.10.2.2 autocommit, Commit, and Rollback

In InnoDB, all user activity occurs inside a transaction. If autocommit mode is enabled, each SQL statement forms a single transaction on its own. By default, MySQL starts the session for each new connection with autocommit enabled, so MySQL does a commit after each SQL statement if that statement did not return an error. If a statement returns an error, the commit or rollback behavior depends on the error. See Section 14.23.4, “InnoDB Error Handling”.

A session that has autocommit enabled can perform a multiple-statement transaction by starting it with an explicit `START TRANSACTION` or `BEGIN` statement and ending it with a `COMMIT` or `ROLLBACK` statement. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”.

If autocommit mode is disabled within a session with `SET autocommit = 0`, the session always has a transaction open. A `COMMIT` or `ROLLBACK` statement ends the current transaction and a new one starts.

If a session that has autocommit disabled ends without explicitly committing the final transaction, MySQL rolls back that transaction.

Some statements implicitly end a transaction, as if you had done a `COMMIT` before executing the statement. For details, see Section 13.3.3, “Statements That Cause an Implicit Commit”.

A `COMMIT` means that the changes made in the current transaction are made permanent and become visible to other sessions. A `ROLLBACK` statement, on the other hand, cancels all modifications made by the current transaction. Both `COMMIT` and `ROLLBACK` release all InnoDB locks that were set during the current transaction.

**Grouping DML Operations with Transactions**

By default, connection to the MySQL server begins with autocommit mode enabled, which automatically commits every SQL statement as you execute it. This mode of operation might be unfamiliar if you have
experience with other database systems, where it is standard practice to issue a sequence of DML statements and commit them or roll them back all together.

To use multiple-statement transactions, switch autocommit off with the SQL statement `SET autocommit = 0` and end each transaction with `COMMIT` or `ROLLBACK` as appropriate. To leave autocommit on, begin each transaction with `START TRANSACTION` and end it with `COMMIT` or `ROLLBACK`. The following example shows two transactions. The first is committed; the second is rolled back.

```
shell> mysql test

mysql> CREATE TABLE customer (a INT, b CHAR (20), INDEX (a));
Query OK, 0 rows affected (0.00 sec)
mysql> -- Do a transaction with autocommit turned on.
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (10, 'Heikki');
Query OK, 1 row affected (0.00 sec)
mysql> COMMIT;
Query OK, 0 rows affected (0.00 sec)
mysql> -- Do another transaction with autocommit turned off.
mysql> SET autocommit=0;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (15, 'John');
Query OK, 1 row affected (0.00 sec)
mysql> INSERT INTO customer VALUES (20, 'Paul');
Query OK, 1 row affected (0.00 sec)
mysql> DELETE FROM customer WHERE b = 'Heikki';
Query OK, 1 row affected (0.00 sec)
mysql> -- Now we undo those last 2 inserts and the delete.
mysql> ROLLBACK;
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT * FROM customer;
+------+--------+
<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Heikki</td>
</tr>
</tbody>
</table>
+------+--------+
1 row in set (0.00 sec)
mysql>
```

### Transactions in Client-Side Languages

In APIs such as PHP, Perl DBI, JDBC, ODBC, or the standard C call interface of MySQL, you can send transaction control statements such as `COMMIT` to the MySQL server as strings just like any other SQL statements such as `SELECT` or `INSERT`. Some APIs also offer separate special transaction commit and rollback functions or methods.

#### 14.10.2.3 Consistent Nonlocking Reads

A consistent read means that InnoDB uses multi-versioning to present to a query a snapshot of the database at a point in time. The query sees the changes made by transactions that committed before that point of time, and no changes made by later or uncommitted transactions. The exception to this rule is that the query sees the changes made by earlier statements within the same transaction. This exception causes the following anomaly: If you update some rows in a table, a `SELECT` sees the latest version of the updated rows, but it might also see older versions of any rows. If other sessions simultaneously update the same table, the anomaly means that you might see the table in a state that never existed in the database.

If the transaction isolation level is `REPEATABLE READ` (the default level), all consistent reads within the same transaction read the snapshot established by the first such read in that transaction. You can get a fresher snapshot for your queries by committing the current transaction and after that issuing new queries.
With **READ COMMITTED** isolation level, each consistent read within a transaction sets and reads its own fresh snapshot.

Consistent read is the default mode in which InnoDB processes **SELECT** statements in **READ COMMITTED** and **REPEATABLE READ** isolation levels. A consistent read does not set any locks on the tables it accesses, and therefore other sessions are free to modify those tables at the same time a consistent read is being performed on the table.

Suppose that you are running in the default **REPEATABLE READ** isolation level. When you issue a consistent read (that is, an ordinary **SELECT** statement), InnoDB gives your transaction a timepoint according to which your query sees the database. If another transaction deletes a row and commits after your timepoint was assigned, you do not see the row as having been deleted. Inserts and updates are treated similarly.

**Note**

The snapshot of the database state applies to **SELECT** statements within a transaction, not necessarily to **DML** statements. If you insert or modify some rows and then commit that transaction, a **DELETE** or **UPDATE** statement issued from another concurrent **REPEATABLE READ** transaction could affect those just-committed rows, even though the session could not query them. If a transaction does update or delete rows committed by a different transaction, those changes do become visible to the current transaction. For example, you might encounter a situation like the following:

```sql
SELECT COUNT(c1) FROM t1 WHERE c1 = 'xyz';
-- Returns 0: no rows match.
DELETE FROM t1 WHERE c1 = 'xyz';
-- Deletes several rows recently committed by other transaction.

SELECT COUNT(c2) FROM t1 WHERE c2 = 'abc';
-- Returns 0: no rows match.
UPDATE t1 SET c2 = 'cba' WHERE c2 = 'abc';
-- Affects 10 rows: another txn just committed 10 rows with 'abc' values.
SELECT COUNT(c2) FROM t1 WHERE c2 = 'cba';
-- Returns 10: this txn can now see the rows it just updated.
```

You can advance your timepoint by committing your transaction and then doing another **SELECT** or **START TRANSACTION WITH CONSISTENT SNAPSHOT**.

This is called **multi-versioned concurrency snapshot**.

In the following example, session A sees the row inserted by B only when B has committed the insert and A has committed as well, so that the timepoint is advanced past the commit of B.

```
Session A                          Session B
--
SET autocommit=0;                 SET autocommit=0;
SELECT * FROM t;                   INSERT INTO t VALUES (1, 2);
  empty set                        COMMIT;
SELECT * FROM t;                   empty set
  empty set
```
If you want to see the “freshest” state of the database, use either the READ COMMITTED isolation level or a locking read:

```sql
SELECT * FROM t LOCK IN SHARE MODE;
```

With READ COMMITTED isolation level, each consistent read within a transaction sets and reads its own fresh snapshot. With LOCK IN SHARE MODE, a locking read occurs instead: A SELECT blocks until the transaction containing the freshest rows ends (see Section 14.10.2.4, “Locking Reads”).

Consistent read does not work over certain DDL statements:

- Consistent read does not work over DROP TABLE, because MySQL cannot use a table that has been dropped and InnoDB destroys the table.

- Consistent read does not work over ALTER TABLE, because that statement makes a temporary copy of the original table and deletes the original table when the temporary copy is built. When you reissue a consistent read within a transaction, rows in the new table are not visible because those rows did not exist when the transaction’s snapshot was taken.

The type of read varies for selects in clauses like INSERT INTO ... SELECT, UPDATE ... (SELECT), and CREATE TABLE ... SELECT that do not specify FOR UPDATE or LOCK IN SHARE MODE:

- By default, InnoDB uses stronger locks and the SELECT part acts like READ COMMITTED, where each consistent read, even within the same transaction, sets and reads its own fresh snapshot.

- To use a consistent read in such cases, enable the innodb_locks_unsafe_for_binlog option and set the isolation level of the transaction to READ UNCOMMITTED, READ COMMITTED, or REPEATABLE READ (that is, anything other than SERIALIZABLE). In this case, no locks are set on rows read from the selected table.

### 14.10.2.4 Locking Reads

If you query data and then insert or update related data within the same transaction, the regular SELECT statement does not give enough protection. Other transactions can update or delete the same rows you just queried. InnoDB supports two types of locking reads that offer extra safety:

- **SELECT ... LOCK IN SHARE MODE**

  Sets a shared mode lock on any rows that are read. Other sessions can read the rows, but cannot modify them until your transaction commits. If any of these rows were changed by another transaction that has not yet committed, your query waits until that transaction ends and then uses the latest values.

- **SELECT ... FOR UPDATE**

  For index records the search encounters, locks the rows and any associated index entries, the same as if you issued an UPDATE statement for those rows. Other transactions are blocked from updating those rows, from doing SELECT ... LOCK IN SHARE MODE, or from reading the data in certain transaction isolation levels. Consistent reads ignore any locks set on the records that exist in the read view. (Old versions of a record cannot be locked; they are reconstructed by applying undo logs on an in-memory copy of the record.)
InnoDB Transaction Model

These clauses are primarily useful when dealing with tree-structured or graph-structured data, either in a single table or split across multiple tables. You traverse edges or tree branches from one place to another, while reserving the right to come back and change any of these “pointer” values.

All locks set by `LOCK IN SHARE MODE` and `FOR UPDATE` queries are released when the transaction is committed or rolled back.

Note

Locking reads are only possible when autocommit is disabled (either by beginning transaction with `START TRANSACTION` or by setting `autocommit` to 0.

A locking read clause in an outer statement does not lock the rows of a table in a nested subquery unless a locking read clause is also specified in the subquery. For example, the following statement does not lock rows in table `t2`.

```
SELECT * FROM t1 WHERE c1 = (SELECT c1 FROM t2) FOR UPDATE;
```

To lock rows in table `t2`, add a locking read clause to the subquery:

```
SELECT * FROM t1 WHERE c1 = (SELECT c1 FROM t2 FOR UPDATE) FOR UPDATE;
```

Locking Read Examples

Suppose that you want to insert a new row into a table `child`, and make sure that the child row has a parent row in table `parent`. Your application code can ensure referential integrity throughout this sequence of operations.

First, use a consistent read to query the table `PARENT` and verify that the parent row exists. Can you safely insert the child row to table `CHILD`? No, because some other session could delete the parent row in the moment between your `SELECT` and your `INSERT`, without you being aware of it.

To avoid this potential issue, perform the `SELECT` using `LOCK IN SHARE MODE`:

```
SELECT * FROM parent WHERE NAME = 'Jones' LOCK IN SHARE MODE;
```

After the `LOCK IN SHARE MODE` query returns the parent 'Jones', you can safely add the child record to the `CHILD` table and commit the transaction. Any transaction that tries to acquire an exclusive lock in the applicable row in the `PARENT` table waits until you are finished, that is, until the data in all tables is in a consistent state.

For another example, consider an integer counter field in a table `CHILD_CODES`, used to assign a unique identifier to each child added to table `CHILD`. Do not use either consistent read or a shared mode read to read the present value of the counter, because two users of the database could see the same value for the counter, and a duplicate-key error occurs if two transactions attempt to add rows with the same identifier to the `CHILD` table.

Here, `LOCK IN SHARE MODE` is not a good solution because if two users read the counter at the same time, at least one of them ends up in deadlock when it attempts to update the counter.

To implement reading and incrementing the counter, first perform a locking read of the counter using `FOR UPDATE`, and then increment the counter. For example:

```
SELECT counter_field FROM child_codes FOR UPDATE;
UPDATE child_codes SET counter_field = counter_field + 1;
```

A `SELECT ... FOR UPDATE` reads the latest available data, setting exclusive locks on each row it reads. Thus, it sets the same locks a searched SQL `UPDATE` would set on the rows.
The preceding description is merely an example of how SELECT ... FOR UPDATE works. In MySQL, the specific task of generating a unique identifier actually can be accomplished using only a single access to the table:

```
UPDATE child_codes SET counter_field = LAST_INSERT_ID(counter_field + 1);
SELECT LAST_INSERT_ID();
```

The SELECT statement merely retrieves the identifier information (specific to the current connection). It does not access any table.

### 14.10.3 Locks Set by Different SQL Statements in InnoDB

A locking read, an UPDATE, or a DELETE generally set record locks on every index record that is scanned in the processing of the SQL statement. It does not matter whether there are WHERE conditions in the statement that would exclude the row. InnoDB does not remember the exact WHERE condition, but only knows which index ranges were scanned. The locks are normally next-key locks that also block inserts into the “gap” immediately before the record. However, gap locking can be disabled explicitly, which causes next-key locking not to be used. For more information, see Section 14.10.1, “InnoDB Locking”. The transaction isolation level also can affect which locks are set; see Section 14.10.2.1, “Transaction Isolation Levels”.

If a secondary index is used in a search and index record locks to be set are exclusive, InnoDB also retrieves the corresponding clustered index records and sets locks on them.

If you have no indexes suitable for your statement and MySQL must scan the entire table to process the statement, every row of the table becomes locked, which in turn blocks all inserts by other users to the table. It is important to create good indexes so that your queries do not unnecessarily scan many rows.

InnoDB sets specific types of locks as follows.

- **SELECT ... FROM** is a consistent read, reading a snapshot of the database and setting no locks unless the transaction isolation level is set to SERIALIZABLE. For SERIALIZABLE level, the search sets shared next-key locks on the index records it encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- For locking reads (SELECT with FOR UPDATE or LOCK IN SHARE MODE), UPDATE, and DELETE statements, the locks that are taken depend on whether the statement uses a unique index with a unique search condition, or a range-type search condition.

  - For a unique index with a unique search condition, InnoDB locks only the index record found, not the gap before it.

  - For other search conditions, and for non-unique indexes, InnoDB locks the index range scanned, using gap locks or next-key locks to block insertions by other sessions into the gaps covered by the range. For information about gap locks and next-key locks, see Section 14.10.1, “InnoDB Locking”.

- For index records the search encounters, SELECT ... FOR UPDATE blocks other sessions from doing SELECT ... LOCK IN SHARE MODE or from reading in certain transaction isolation levels. Consistent reads ignore any locks set on the records that exist in the read view.

- UPDATE ... WHERE ... sets an exclusive next-key lock on every record the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- When UPDATE modifies a clustered index record, implicit locks are taken on affected secondary index records. The UPDATE operation also takes shared locks on affected secondary index records when
performing duplicate check scans prior to inserting new secondary index records, and when inserting new secondary index records.

- **DELETE FROM ... WHERE ...** sets an exclusive next-key lock on every record the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- **INSERT** sets an exclusive lock on the inserted row. This lock is an index-record lock, not a next-key lock (that is, there is no gap lock) and does not prevent other sessions from inserting into the gap before the inserted row.

Prior to inserting the row, a type of gap lock called an insert intention gap lock is set. This lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6 each lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

If a duplicate-key error occurs, a shared lock on the duplicate index record is set. This use of a shared lock can result in deadlock should there be multiple sessions trying to insert the same row if another session already has an exclusive lock. This can occur if another session deletes the row. Suppose that an InnoDB table **t1** has the following structure:

```
CREATE TABLE t1 (i INT, PRIMARY KEY (i)) ENGINE = InnoDB;
```

Now suppose that three sessions perform the following operations in order:

**Session 1:**

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

**Session 2:**

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

**Session 3:**

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

**Session 1:**

```
ROLLBACK;
```

The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 rolls back, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

A similar situation occurs if the table already contains a row with key value 1 and three sessions perform the following operations in order:

**Session 1:**

```
START TRANSACTION;
DELETE FROM t1 WHERE i = 1;
```
Session 2:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 3:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 1:

```
COMMIT;
```

The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 commits, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

- `INSERT ... ON DUPLICATE KEY UPDATE` differs from a simple `INSERT` in that an exclusive lock rather than a shared lock is placed on the row to be updated when a duplicate-key error occurs. An exclusive index-record lock is taken for a duplicate primary key value. An exclusive next-key lock is taken for a duplicate unique key value.

- `REPLACE` is done like an `INSERT` if there is no collision on a unique key. Otherwise, an exclusive next-key lock is placed on the row to be replaced.

- `INSERT INTO t SELECT ... FROM s WHERE ...` sets an exclusive index record lock (without a gap lock) on each row inserted into `t`. If the transaction isolation level is `READ COMMITTED`, or `innodb_locks_unsafe_for_binlog` is enabled and the transaction isolation level is not `SERIALIZABLE`, InnoDB does the search on `s` as a consistent read (no locks). Otherwise, InnoDB sets shared next-key locks on rows from `s`. InnoDB has to set locks in the latter case: During roll-forward recovery using a statement-based binary log, every SQL statement must be executed in exactly the same way it was done originally.

```
CREATE TABLE ... SELECT ... performs the SELECT with shared next-key locks or as a consistent read, as for INSERT ... SELECT.
```

When a `SELECT` is used in the constructs `REPLACE INTO t SELECT ... FROM s WHERE ...` or `UPDATE t ... WHERE col IN (SELECT ... FROM s ...)`, InnoDB sets shared next-key locks on rows from table `s`.

- InnoDB sets an exclusive lock on the end of the index associated with the `AUTO_INCREMENT` column while initializing a previously specified `AUTO_INCREMENT` column on a table.

With `innodb_autoinc_lock_mode=0`, InnoDB uses a special `AUTO-INC` table lock mode where the lock is obtained and held to the end of the current SQL statement (not to the end of the entire transaction) while accessing the auto-increment counter. Other clients cannot insert into the table while the `AUTO-INC` table lock is held. The same behavior occurs for “bulk inserts” with `innodb_autoinc_lock_mode=1`. Table-level `AUTO-INC` locks are not used with `innodb_autoinc_lock_mode=2`. For more information, See Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”.

```
InnoDB fetches the value of a previously initialized AUTO_INCREMENT column without setting any locks.
```
Phantom Rows

- If a **FOREIGN KEY** constraint is defined on a table, any insert, update, or delete that requires the constraint condition to be checked sets shared record-level locks on the records that it looks at to check the constraint. **InnoDB** also sets these locks in the case where the constraint fails.

- **LOCK TABLES** sets table locks, but it is the higher MySQL layer above the **InnoDB** layer that sets these locks. **InnoDB** is aware of table locks if **innodb_table_locks = 1** (the default) and **autocommit = 0**, and the MySQL layer above **InnoDB** knows about row-level locks.

  Otherwise, **InnoDB**'s automatic deadlock detection cannot detect deadlocks where such table locks are involved. Also, because in this case the higher MySQL layer does not know about row-level locks, it is possible to get a table lock on a table where another session currently has row-level locks. However, this does not endanger transaction integrity, as discussed in Section 14.10.5.2, “Deadlock Detection and Rollback”.

- **LOCK TABLES** acquires two locks on each table if **innodb_table_locks=1** (the default). In addition to a table lock on the MySQL layer, it also acquires an **InnoDB** table lock. Versions of MySQL before 4.1.2 did not acquire **InnoDB** table locks; the old behavior can be selected by setting **innodb_table_locks=0**. If no **InnoDB** table lock is acquired, **LOCK TABLES** completes even if some records of the tables are being locked by other transactions.

  As of MySQL 5.5.3, **innodb_table_locks=0** has no effect for tables locked explicitly with **LOCK TABLES ... WRITE**. It still has an effect for tables locked for read or write by **LOCK TABLES ... WRITE** implicitly (for example, through triggers) or by **LOCK TABLES ... READ**.

- All **InnoDB** locks held by a transaction are released when the transaction is committed or aborted. Thus, it does not make much sense to invoke **LOCK TABLES** on **InnoDB** tables in **autocommit=1** mode because the acquired **InnoDB** table locks would be released immediately.

- You cannot lock additional tables in the middle of a transaction because **LOCK TABLES** performs an implicit **COMMIT** and **UNLOCK TABLES**.

### 14.10.4 Phantom Rows

The so-called **phantom** problem occurs within a transaction when the same query produces different sets of rows at different times. For example, if a **SELECT** is executed twice, but returns a row the second time that was not returned the first time, the row is a “phantom” row.

Suppose that there is an index on the **id** column of the **child** table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```sql
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where **id** is bigger than 100. Let the table contain rows having **id** values of 90 and 102. If the locks set on the index records in the scanned range do not lock out inserts made in the gaps (in this case, the gap between 90 and 102), another session can insert a new row into the table with an **id** of 101. If you were to execute the same **SELECT** within the same transaction, you would see a new row with an **id** of 101 (a “phantom”) in the result set returned by the query. If we regard a set of rows as a data item, the new phantom child would violate the isolation principle of transactions that a transaction should be able to run so that the data it has read does not change during the transaction.

To prevent phantoms, **InnoDB** uses an algorithm called **next-key locking** that combines index-row locking with gap locking. **InnoDB** performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the “gap” before...
that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record \( R \) in an index, another session cannot insert a new index record in the gap immediately before \( R \) in the index order.

When InnoDB scans an index, it can also lock the gap after the last record in the index. Just that happens in the preceding example: To prevent any insert into the table where \( \text{id} \) would be bigger than 100, the locks set by InnoDB include a lock on the gap following \( \text{id} \) value 102.

You can use next-key locking to implement a uniqueness check in your application: If you read your data in share mode and do not see a duplicate for a row you are going to insert, then you can safely insert your row and know that the next-key lock set on the successor of your row during the read prevents anyone meanwhile inserting a duplicate for your row. Thus, the next-key locking enables you to “lock” the nonexistence of something in your table.

Gap locking can be disabled as discussed in Section 14.10.1, “InnoDB Locking”. This may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled.

### 14.10.5 Deadlocks in InnoDB

A deadlock is a situation where different transactions are unable to proceed because each holds a lock that the other needs. Because both transactions are waiting for a resource to become available, neither ever release the locks it holds.

A deadlock can occur when transactions lock rows in multiple tables (through statements such as `UPDATE` or `SELECT ... FOR UPDATE`), but in the opposite order. A deadlock can also occur when such statements lock ranges of index records and gaps, with each transaction acquiring some locks but not others due to a timing issue. For a deadlock example, see Section 14.10.5.1, “An InnoDB Deadlock Example”.

To reduce the possibility of deadlocks, use transactions rather than `LOCK TABLES` statements; keep transactions that insert or update data small enough that they do not stay open for long periods of time; when different transactions update multiple tables or large ranges of rows, use the same order of operations (such as `SELECT ... FOR UPDATE`) in each transaction; create indexes on the columns used in `SELECT ... FOR UPDATE` and `UPDATE ... WHERE` statements. The possibility of deadlocks is not affected by the isolation level, because the isolation level changes the behavior of read operations, while deadlocks occur because of write operations. For more information about avoiding and recovering from deadlock conditions, see Section 14.10.5.3, “How to Minimize and Handle Deadlocks”.

If a deadlock does occur, InnoDB detects the condition and rolls back one of the transactions (the victim). Thus, even if your application logic is correct, you must still handle the case where a transaction must be retried. To see the last deadlock in an InnoDB user transaction, use the `SHOW ENGINE INNODB STATUS` command. If frequent deadlocks highlight a problem with transaction structure or application error handling, run with the `innodb_print_all_deadlocks` setting enabled to print information about all deadlocks to the `mysqlld` error log. For more information about how deadlocks are automatically detected and handled, see Section 14.10.5.2, “Deadlock Detection and Rollback”.

### 14.10.5.1 An InnoDB Deadlock Example

The following example illustrates how an error can occur when a lock request would cause a deadlock. The example involves two clients, A and B.

First, client A creates a table containing one row, and then begins a transaction. Within the transaction, A obtains an \( S \) lock on the row by selecting it in share mode:

```sql
mysql> CREATE TABLE t (i INT) ENGINE = InnoDB;
Query OK, 0 rows affected (1.07 sec)
```
Deadlocks in InnoDB

Next, client B begins a transaction and attempts to delete the row from the table:

```
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)
mysql> DELETE FROM t WHERE i = 1;
```

The delete operation requires an \textit{x} lock. The lock cannot be granted because it is incompatible with the \textit{s} lock that client A holds, so the request goes on the queue of lock requests for the row and client B blocks.

Finally, client A also attempts to delete the row from the table:

```
mysql> DELETE FROM t WHERE i = 1;
ERROR 1213 (40001): Deadlock found when trying to get lock;
try restarting transaction
```

Deadlock occurs here because client A needs an \textit{x} lock to delete the row. However, that lock request cannot be granted because client B already has a request for an \textit{x} lock and is waiting for client A to release its \textit{s} lock. Nor can the \textit{s} lock held by A be upgraded to an \textit{x} lock because of the prior request by B for an \textit{x} lock. As a result, InnoDB generates an error for one of the clients and releases its locks. The client returns this error:

```
ERROR 1213 (40001): Deadlock found when trying to get lock;
try restarting transaction
```

At that point, the lock request for the other client can be granted and it deletes the row from the table.

14.10.5.2 Deadlock Detection and Rollback

InnoDB automatically detects transaction deadlocks and rolls back a transaction or transactions to break the deadlock. InnoDB tries to pick small transactions to roll back, where the size of a transaction is determined by the number of rows inserted, updated, or deleted.

InnoDB is aware of table locks if \texttt{innodb_table_locks} = 1 (the default) and \texttt{autocommit} = 0, and the MySQL layer above it knows about row-level locks. Otherwise, InnoDB cannot detect deadlocks where a table lock set by a MySQL \texttt{LOCK TABLES} statement or a lock set by a storage engine other than InnoDB is involved. Resolve these situations by setting the value of the \texttt{innodb_lock_wait_timeout} system variable.

When InnoDB performs a complete rollback of a transaction, all locks set by the transaction are released. However, if just a single SQL statement is rolled back as a result of an error, some of the locks set by the statement may be preserved. This happens because InnoDB stores row locks in a format such that it cannot know afterward which lock was set by which statement.

If a \texttt{SELECT} calls a stored function in a transaction, and a statement within the function fails, that statement rolls back. Furthermore, if \texttt{ROLLBACK} is executed after that, the entire transaction rolls back.
If the `LATEST DETECTED DEADLOCK` section of InnoDB Monitor output includes a message stating, "TOO DEEP OR LONG SEARCH IN THE LOCK TABLE WAITS-FOR GRAPH, WE WILL ROLL BACK FOLLOWING TRANSACTION," this indicates that the number of transactions on the wait-for list has reached a limit of 200. A wait-for list that exceeds 200 transactions is treated as a deadlock and the transaction attempting to check the wait-for list is rolled back. The same error may also occur if the locking thread must look at more than 1,000,000 locks owned by transactions on the wait-for list.

For techniques to organize database operations to avoid deadlocks, see Section 14.10.5, “Deadlocks in InnoDB”.

### 14.10.5.3 How to Minimize and Handle Deadlocks

This section builds on the conceptual information about deadlocks in Section 14.10.5.2, “Deadlock Detection and Rollback”. It explains how to organize database operations to minimize deadlocks and the subsequent error handling required in applications.

**Deadlocks** are a classic problem in transactional databases, but they are not dangerous unless they are so frequent that you cannot run certain transactions at all. Normally, you must write your applications so that they are always prepared to re-issue a transaction if it gets rolled back because of a deadlock.

InnoDB uses automatic row-level locking. You can get deadlocks even in the case of transactions that just insert or delete a single row. That is because these operations are not really “atomic”; they automatically set locks on the (possibly several) index records of the row inserted or deleted.

You can cope with deadlocks and reduce the likelihood of their occurrence with the following techniques:

- At any time, issue the `SHOW ENGINE INNODB STATUS` command to determine the cause of the most recent deadlock. That can help you to tune your application to avoid deadlocks.

- If frequent deadlock warnings cause concern, collect more extensive debugging information by enabling the `innodb_print_all_deadlocks` configuration option. Information about each deadlock, not just the latest one, is recorded in the MySQL error log. Disable this option when you are finished debugging.

- Always be prepared to re-issue a transaction if it fails due to deadlock. Deadlocks are not dangerous. Just try again.

- Keep transactions small and short in duration to make them less prone to collision.

- Commit transactions immediately after making a set of related changes to make them less prone to collision. In particular, do not leave an interactive `mysql` session open for a long time with an uncommitted transaction.

- If you use locking reads (`SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`), try using a lower isolation level such as `READ COMMITTED`.

- When modifying multiple tables within a transaction, or different sets of rows in the same table, do those operations in a consistent order each time. Then transactions form well-defined queues and do not deadlock. For example, organize database operations into functions within your application, or call stored routines, rather than coding multiple similar sequences of `INSERT`, `UPDATE`, and `DELETE` statements in different places.

- Add well-chosen indexes to your tables. Then your queries need to scan fewer index records and consequently set fewer locks. Use `EXPLAIN SELECT` to determine which indexes the MySQL server regards as the most appropriate for your queries.

- Use less locking. If you can afford to permit a `SELECT` to return data from an old snapshot, do not add the clause `FOR UPDATE` or `LOCK IN SHARE MODE` to it. Using the `READ COMMITTED` isolation level is good here, because each consistent read within the same transaction reads from its own fresh snapshot.
• If nothing else helps, serialize your transactions with table-level locks. The correct way to use
LOCK TABLES with transactional tables, such as InnoDB tables, is to begin a transaction with SET
autocommit = 0 (not START TRANSACTION) followed by LOCK TABLES, and to not call UNLOCK
TABLES until you commit the transaction explicitly. For example, if you need to write to table t1 and read
from table t2, you can do this:

```
SET autocommit=0;
LOCK TABLES t1 WRITE, t2 READ, ...;... do something with tables t1 and t2 here ...
COMMIT;
UNLOCK TABLES;
```

Table-level locks prevent concurrent updates to the table, avoiding deadlocks at the expense of less
responsiveness for a busy system.

• Another way to serialize transactions is to create an auxiliary “semaphore” table that contains just
a single row. Have each transaction update that row before accessing other tables. In that way, all
transactions happen in a serial fashion. Note that the InnoDB instant deadlock detection algorithm also
works in this case, because the serializing lock is a row-level lock. With MySQL table-level locks, the
timeout method must be used to resolve deadlocks.

## 14.11 InnoDB Configuration

This section provides configuration information and procedures for InnoDB initialization, startup, and
various components and features of the InnoDB storage engine. For information about optimizing
database operations for InnoDB tables, see Section 8.5, “Optimizing for InnoDB Tables”.

### 14.11.1 InnoDB Startup Configuration

The first decisions to make about InnoDB configuration involve the configuration of data files, log files, and
memory buffers. It is recommended that you define data file, log file, and page size configuration before
creating the InnoDB instance. Modifying data file or log file configuration after the InnoDB instance is
created may involve a non-trivial procedure.

In addition to these topics, this section provides information about specifying InnoDB options in a
configuration file, viewing InnoDB initialization information, and important storage considerations.

• Specifying Options in a MySQL Configuration File
• Viewing InnoDB Initialization Information
• Important Storage Considerations
• System Tablespace Data File Configuration
• Redo Log File Configuration
• Memory Configuration

### Specifying Options in a MySQL Configuration File

Because MySQL uses data file and log file configuration settings to initialize the InnoDB instance, it is
recommended that you define these settings in a configuration file that MySQL reads at startup, prior to
initializing InnoDB for the first time. InnoDB is initialized when the MySQL server is started, and the first
initialization of InnoDB normally occurs the first time you start the MySQL server.

You can place InnoDB options in the [mysqld] group of any option file that your server reads when it
starts. The locations of MySQL option files are described in Section 4.2.2.2, “Using Option Files”.
To make sure that `mysqld` reads options only from a specific file, use the `--defaults-file` option as the first option on the command line when starting the server:

```bash
mysqld --defaults-file=path_to_configuration_file
```

**Viewing InnoDB Initialization Information**

To view InnoDB initialization information during startup, start `mysqld` from a command prompt. When `mysqld` is started from a command prompt, initialization information is printed to the console.

For example, on Windows, if `mysqld` is located in `C:\Program Files\MySQL\MySQL Server 5.5\bin`, start the MySQL server like this:

```bash
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --console
```

On Unix-like systems, `mysqld` is located in the `bin` directory of your MySQL installation:

```bash
shell> bin/mysqld --user=mysql &
```

If you do not send server output to the console, check the error log after startup to see the initialization information InnoDB printed during the startup process.

For information about starting MySQL using other methods, see Section 2.10.5, “Starting and Stopping MySQL Automatically”.

**Note**

InnoDB does not open all user tables and associated data files at startup. However, InnoDB does check for the existence of tablespace files (`*.ibd` files) that are referenced in the data dictionary. If a tablespace file is not found, InnoDB logs an error and continues the startup sequence. Tablespace files that are referenced in the redo log may be opened during crash recovery for redo application.

**Important Storage Considerations**

Review the following storage-related considerations before proceeding with your startup configuration.

- In some cases, database performance improves if the data is not all placed on the same physical disk. Putting log files on a different disk from data is very often beneficial for performance. For example, you can place system tablespace data files and log files on different disks. You can also use raw disk partitions (raw devices) for InnoDB data files, which may speed up I/O. See Using Raw Disk Partitions for the System Tablespace.

- InnoDB is a transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. However, it cannot do so if the underlying operating system or hardware does not work as advertised. Many operating systems or disk subsystems may delay or reorder write operations to improve performance. On some operating systems, the very `fsync()` system call that should wait until all unwritten data for a file has been flushed might actually return before the data has been flushed to stable storage. Because of this, an operating system crash or a power outage may destroy recently committed data, or in the worst case, even corrupt the database because of write operations having been reordered. If data integrity is important to you, perform some “pull-the-plug” tests before using anything in production. On macOS, InnoDB uses a special `fcntl()` file flush method. Under Linux, it is advisable to disable the write-back cache.

On ATA/SATA disk drives, a command such as `hdparm -W0 /dev/hda` may work to disable the write-back cache. Beware that some drives or disk controllers may be unable to disable the write-back cache.
InnoDB Startup Configuration

• With regard to InnoDB recovery capabilities that protect user data, InnoDB uses a file flush technique involving a structure called the doublewrite buffer, which is enabled by default (innodb_doublewrite=ON). The doublewrite buffer adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for fsync() operations. It is recommended that the innodb_doublewrite option remains enabled if you are concerned with data integrity or possible failures. For additional information about the doublewrite buffer, see Section 14.15.1, "InnoDB Disk I/O".

• Before using NFS with InnoDB, review potential issues outlined in Using NFS with MySQL.

• Running MySQL server on a 4K sector hard drive on Windows is not supported with innodb_flush_method=async_unbuffered, which is the default setting. The workaround is to use innodb_flush_method=normal.

System Tablespace Data File Configuration

The innodb_data_file_path startup option defines the name, size, and attributes of InnoDB system tablespace data files. If you do not configure this option prior to initializing the MySQL server, the default behavior is to create a single auto-extending data file, slightly larger than 10MB, named ibdata1:

```sql
SHOW VARIABLES LIKE 'innodb_data_file_path';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>innodb_data_file_path</td>
<td>ibdata1:10M:autoextend</td>
</tr>
</tbody>
</table>

The full data file specification syntax includes the file name, file size, autoextend attribute, and max attribute:

```
file_name:file_size[autoextend[:max:max_file_size]]
```

File sizes are specified in kilobytes, megabytes, or gigabytes by appending K, M or G to the size value. If specifying the data file size in kilobytes, do so in multiples of 1024. Otherwise, kilobyte values are rounded to nearest megabyte (MB) boundary. The sum of file sizes must be, at a minimum, slightly larger than 10MB.

You can specify more than one data file using a semicolon-separated list. For example:

```ini
[mysqld]
inno_db_data_file_path=ibdata1:50M;ibdata2:50M:autoextend
```

The autoextend and max attributes can be used only for the data file that is specified last.

When the autoextend attribute is specified, the data file automatically increases in size by 8MB increments as space is required. The innodb_autoextend_increment variable controls the increment size.

To specify a maximum size for an auto-extending data file, use the max attribute following the autoextend attribute. Use the max attribute only in cases where constraining disk usage is of critical importance. The following configuration permits ibdata1 to grow to a limit of 500MB:

```ini
[mysqld]
inno_db_data_file_path=ibdata1:10M:autoextend:max:500M
```

If your disk becomes full, you can add a data file on another disk. For instructions, see Resizing the System Tablespace.
InnoDB Startup Configuration

The size limit for individual files is determined by your operating system. You can set the file size to more than 4GB on operating systems that support large files. You can also use raw disk partitions as data files. See Using Raw Disk Partitions for the System Tablespace.

InnoDB is not aware of the file system maximum file size, so be cautious on file systems where the maximum file size is a small value such as 2GB.

System tablespace files are created in the data directory by default (datadir). To specify an alternate location, use the innodb_data_home_dir option. For example, to create a system tablespace data file in a directory named myibdata, use this configuration:

```plaintext
[mysqld]
innodb_data_home_dir = /myibdata/
innodb_data_file_path=ibdata1:50M:autoextend
```

A trailing slash is required when specifying a value for innodb_data_home_dir. InnoDB does not create directories, so ensure that the specified directory exists before you start the server. Also, ensure that the MySQL server has the proper access rights to create files in the directory.

InnoDB forms the directory path for each data file by textually concatenating the value of innodb_data_home_dir to the data file name. If innodb_data_home_dir is not defined, the default value is "/" , which is the data directory. (The MySQL server changes its current working directory to the data directory when it begins executing.)

If you specify innodb_data_home_dir as an empty string, you can specify absolute paths for data files listed in the innodb_data_file_path value. The following configuration is equivalent to the preceding one:

```plaintext
[mysqld]
innodb_data_home_dir =
innodb_data_file_path=/myibdata/ibdata1:50M:autoextend
```

Redo Log File Configuration

By default, InnoDB creates two 5MB redo log files in the data directory named ib_logfile0 and ib_logfile1.

The following options can be used to modify the default configuration:

- **innodb_log_group_home_dir** defines directory path to the InnoDB log files (the redo logs). If this option is not configured, InnoDB log files are created in the MySQL data directory (datadir).

You might use this option to place InnoDB log files in a different physical storage location than InnoDB data files to avoid potential I/O resource conflicts. For example:

```plaintext
[mysqld]
innodb_log_group_home_dir = /dr3/iblogs
```

**Note**

InnoDB does not create directories, so make sure that the log directory exists before you start the server. Use the Unix or DOS mkdir command to create any necessary directories.

Make sure that the MySQL server has the proper access rights to create files in the log directory. More generally, the server must have access rights in any directory where it needs to create log files.
InnoDB Startup Configuration

- `innodb_log_files_in_group` defines the number of log files in the log group. The default and recommended value is 2.

- `innodb_log_file_size` defines the size in bytes of each log file in the log group. The combined size of log files (`innodb_log_file_size * innodb_log_files_in_group`) cannot exceed a maximum value that is slightly less than 4GB. A pair of 2047 MB log files, for example, approaches the limit but does not exceed it. The default log file size is 5MB. Generally, the combined size of the log files should be large enough that the server can smooth out peaks and troughs in workload activity, which often means that there is enough redo log space to handle more than an hour of write activity. The larger the value, the less checkpoint flush activity is needed in the buffer pool, saving disk I/O. For additional information, see Section 8.5.3, “Optimizing InnoDB Redo Logging”.

Memory Configuration

MySQL allocates memory to various caches and buffers to improve performance of database operations. When allocating memory for InnoDB, always consider memory required by the operating system, memory allocated to other applications, and memory allocated for other MySQL buffers and caches. For example, if you use MyISAM tables, consider the amount of memory allocated for the key buffer (`key_buffer_size`). For an overview of MySQL buffers and caches, see Section 8.12.4.1, “How MySQL Uses Memory”.

Buffers specific to InnoDB are configured using the following parameters:

- `innodb_buffer_pool_size` defines size of the buffer pool, which is the memory area that holds cached data for InnoDB tables, indexes, and other auxiliary buffers. The size of the buffer pool is important for system performance, and it is typically recommended that `innodb_buffer_pool_size` is configured to 50 to 75 percent of system memory. The default buffer pool size is 128MB. For additional guidance, see Section 8.12.4.1, “How MySQL Uses Memory”. For information about how to configure InnoDB buffer pool size, see Configuring InnoDB Buffer Pool Size. Buffer pool size can be configured at startup.

On systems with a large amount of memory, you can improve concurrency by dividing the buffer pool into multiple buffer pool instances. The number of buffer pool instances is controlled by the `innodb_buffer_pool_instances` option. By default, InnoDB creates one buffer pool instance. The number of buffer pool instances can be configured at startup. For more information, see Section 14.11.2.1, “Configuring Multiple Buffer Pool Instances”.

- `innodb_additional_mem_pool_size` defines size in bytes of a memory pool InnoDB uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you allocate here. If InnoDB runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 8MB.

- `innodb_log_buffer_size` defines the size in bytes of the buffer that InnoDB uses to write to the log files on disk. The default size is 8MB. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. If you have transactions that update, insert, or delete many rows, you might consider increasing the size of the log buffer to save disk I/O. `innodb_log_buffer_size` can be configured at startup. For related information, see Section 8.5.3, “Optimizing InnoDB Redo Logging”.

**Warning**

On 32-bit GNU/Linux x86, be careful not to set memory usage too high. glibc may permit the process heap to grow over thread stacks, which crashes your server. It is a risk if the memory allocated to the mysqld process for global and per-thread buffers and caches is close to or exceeds 2GB.
A formula similar to the following that calculates global and per-thread memory allocation for MySQL can be used to estimate MySQL memory usage. You may need to modify the formula to account for buffers and caches in your MySQL version and configuration. For an overview of MySQL buffers and caches, see Section 8.12.4.1, “How MySQL Uses Memory”.

\[
\text{innodb_buffer_pool_size} + \text{key_buffer_size} + \text{max_connections} \times (\text{sort_buffer_size} + \text{read_buffer_size} + \text{binlog_cache_size}) + \text{max_connections} \times 2\text{MB}
\]

Each thread uses a stack (often 2MB, but only 256KB in MySQL binaries provided by Oracle Corporation.) and in the worst case also uses \text{sort_buffer_size} + \text{read_buffer_size} additional memory.

On Linux, if the kernel is enabled for large page support, InnoDB can use large pages to allocate memory for its buffer pool and additional memory pool. See Section 8.12.4.2, “Enabling Large Page Support”.

14.11.2 InnoDB Buffer Pool Configuration

This section provides configuration and tuning information for the InnoDB buffer pool.

14.11.2.1 Configuring Multiple Buffer Pool Instances

For systems with buffer pools in the multi-gigabyte range, dividing the buffer pool into separate instances can improve concurrency, by reducing contention as different threads read and write to cached pages. This feature is typically intended for systems with a buffer pool size in the multi-gigabyte range. Multiple buffer pool instances are configured using the \text{innodb_buffer_pool_instances} configuration option, and you might also adjust the \text{innodb_buffer_pool_size} value.

When the InnoDB buffer pool is large, many data requests can be satisfied by retrieving from memory. You might encounter bottlenecks from multiple threads trying to access the buffer pool at once. You can enable multiple buffer pools to minimize this contention. Each page that is stored in or read from the buffer pool is assigned to one of the buffer pools randomly, using a hashing function. Each buffer pool manages its own free lists, flush lists, LRUs, and all other data structures connected to a buffer pool, and is protected by its own buffer pool mutex.

To enable multiple buffer pool instances, set the \text{innodb_buffer_pool_instances} configuration option to a value greater than 1 (the default) up to 64 (the maximum). This option takes effect only when you set \text{innodb_buffer_pool_size} to a size of 1GB or more. The total size you specify is divided among all the buffer pools. For best efficiency, specify a combination of \text{innodb_buffer_pool_instances} and \text{innodb_buffer_pool_size} so that each buffer pool instance is at least 1GB.

14.11.2.2 Making the Buffer Pool Scan Resistant

Rather than using a strict LRU algorithm, InnoDB uses a technique to minimize the amount of data that is brought into the buffer pool and never accessed again. The goal is to make sure that frequently accessed (“hot”) pages remain in the buffer pool, even as read-ahead and full table scans bring in new blocks that might or might not be accessed afterward.

Newly read blocks are inserted into the middle of the LRU list. All newly read pages are inserted at a location that by default is \( \frac{3}{8} \) from the tail of the LRU list. The pages are moved to the front of the list (the most-recently used end) when they are accessed in the buffer pool for the first time. Thus, pages that are never accessed never make it to the front portion of the LRU list, and “age out” sooner than with a strict LRU approach. This arrangement divides the LRU list into two segments, where the pages downstream of the insertion point are considered “old” and are desirable victims for LRU eviction.
InnoDB Buffer Pool Configuration

For an explanation of the inner workings of the InnoDB buffer pool and specifics about the LRU algorithm, see Section 14.8.1, “Buffer Pool”.

You can control the insertion point in the LRU list and choose whether InnoDB applies the same optimization to blocks brought into the buffer pool by table or index scans. The configuration parameter `innodb_old_blocks_pct` controls the percentage of “old” blocks in the LRU list. The default value of `innodb_old_blocks_pct` is 37, corresponding to the original fixed ratio of 3/8. The value range is 5 (new pages in the buffer pool age out very quickly) to 95 (only 5% of the buffer pool is reserved for hot pages, making the algorithm close to the familiar LRU strategy).

The optimization that keeps the buffer pool from being churned by read-ahead can avoid similar problems due to table or index scans. In these scans, a data page is typically accessed a few times in quick succession and is never touched again. The configuration parameter `innodb_old_blocks_time` specifies the time window (in milliseconds) after the first access to a page during which it can be accessed without being moved to the front (most-recently used end) of the LRU list. The default value of `innodb_old_blocks_time` is 0, corresponding to the original behavior of moving a page to the most-recently used end of the buffer pool list when it is first accessed in the buffer pool. Increasing this value makes more and more blocks likely to age out faster from the buffer pool.

Both `innodb_old_blocks_pct` and `innodb_old_blocks_time` can be specified in the MySQL option file (my.cnf or my.ini) or changed at runtime with the `SET GLOBAL` statement. Changing the value at runtime requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

To help you gauge the effect of setting these parameters, the `SHOW ENGINE INNODB STATUS` command reports buffer pool statistics. For details, see Monitoring the Buffer Pool Using the InnoDB Standard Monitor.

Because the effects of these parameters can vary widely based on your hardware configuration, your data, and the details of your workload, always benchmark to verify the effectiveness before changing these settings in any performance-critical or production environment.

In mixed workloads where most of the activity is OLTP type with periodic batch reporting queries which result in large scans, setting the value of `innodb_old_blocks_time` during the batch runs can help keep the working set of the normal workload in the buffer pool.

When scanning large tables that cannot fit entirely in the buffer pool, setting `innodb_old_blocks_pct` to a small value keeps the data that is only read once from consuming a significant portion of the buffer pool. For example, setting `innodb_old_blocks_pct=5` restricts this data that is only read once to 5% of the buffer pool.

When scanning small tables that do fit into memory, there is less overhead for moving pages around within the buffer pool, so you can leave `innodb_old_blocks_pct` at its default value, or even higher, such as `innodb_old_blocks_pct=50`.

The effect of the `innodb_old_blocks_time` parameter is harder to predict than the `innodb_old_blocks_pct` parameter, is relatively small, and varies more with the workload. To arrive at an optimal value, conduct your own benchmarks if the performance improvement from adjusting `innodb_old_blocks_pct` is not sufficient.

14.11.2.3 Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)

A read-ahead request is an I/O request to prefetch multiple pages in the buffer pool asynchronously, in anticipation that these pages will be needed soon. The requests bring in all the pages in one extent. InnoDB uses two read-ahead algorithms to improve I/O performance:

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1767
Linear read-ahead is a technique that predicts what pages might be needed soon based on pages in the buffer pool being accessed sequentially. You control when InnoDB performs a read-ahead operation by adjusting the number of sequential page accesses required to trigger an asynchronous read request, using the configuration parameter `innodb_read_ahead_threshold`. Before this parameter was added, InnoDB would only calculate whether to issue an asynchronous prefetch request for the entire next extent when it read the last page of the current extent.

The configuration parameter `innodb_read_ahead_threshold` controls how sensitive InnoDB is in detecting patterns of sequential page access. If the number of pages read sequentially from an extent is greater than or equal to `innodb_read_ahead_threshold`, InnoDB initiates an asynchronous read-ahead operation of the entire following extent. `innodb_read_ahead_threshold` can be set to any value from 0-64. The default value is 56. The higher the value, the more strict the access pattern check. For example, if you set the value to 48, InnoDB triggers a linear read-ahead request only when 48 pages in the current extent have been accessed sequentially. If the value is 8, InnoDB triggers an asynchronous read-ahead even if as few as 8 pages in the extent are accessed sequentially. You can set the value of this parameter in the MySQL configuration file, or change it dynamically with the `SET GLOBAL` statement, which requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

Random read-ahead is a technique that predicts when pages might be needed soon based on pages already in the buffer pool, regardless of the order in which those pages were read. If 13 consecutive pages from the same extent are found in the buffer pool, InnoDB asynchronously issues a request to prefetch the remaining pages of the extent. To enable this feature, set the configuration variable `innodb_random_read_ahead` to `ON`.

Random read-ahead functionality was removed from the InnoDB Plugin (version 1.0.4) and was therefore not included in MySQL 5.5.0 when InnoDB Plugin became the “built-in” version of InnoDB. Random read-ahead was reintroduced in MySQL 5.1.59 and 5.5.16 and higher along with the `innodb_random_read_ahead` configuration option, which is disabled by default. To enable this feature, set the configuration variable `innodb_random_read_ahead` to `ON`.

The `SHOW ENGINE INNODB STATUS` command displays statistics to help you evaluate the effectiveness of the read-ahead algorithm. Statistics include counter information for the following global status variables:

- `innodb_buffer_pool_read_ahead`
- `innodb_buffer_pool_read_ahead_evicted`
- `innodb_buffer_pool_read_ahead_rnd`

This information can be useful when fine-tuning the `innodb_random_read_ahead` setting.

For more information about I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O” and Section 8.12.2, “Optimizing Disk I/O”.

### 14.11.2.4 Configuring Buffer Pool Flushing

InnoDB performs certain tasks in the background, including flushing of dirty pages from the buffer pool, a task performed by the master thread. Dirty pages are those that have been modified but are not yet written to the data files on disk. InnoDB aggressively flushes buffer pool pages if the percentage of dirty pages in the buffer pool reaches the `innodb_max_dirty_pages_pct` threshold.

**Adaptive Flushing**

InnoDB uses an adaptive flushing algorithm to dynamically adjust the rate of flushing based on the speed of redo log generation and the current rate of flushing. The intent is to smooth overall performance by
ensuring that flushing activity keeps pace with the current workload. Automatically adjusting the flushing rate helps avoid sudden dips in throughput that can occur when bursts of I/O activity due to buffer pool flushing affects the I/O capacity available for ordinary read and write activity.

Sharp checkpoints, which are typically associated with write-intensive workloads that generate a lot of redo entries, can cause a sudden change in throughput, for example. A sharp checkpoint occurs when InnoDB wants to reuse a portion of a log file. Before doing so, all dirty pages with redo entries in that portion of the log file must be flushed. If log files become full, a sharp checkpoint occurs, causing a temporary reduction in throughput. This scenario can occur even if innodb_max_dirty_pages_pct threshold is not reached.

The adaptive flushing algorithm helps avoid such scenarios by tracking the number of dirty pages in the buffer pool and the rate at which redo log records are being generated. Based on this information, it decides how many dirty pages to flush from the buffer pool each second, which permits it to manage sudden changes in workload.

Internal benchmarking has shown that the algorithm not only maintains throughput over time, but can also improve overall throughput significantly. However, adaptive flushing can affect the I/O pattern of a workload significantly and may not be appropriate in all cases. If adaptive flushing is not appropriate to the characteristics of your workload, you can disable it. Adaptive flushing controlled by the innodb_adaptive flushing variable, which is enabled by default.

Be aware that if flushing falls behind, the rate of buffer pool flushing can exceed the I/O capacity available to InnoDB, as defined by innodb_io_capacity setting.

The innodb_io_capacity setting is applicable to all buffer pool instances. When dirty pages are flushed, I/O capacity is divided equally among buffer pool instances.

14.11.3 Configuring the Memory Allocator for InnoDB

When InnoDB was developed, the memory allocators supplied with operating systems and run-time libraries were often lacking in performance and scalability. At that time, there were no memory allocator libraries tuned for multi-core CPUs. Therefore, InnoDB implemented its own memory allocator in the mem subsystem. This allocator is guarded by a single mutex, which may become a bottleneck. InnoDB also implements a wrapper interface around the system allocator (malloc and free) that is likewise guarded by a single mutex.

Today, as multi-core systems have become more widely available, and as operating systems have matured, significant improvements have been made in the memory allocators provided with operating systems. These new memory allocators perform better and are more scalable than they were in the past. Most workloads, especially those where memory is frequently allocated and released (such as multi-table joins), benefit from using a more highly tuned memory allocator as opposed to the internal, InnoDB-specific memory allocator.

You can control whether InnoDB uses its own memory allocator or an allocator of the operating system, by setting the value of the system configuration parameter innodb_use_sys_malloc in the MySQL option file (my.cnf or my.ini). If set to ON or 1 (the default), InnoDB uses the malloc and free functions of the underlying system rather than manage memory pools itself. This parameter is not dynamic, and takes effect only when the system is started. To continue to use the InnoDB memory allocator, set innodb_use_sys_malloc to 0.

Note

When the InnoDB memory allocator is disabled, InnoDB ignores the value of the parameter innodb_additional_mem_pool_size. The InnoDB memory allocator uses an additional memory pool for satisfying allocation requests without having to fall back to the system memory allocator. When the InnoDB memory
allocator is disabled, all such allocation requests are fulfilled by the system memory allocator.

On Unix-like systems that use dynamic linking, replacing the memory allocator may be as easy as making the environment variable `LD_PRELOAD` or `LD_LIBRARY_PATH` point to the dynamic library that implements the allocator. On other systems, some relinking may be necessary. Please refer to the documentation of the memory allocator library of your choice.

Since InnoDB cannot track all memory use when the system memory allocator is used (`innodb_use_sys_malloc` is ON), the section “BUFFER POOL AND MEMORY” in the output of the `SHOW ENGINE INNODB STATUS` command only includes the buffer pool statistics in the “Total memory allocated”. Any memory allocated using the `mem` subsystem or using `ut_malloc` is excluded.

For more information about the performance implications of InnoDB memory usage, see Section 8.10, “Buffering and Caching”.

### 14.11.4 Configuring Thread Concurrency for InnoDB

InnoDB uses operating system threads to process requests from user transactions. (Transactions may issue many requests to InnoDB before they commit or roll back.) On modern operating systems and servers with multi-core processors, where context switching is efficient, most workloads run well without any limit on the number of concurrent threads. Scalability improvements in MySQL 5.5 and up reduce the need to limit the number of concurrently executing threads inside InnoDB.

In situations where it is helpful to minimize context switching between threads, InnoDB can use a number of techniques to limit the number of concurrently executing operating system threads (and thus the number of requests that are processed at any one time). When InnoDB receives a new request from a user session, if the number of threads concurrently executing is at a pre-defined limit, the new request sleeps for a short time before it tries again. A request that cannot be rescheduled after the sleep is put in a first-in/first-out queue and eventually is processed. Threads waiting for locks are not counted in the number of concurrently executing threads.

You can limit the number of concurrent threads by setting the configuration parameter `innodb_thread_concurrency`. Once the number of executing threads reaches this limit, additional threads sleep for a number of microseconds, set by the configuration parameter `innodb_thread_sleep_delay`, before being placed into the queue.

The default value for `innodb_thread_concurrency` and the implied default limit on the number of concurrent threads has been changed in various releases of MySQL and InnoDB. The default value of `innodb_thread_concurrency` is 0, so that by default there is no limit on the number of concurrently executing threads, as shown in Table 14.3, “Changes to innodb_thread_concurrency”.

<table>
<thead>
<tr>
<th>InnoDB Version</th>
<th>MySQL Version</th>
<th>Default value</th>
<th>Default limit of concurrent threads</th>
<th>Value to allow unlimited threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-in</td>
<td>Earlier than 5.1.11</td>
<td>20</td>
<td>No limit</td>
<td>20 or higher</td>
</tr>
<tr>
<td>Built-in</td>
<td>5.1.11 and newer</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>InnoDB before 1.0.3</td>
<td>(corresponding to Plugin)</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>InnoDB 1.0.3 and newer</td>
<td>(corresponding to Plugin)</td>
<td>0</td>
<td>No limit</td>
<td>0</td>
</tr>
</tbody>
</table>
InnoDB causes threads to sleep only when the number of concurrent threads is limited. When there is no limit on the number of threads, all contend equally to be scheduled. That is, if `innodb_thread_concurrency` is 0, the value of `innodb_thread_sleep_delay` is ignored.

When there is a limit on the number of threads (when `innodb_thread_concurrency` is > 0), InnoDB reduces context switching overhead by permitting multiple requests made during the execution of a single SQL statement to enter InnoDB without observing the limit set by `innodb_thread_concurrency`. Since an SQL statement (such as a join) may comprise multiple row operations within InnoDB, InnoDB assigns a specified number of “tickets” that allow a thread to be scheduled repeatedly with minimal overhead.

When a new SQL statement starts, a thread has no tickets, and it must observe `innodb_thread_concurrency`. Once the thread is entitled to enter InnoDB, it is assigned a number of tickets that it can use for subsequently entering InnoDB to perform row operations. If the tickets run out, the thread is evicted, and `innodb_thread_concurrency` is observed again which may place the thread back into the first-in/first-out queue of waiting threads. When the thread is once again entitled to enter InnoDB, tickets are assigned again. The number of tickets assigned is specified by the global option `innodb_concurrency_tickets`, which is 500 by default. A thread that is waiting for a lock is given one ticket once the lock becomes available.

The correct values of these variables depend on your environment and workload. Try a range of different values to determine what value works for your applications. Before limiting the number of concurrently executing threads, review configuration options that may improve the performance of InnoDB on multi-core and multi-processor computers, such as `innodb_use_sys_malloc` and `innodb_adaptive_hash_index`.

For general performance information about MySQL thread handling, see Section 8.12.5.1, “How MySQL Handles Client Connections”.

### 14.11.5 Configuring the Number of Background InnoDB I/O Threads

InnoDB uses background threads to service various types of I/O requests. You can configure the number of background threads that service read and write I/O on data pages using the `innodb_read_io_threads` and `innodb_write_io_threads` configuration parameters. These parameters signify the number of background threads used for read and write requests, respectively. They are effective on all supported platforms. You can set values for these parameters in the MySQL option file (`my.cnf` or `my.ini`); you cannot change values dynamically. The default value for these parameters is 4 and permissible values range from 1–64.

These parameters replace `innodb_file_io_threads` from earlier versions of MySQL. If you try to set a value for this obsolete parameter, a warning is written to the log file and the value is ignored. This parameter only applied to Windows platforms. (On non-Windows platforms, there was only one thread each for read and write.)

The purpose of these configuration options to make InnoDB more scalable on high end systems. Each background thread can handle up to 256 pending I/O requests. A major source of background I/O is read-ahead requests. InnoDB tries to balance the load of incoming requests in such way that most background threads share work equally. InnoDB also attempts to allocate read requests from the same extent to the same thread, to increase the chances of coalescing the requests. If you have a high end I/O subsystem and you see more than 64 × `innodb_read_io_threads` pending read requests in `SHOW ENGINE INNODB STATUS` output, you might improve performance by increasing the value of `innodb_read_io_threads`.

On Linux systems, InnoDB uses the asynchronous I/O subsystem by default to perform read-ahead and write requests for data file pages, which changes the way that InnoDB background threads service these types of I/O requests. For more information, see Section 14.11.6, “Using Asynchronous I/O on Linux”.

1771
For more information about InnoDB I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

### 14.11.6 Using Asynchronous I/O on Linux

InnoDB uses the asynchronous I/O subsystem (native AIO) on Linux to perform read-ahead and write requests for data file pages. This behavior is controlled by the `innodb_use_native_aio` configuration option, which applies to Linux systems only and is enabled by default. On other Unix-like systems, InnoDB uses synchronous I/O only. Historically, InnoDB only used asynchronous I/O on Windows systems. Using the asynchronous I/O subsystem on Linux requires the `libaio` library.

With synchronous I/O, query threads queue I/O requests, and InnoDB background threads retrieve the queued requests one at a time, issuing a synchronous I/O call for each. When an I/O request is completed and the I/O call returns, the InnoDB background thread that is handling the request calls an I/O completion routine and returns to process the next request. The number of requests that can be processed in parallel is \( n \), where \( n \) is the number of InnoDB background threads. The number of InnoDB background threads is controlled by `innodb_read_io_threads` and `innodb_write_io_threads`. See Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”.

With native AIO, query threads dispatch I/O requests directly to the operating system, thereby removing the limit imposed by the number of background threads. InnoDB background threads wait for I/O events to signal completed requests. When a request is completed, a background thread calls an I/O completion routine and resumes waiting for I/O events.

The advantage of native AIO is scalability for heavily I/O-bound systems that typically show many pending reads/writes in `SHOW ENGINE INNODB STATUS\G` output. The increase in parallel processing when using native AIO means that the type of I/O scheduler or properties of the disk array controller have a greater influence on I/O performance.

A potential disadvantage of native AIO for heavily I/O-bound systems is lack of control over the number of I/O write requests dispatched to the operating system at once. Too many I/O write requests dispatched to the operating system for parallel processing could, in some cases, result in I/O read starvation, depending on the amount of I/O activity and system capabilities.

If a problem with the asynchronous I/O subsystem in the OS prevents InnoDB from starting, you can start the server with `innodb_use_native_aio=0`. This option may also be disabled automatically during startup if InnoDB detects a potential problem such as a combination of `tmpdir` location, `tmpfs` file system, and Linux kernel that does not support asynchronous I/O on `tmpfs`.

### 14.11.7 Configuring InnoDB I/O Capacity

The InnoDB master thread and other threads perform various tasks in the background, most of which are I/O related, such as flushing dirty pages from the buffer pool and writing changes from the change buffer to the appropriate secondary indexes. InnoDB attempts to perform these tasks in a way that does not adversely affect the normal working of the server. It tries to estimate the available I/O bandwidth and tune its activities to take advantage of available capacity.

The `innodb_io_capacity` variable defines the overall I/O capacity available to InnoDB. It should be set to approximately the number of I/O operations that the system can perform per second (IOPS). When `innodb_io_capacity` is set, InnoDB estimates the I/O bandwidth available for background tasks based on the set value.

You can set `innodb_io_capacity` to a value of 100 or greater. The default value is 200. Typically, values around 100 are appropriate for consumer-level storage devices, such as hard drives up to 7200 RPMs. Faster hard drives, RAID configurations, and solid state drives (SSDs) benefit from higher values.
Ideally, keep the setting as low as practical, but not so low that background activities fall behind. If the value is too high, data is removed from the buffer pool and change buffer too quickly for caching to provide a significant benefit. For busy systems capable of higher I/O rates, you can set a higher value to help the server handle the background maintenance work associated with a high rate of row changes. Generally, you can increase the value as a function of the number of drives used for InnoDB I/O. For example, you can increase the value on systems that use multiple disks or SSDs.

The default setting of 200 is generally sufficient for a lower-end SSD. For a higher-end, bus-attached SSD, consider a higher setting such as 1000, for example. For systems with individual 5400 RPM or 7200 RPM drives, you might lower the value to 100, which represents an estimated proportion of the I/O operations per second (IOPS) available to older-generation disk drives that can perform about 100 IOPS.

Although you can specify a high value such as a million, in practice such large values have little benefit. Generally, a value higher than 20000 is not recommended unless you are certain that lower values are insufficient for your workload.

Consider write workload when tuning innodb_io_capacity. Systems with large write workloads are likely to benefit from a higher setting. A lower setting may be sufficient for systems with a small write workload.

The innodb_io_capacity setting is not a per buffer pool instance setting. Available I/O capacity is distributed equally among buffer pool instances for flushing activities.

You can set the innodb_io_capacity value in the MySQL option file (my.cnf or my.ini) or modify it at runtime using a SET GLOBAL statement, which requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

**14.11.8 Configuring Spin Lock Polling**

InnoDB mutexes and rw-locks are typically reserved for short intervals. On a multi-core system, it can be more efficient for a thread to continuously check if it can acquire a mutex or rw-lock for a period of time before it sleeps. If the mutex or rw-lock becomes available during this period, the thread can continue immediately, in the same time slice. However, too-frequent polling of a shared object such as a mutex or rw-lock by multiple threads can cause “cache ping pong”, which results in processors invalidating portions of each other’s cache. InnoDB minimizes this issue by forcing a random delay between polls to desynchronize polling activity. The random delay is implemented as a spin-wait loop.

The duration of a spin-wait loop is determined by the number of PAUSE instructions that occur in the loop. That number is generated by randomly selecting an integer ranging from 0 up to but not including the innodb_spin_wait_delay value, and multiplying that value by 50. For example, an integer is randomly selected from the following range for an innodb_spin_wait_delay setting of 6:

\{0,1,2,3,4,5\}

The selected integer is multiplied by 50, resulting in one of six possible PAUSE instruction values:

\{0,50,100,150,200,250\}

For that set of values, 250 is the maximum number of PAUSE instructions that can occur in a spin-wait loop. An innodb_spin_wait_delay setting of 5 results in a set of five possible values \{0,50,100,150,200\}, where 200 is the maximum number of PAUSE instructions, and so on. In this way, the innodb_spin_wait_delay setting controls the maximum delay between spin lock polls.

The duration of the delay loop depends on the C compiler and the target processor. In the 100MHz Pentium era, an innodb_spin_wait_delay unit was calibrated to be equivalent to one microsecond. That time equivalence did not hold, but PAUSE instruction duration has remained fairly constant in terms of processor cycles relative to other CPU instructions on most processor architectures.
On a system where all processor cores share a fast cache memory, you might reduce the maximum delay or disable the busy loop altogether by setting `innodb_spin_wait_delay=0`. On a system with multiple processor chips, the effect of cache invalidation can be more significant and you might increase the maximum delay.

The `innodb_spin_wait_delay` variable is dynamic. It can be specified in a MySQL option file or modified at runtime using a `SET GLOBAL` statement. Runtime modification requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

### 14.11.9 Purge Configuration

**InnoDB** does not physically remove a row from the database immediately when you delete it with an SQL statement. A row and its index records are only physically removed when **InnoDB** discards the undo log record written for the deletion. This removal operation, which only occurs after the row is no longer required for multi-version concurrency control (MVCC) or rollback, is called a purge.

Purge runs on a periodic schedule. It parses and processes undo log pages from the history list, which is a list of undo log pages for committed transactions that is maintained by the **InnoDB** transaction system. Purge frees the undo log pages from the history list after processing them.

#### Configuring a Dedicated Purge Thread

By default, purge operations are performed by the **InnoDB** master thread. Starting with MySQL 5.5, purge operations can performed in the background by a dedicated purge thread rather than as part of the **InnoDB** master thread. The use of a dedicated purge thread may improve scalability by allowing the main database operations to run independently from maintenance work happening in the background.

You can enable a dedicated purge thread by the setting `innodb_purge_threads` to 1. The default value is 0, which means that the purge operation is performed by the **InnoDB** master thread.

#### Configuring Purge Batch Size

The `innodb_purge_batch_size` variable defines the number of undo log pages that purge parses and processes in one batch from the history list. The default value is 20.

The purge system also frees the undo log pages that are no longer required. It does so every 128 iterations through the undo logs. In addition to defining the number of undo log pages parsed and processed in a batch, the `innodb_purge_batch_size` variable defines the number of undo log pages that purge frees every 128 iterations through the undo logs.

The `innodb_purge_batch_size` variable is intended for advanced performance tuning and experimentation. Most users need not change `innodb_purge_batch_size` from its default value.

#### Configuring the Maximum Purge Lag

The `innodb_max_purge_lag` variable defines the desired maximum purge lag. When the purge lag exceeds the `innodb_max_purge_lag` threshold, a delay is imposed on **INSERT**, **UPDATE**, and **DELETE** operations to allow time for purge operations to catch up. The default value is 0, which means there is no maximum purge lag and no delay.

The **InnoDB** transaction system maintains a list of transactions that have index records delete-marked by **UPDATE** or **DELETE** operations. The length of the list is the purge lag. The purge lag delay is calculated by the following formula, which results in a minimum delay of 5000 microseconds:

\[
\text{(purge lag/innodb_max_purge_lag - 0.5) } \times 10000
\]
The delay is calculated at the beginning of a purge batch, every ten seconds. The operations are not delayed if purge cannot run because of an old consistent read view that could see the rows to be purged.

A typical innodb_max_purge_lag setting for a problematic workload might be 1000000 (1 million), assuming that transactions are small, only 100 bytes in size, and it is permissible to have 100MB of unpurged table rows.

The purge lag is presented as the History list length value in the TRANSACTIONS section of SHOW ENGINE INNODB STATUS output.

```
mysql> SHOW ENGINE INNODB STATUS;
...
------------
TRANSACTIONS
------------
Trx id counter 0 290328385
Purge done for trx’s n:o < 0 290315608 undo n:o < 0 17
History list length 20
```

The History list length is typically a low value, usually less than a few thousand, but a write-heavy workload or long running transactions can cause it to increase, even for transactions that are read only. The reason that a long running transaction can cause the History list length to increase is that under a consistent read transaction isolation level such as REPEATABLE READ, a transaction must return the same result as when the read view for that transaction was created. Consequently, the InnoDB multi-version concurrency control (MVCC) system must keep a copy of the data in the undo log until all transactions that depend on that data have completed. The following are examples of long running transactions that could cause the History list length to increase:

- A mysqldump operation that uses the --single-transaction option while there is a significant amount of concurrent DML.

- Running a SELECT query after disabling autocommit, and forgetting to issue an explicit COMMIT or ROLLBACK.

### 14.11.10 Configuring Optimizer Statistics for InnoDB

The MySQL query optimizer uses estimated statistics about key distributions to choose the indexes for an execution plan, based on the relative selectivity of the index. Certain operations cause InnoDB to sample random pages from each index on a table to estimate the cardinality of the index. (This technique is known as random dives.) These operations include the ANALYZE TABLE statement, the SHOW TABLE STATUS statement, and accessing the table for the first time after a restart.

To give you control over the quality of the statistics estimate (and thus better information for the query optimizer), you can now change the number of sampled pages using the parameter innodb_stats_sample_pages. Previously, the number of sampled pages was always 8, which could be insufficient to produce an accurate estimate, leading to poor index choices by the query optimizer. This technique is especially important for large tables and tables used in joins. Unnecessary full table scans for such tables can be a substantial performance issue.

You can set the global parameter innodb_stats_sample_pages, at runtime. The default value for this parameter is 8, preserving the same behavior as in past releases.

**Note**

The value of innodb_stats_sample_pages affects the index sampling for all tables and indexes. There are the following potentially significant impacts when you change the index sample size:
InnoDB Table Compression

- Small values like 1 or 2 can result in very inaccurate estimates of cardinality.
- Increasing the `innodb_stats_sample_pages` value might require more disk reads. Values much larger than 8 (say, 100), can cause a big slowdown in the time it takes to open a table or execute `SHOW TABLE STATUS`.
- The optimizer might choose very different query plans based on different estimates of index selectivity.

To disable the cardinality estimation for metadata statements such as `SHOW TABLE STATUS` or `SHOW INDEX`, or when accessing the `INFORMATION_SCHEMA.TABLES` or `INFORMATION_SCHEMA.STATISTICS` tables, execute the statement `SET GLOBAL innodb_stats_on_metadata=OFF`. The ability to set this option dynamically is also relatively new.

All InnoDB tables are opened, and the statistics are re-estimated for all associated indexes, when the mysql client starts with the `--auto-rehash` setting on (the default). To improve the start up time of the mysql client, you can turn auto-rehash off using the `--disable-auto-rehash` option. The auto-rehash feature enables automatic name completion of database, table, and column names for interactive users.

Whatever value of `innodb_stats_sample_pages` works best for a system, set the option and leave it at that value. Choose a value that results in reasonably accurate estimates for all tables in your database without requiring excessive I/O. Because the statistics are automatically recalculated at various times other than on execution of `ANALYZE TABLE`, it does not make sense to increase the index sample size, run `ANALYZE TABLE`, then decrease sample size again. The more accurate statistics calculated by `ANALYZE` running with a high value of `innodb_stats_sample_pages` can be wiped away later.

Although it is not possible to specify the sample size on a per-table basis, smaller tables generally require fewer index samples than larger tables do. If your database has many large tables, consider using a higher value for `innodb_stats_sample_pages` than if you have mostly smaller tables.

### 14.11.10.1 Estimating ANALYZE TABLE Complexity for InnoDB Tables

`ANALYZE TABLE` complexity for InnoDB tables is dependent on:

- The number of pages sampled, as defined by `innodb_stats_sample_pages`.
- The number of indexed columns in a table
- The number of partitions. If a table has no partitions, the number of partitions is considered to be 1.

Using these parameters, an approximate formula for estimating `ANALYZE TABLE` complexity would be:

\[
\text{innodb_stats_sample_pages} \times \text{number of indexed columns in a table} \times \text{number of partitions}
\]

Typically, the greater the resulting value, the greater the execution time for `ANALYZE TABLE`.

For more information about the `innodb_stats_sample_pages` configuration parameter, see Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”.

### 14.12 InnoDB Table Compression

By using the SQL syntax and InnoDB configuration options for `compression`, you can create tables where the data is stored in compressed form. Compression can help to improve both raw performance and scalability. The compression means less data is transferred between disk and memory, and takes up less
space on disk and in memory. The benefits are amplified for tables with secondary indexes, because index data is compressed also. Compression can be especially important for SSD storage devices, because they tend to have lower capacity than HDD devices.

### 14.12.1 Overview of Table Compression

Because processors and cache memories have increased in speed more than disk storage devices, many workloads are disk-bound. Data compression enables smaller database size, reduced I/O, and improved throughput, at the small cost of increased CPU utilization. Compression is especially valuable for read-intensive applications, on systems with enough RAM to keep frequently used data in memory.

An InnoDB table created with `ROW_FORMAT=COMPRESSED` can use a smaller page size on disk than the usual 16KB default. Smaller pages require less I/O to read from and write to disk, which is especially valuable for SSD devices.

The page size is specified through the `KEY_BLOCK_SIZE` parameter. The different page size means the table must be in its own `.ibd` file rather than in the system tablespace, which requires enabling the `innodb_file_per_table` option. The level of compression is the same regardless of the `KEY_BLOCK_SIZE` value. As you specify smaller values for `KEY_BLOCK_SIZE`, you get the I/O benefits of increasingly smaller pages. But if you specify a value that is too small, there is additional overhead to reorganize the pages when data values cannot be compressed enough to fit multiple rows in each page. There is a hard limit on how small `KEY_BLOCK_SIZE` can be for a table, based on the lengths of the key columns for each of its indexes. Specify a value that is too small, and the `CREATE TABLE` or `ALTER TABLE` statement fails.

In the buffer pool, the compressed data is held in small pages, with a page size based on the `KEY_BLOCK_SIZE` value. For extracting or updating the column values, MySQL also creates a 16KB page in the buffer pool with the uncompressed data. Within the buffer pool, any updates to the uncompressed page are also re-written back to the equivalent compressed page. You might need to size your buffer pool to accommodate the additional data of both compressed and uncompressed pages, although the uncompressed pages are evicted from the buffer pool when space is needed, and then uncompressed again on the next access.

### 14.12.2 Enabling Compression for a Table

Before creating a compressed table, make sure the `innodb_file_per_table` configuration option is enabled, and `innodb_file_format` is set to Barracuda. You can set these parameters in the MySQL configuration file `my.cnf` or `my.ini`, or with the `SET` statement without shutting down the MySQL server.

To enable compression for a table, you use the clauses `ROW_FORMAT=COMPRESSED, KEY_BLOCK_SIZE`, or both in a `CREATE TABLE` or `ALTER TABLE` statement.

To create a compressed table, you might use statements like these:

```sql
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=Barracuda;
CREATE TABLE t1
  (c1 INT PRIMARY KEY)
  ROW_FORMAT=COMPRESSED
  KEY_BLOCK_SIZE=8;
```

- If you specify `ROW_FORMAT=COMPRESSED`, you can omit `KEY_BLOCK_SIZE`; the default compressed page size of 8KB is used.
- If you specify `KEY_BLOCK_SIZE`, you can omit `ROW_FORMAT=COMPRESSED`; compression is enabled automatically.
To determine the best value for `KEY_BLOCK_SIZE`, typically you create several copies of the same table with different values for this clause, then measure the size of the resulting `.ibd` files and see how well each performs with a realistic workload.

For additional performance-related configuration options, see Section 14.12.3, “Tuning Compression for InnoDB Tables”.

The default uncompressed size of InnoDB data pages is 16KB. Depending on the combination of option values, MySQL uses a page size of 1KB, 2KB, 4KB, 8KB, or 16KB for the `.ibd` file of the table. The actual compression algorithm is not affected by the `KEY_BLOCK_SIZE` value; the value determines how large each compressed chunk is, which in turn affects how many rows can be packed into each compressed page.

Setting `KEY_BLOCK_SIZE=16` typically does not result in much compression, since the normal InnoDB page size is 16KB. This setting may still be useful for tables with many long BLOB, VARCHAR or TEXT columns, because such values often do compress well, and might therefore require fewer overflow pages as described in Section 14.12.5, “How Compression Works for InnoDB Tables”.

All indexes of a table (including the clustered index) are compressed using the same page size, as specified in the `CREATE TABLE` or `ALTER TABLE` statement. Table attributes such as `ROW_FORMAT` and `KEY_BLOCK_SIZE` are not part of the `CREATE INDEX` syntax, and are ignored if they are specified (although you see them in the output of the `SHOW CREATE TABLE` statement).

Restrictions on Compressed Tables

Because MySQL versions prior to 5.1 cannot process compressed tables, using compression requires specifying the configuration parameter `innodb_file_format=Barracuda`, to avoid accidentally introducing compatibility issues.

Table compression is also not available for the InnoDB system tablespace. The system tablespace (space 0, the `ibdata*` files) can contain user data, but it also contains internal system information, and therefore is never compressed. Thus, compression applies only to tables (and indexes) stored in their own tablespaces, that is, created with the `innodb_file_per_table` option enabled.

Compression applies to an entire table and all its associated indexes, not to individual rows, despite the clause name `ROW_FORMAT`.

14.12.3 Tuning Compression for InnoDB Tables

Most often, the internal optimizations described in InnoDB Data Storage and Compression ensure that the system runs well with compressed data. However, because the efficiency of compression depends on the nature of your data, you can make decisions that affect the performance of compressed tables:

- Which tables to compress.
- What compressed page size to use.
- Whether to adjust the size of the buffer pool based on run-time performance characteristics, such as the amount of time the system spends compressing and uncompressing data. Whether the workload is more like a data warehouse (primarily queries) or an OLTP system (mix of queries and DML).
- If the system performs DML operations on compressed tables, and the way the data is distributed leads to expensive compression failures at runtime, you might adjust additional advanced configuration options.

Use the guidelines in this section to help make those architectural and configuration choices. When you are ready to conduct long-term testing and put compressed tables into production, see Section 14.12.4,
“Monitoring InnoDB Table Compression at Runtime” for ways to verify the effectiveness of those choices under real-world conditions.

When to Use Compression

In general, compression works best on tables that include a reasonable number of character string columns and where the data is read far more often than it is written. Because there are no guaranteed ways to predict whether or not compression benefits a particular situation, always test with a specific workload and data set running on a representative configuration. Consider the following factors when deciding which tables to compress.

Data Characteristics and Compression

A key determinant of the efficiency of compression in reducing the size of data files is the nature of the data itself. Recall that compression works by identifying repeated strings of bytes in a block of data. Completely randomized data is the worst case. Typical data often has repeated values, and so compresses effectively. Character strings often compress well, whether defined in CHAR, VARCHAR, TEXT or BLOB columns. On the other hand, tables containing mostly binary data (integers or floating point numbers) or data that is previously compressed (for example JPEG or PNG images) may not generally compress well, significantly or at all.

You choose whether to turn on compression for each InnoDB table. A table and all of its indexes use the same (compressed) page size. It might be that the primary key (clustered) index, which contains the data for all columns of a table, compresses more effectively than the secondary indexes. For those cases where there are long rows, the use of compression might result in long column values being stored “off-page”, as discussed in DYNAMIC Row Format. Those overflow pages may compress well. Given these considerations, for many applications, some tables compress more effectively than others, and you might find that your workload performs best only with a subset of tables compressed.

To determine whether or not to compress a particular table, conduct experiments. You can get a rough estimate of how efficiently your data can be compressed by using a utility that implements LZ77 compression (such as gzip or WinZip) on a copy of the .ibd file for an uncompressed table. You can expect less compression from a MySQL compressed table than from file-based compression tools, because MySQL compresses data in chunks based on the page size, 16KB by default. In addition to user data, the page format includes some internal system data that is not compressed. File-based compression utilities can examine much larger chunks of data, and so might find more repeated strings in a huge file than MySQL can find in an individual page.

Another way to test compression on a specific table is to copy some data from your uncompressed table to a similar, compressed table (having all the same indexes) and look at the size of the resulting .ibd file. For example:

```
USE test;
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=Barracuda;
SET GLOBAL autocommit=0;

-- Create an uncompressed table with a million or two rows.
CREATE TABLE big_table AS SELECT * FROM information_schema.columns;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
```

1779
Tuning Compression for InnoDB Tables

```sql
COMMIT;
ALTER TABLE big_table ADD id int unsigned NOT NULL PRIMARY KEY auto_increment;
SHOW CREATE TABLE big_table\G
select count(id) from big_table;
-- Check how much space is needed for the uncompressed table.
\! ls -l data/test/big_table.ibd
CREATE TABLE key_block_size_4 LIKE big_table;
ALTER TABLE key_block_size_4 key_block_size=4 row_format=compressed;
INSERT INTO key_block_size_4 SELECT * FROM big_table;
commit;
-- Check how much space is needed for a compressed table
-- with particular compression settings.
\! ls -l data/test/key_block_size_4.ibd
```

This experiment produced the following numbers, which of course could vary considerably depending on your table structure and data:

```
-rw-rw----  1 cirrus  staff  310378496 Jan  9 13:44 data/test/big_table.ibd
-rw-rw----  1 cirrus  staff  83886080 Jan  9 15:10 data/test/key_block_size_4.ibd
```

To see whether compression is efficient for your particular workload, use a MySQL instance with no other compressed tables and run queries against the INFORMATION_SCHEMA.INNODB_CMP table. For example, you examine the ratio of successful compression operations to overall compression operations. (In the INNODB_CMP table, compare COMPRESS_OPS to COMPRESS_OPS_OK. See INNODB_CMP for more information.) If a high percentage of compression operations complete successfully, the table might be a good candidate for compression.

### Compression and Application and Schema Design

Decide whether to compress data in your application or in the table; do not use both types of compression for the same data. When you compress the data in the application and store the results in a compressed table, extra space savings are extremely unlikely, and the double compression just wastes CPU cycles.

### Compressing in the Database

The InnoDB table compression is automatic and applies to all columns and index values. The columns can still be tested with operators such as LIKE, and sort operations can still use indexes even when the index values are compressed. Because indexes are often a significant fraction of the total size of a database, compression could result in significant savings in storage, I/O or processor time. The compression and decompression operations happen on the database server, which likely is a powerful system that is sized to handle the expected load.

### Compressing in the Application

If you compress data such as text in your application, before it is inserted into the database, You might save overhead for data that does not compress well by compressing some columns and not others. This approach uses CPU cycles for compression and uncompression on the client machine rather than the database server, which might be appropriate for a distributed application with many clients, or where the client machine has spare CPU cycles.

### Hybrid Approach

Of course, it is possible to combine these approaches. For some applications, it may be appropriate to use some compressed tables and some uncompressed tables. It may be best to externally compress some
data (and store it in uncompressed InnoDB tables) and allow InnoDB to compress (some of) the other tables in the application. As always, up-front design and real-life testing are valuable in reaching the right decision.

**Workload Characteristics and Compression**

In addition to choosing which tables to compress (and the page size), the workload is another key determinant of performance. If the application is dominated by reads, rather than updates, fewer pages need to be reorganized and recompressed after the index page runs out of room for the per-page “modification log” that InnoDB maintains for compressed data. If the updates predominantly change non-indexed columns or those containing BLOBs or large strings that happen to be stored “off-page”, the overhead of compression may be acceptable. If the only changes to a table are INSERTs that use a monotonically increasing primary key, and there are few secondary indexes, there is little need to reorganize and recompress index pages. Since InnoDB can “delete-mark” and delete rows on compressed pages “in place” by modifying uncompressed data, DELETE operations on a table are relatively efficient.

For some environments, the time it takes to load data can be as important as run-time retrieval. Especially in data warehouse environments, many tables may be read-only or read-mostly. In those cases, it might or might not be acceptable to pay the price of compression in terms of increased load time, unless the resulting savings in fewer disk reads or in storage cost is significant.

Fundamentally, compression works best when the CPU time is available for compressing and uncompressing data. Thus, if your workload is I/O bound, rather than CPU-bound, you might find that compression can improve overall performance. When you test your application performance with different compression configurations, test on a platform similar to the planned configuration of the production system.

**Configuration Characteristics and Compression**

Reading and writing database pages from and to disk is the slowest aspect of system performance. Compression attempts to reduce I/O by using CPU time to compress and uncompress data, and is most effective when I/O is a relatively scarce resource compared to processor cycles.

This is often especially the case when running in a multi-user environment with fast, multi-core CPUs. When a page of a compressed table is in memory, InnoDB often uses an additional 16K in the buffer pool for an uncompressed copy of the page. The adaptive LRU algorithm in the InnoDB storage engine attempts to balance the use of memory between compressed and uncompressed pages to take into account whether the workload is running in an I/O-bound or CPU-bound manner. Still, a configuration with more memory dedicated to the InnoDB buffer pool tends to run better when using compressed tables than a configuration where memory is highly constrained.

**Choosing the Compressed Page Size**

The optimal setting of the compressed page size depends on the type and distribution of data that the table and its indexes contain. The compressed page size should always be bigger than the maximum record size, or operations may fail as noted in Compression of B-Tree Pages.

Setting the compressed page size too large wastes some space, but the pages do not have to be compressed as often. If the compressed page size is set too small, inserts or updates may require time-consuming recompression, and the B-tree nodes may have to be split more frequently, leading to bigger data files and less efficient indexing.

Typically, you set the compressed page size to 8K or 4K bytes. Given that the maximum row size for an InnoDB table is around 8K, `KEY_BLOCK_SIZE=8` is usually a safe choice.

**14.12.4 Monitoring InnoDB Table Compression at Runtime**
How Compression Works for InnoDB Tables

Overall application performance, CPU and I/O utilization and the size of disk files are good indicators of how effective compression is for your application. This section builds on the performance tuning advice from Section 14.12.3, “Tuning Compression for InnoDB Tables”, and shows how to find problems that might not turn up during initial testing.

To dig deeper into performance considerations for compressed tables, you can monitor compression performance at runtime using the Information Schema tables described in Example 14.1, “Using the Compression Information Schema Tables”. These tables reflect the internal use of memory and the rates of compression used overall.

The INNODB_CMP table reports information about compression activity for each compressed page size (KEY_BLOCK_SIZE) in use. The information in these tables is system-wide: it summarizes the compression statistics across all compressed tables in your database. You can use this data to help decide whether or not to compress a table by examining these tables when no other compressed tables are being accessed. It involves relatively low overhead on the server, so you might query it periodically on a production server to check the overall efficiency of the compression feature.

The key statistics to consider are the number of, and amount of time spent performing, compression and decompression operations. Since InnoDB must split B-tree nodes when they are too full to contain the compressed data following a modification, compare the number of “successful” compression operations with the number of such operations overall. Based on the information in the INNODB_CMP tables and overall application performance and hardware resource utilization, you might make changes in your hardware configuration, adjust the size of the InnoDB buffer pool, choose a different page size, or select a different set of tables to compress.

If the amount of CPU time required for compressing and decompressing is high, changing to faster CPUs, or those with more cores, can help improve performance with the same data, application workload and set of compressed tables. Increasing the size of the InnoDB buffer pool might also help performance, so that more uncompressed pages can stay in memory, reducing the need to decompress pages that exist in memory only in compressed form.

A large number of compression operations overall (compared to the number of INSERT, UPDATE and DELETE operations in your application and the size of the database) could indicate that some of your compressed tables are being updated too heavily for effective compression. If so, choose a larger page size, or be more selective about which tables you compress.

If the number of “successful” compression operations (COMPRESS_OPS_OK) is a high percentage of the total number of compression operations (COMPRESS_OPS), then the system is likely performing well. If the ratio is low, then InnoDB is reorganizing, recompressing, and splitting B-tree nodes more often than is desirable. In this case, avoid compressing some tables, or increase KEY_BLOCK_SIZE for some of the compressed tables. You might turn off compression for tables that cause the number of “compression failures” in your application to be more than 1% or 2% of the total. (Such a failure ratio might be acceptable during a temporary operation such as a data load).

14.12.5 How Compression Works for InnoDB Tables

This section describes some internal implementation details about compression for InnoDB tables. The information presented here may be helpful in tuning for performance, but is not necessary to know for basic use of compression.

Compression Algorithms

Some operating systems implement compression at the file system level. Files are typically divided into fixed-size blocks that are compressed into variable-size blocks, which easily leads into fragmentation. Every time something inside a block is modified, the whole block is recompressed before it is written.
How Compression Works for InnoDB Tables

to disk. These properties make this compression technique unsuitable for use in an update-intensive database system.

InnoDB implements compression with the help of the well-known zlib library, which implements the LZ77 compression algorithm. This compression algorithm is mature, robust, and efficient in both CPU utilization and in reduction of data size. The algorithm is "lossless", so that the original uncompressed data can always be reconstructed from the compressed form. LZ77 compression works by finding sequences of data that are repeated within the data to be compressed. The patterns of values in your data determine how well it compresses, but typical user data often compresses by 50% or more.

Note
Prior to MySQL 5.5.62, InnoDB supports the zlib library up to version 1.2.3. In MySQL 5.5.62 and later, InnoDB supports the zlib library up to version 1.2.11.

Unlike compression performed by an application, or compression features of some other database management systems, InnoDB compression applies both to user data and to indexes. In many cases, indexes can constitute 40-50% or more of the total database size, so this difference is significant. When compression is working well for a data set, the size of the InnoDB data files (the .ibd files) is 25% to 50% of the uncompressed size or possibly smaller. Depending on the workload, this smaller database can in turn lead to a reduction in I/O, and an increase in throughput, at a modest cost in terms of increased CPU utilization.

InnoDB Data Storage and Compression

All user data in InnoDB tables is stored in pages comprising a B-tree index (the clustered index). In some other database systems, this type of index is called an "index-organized table". Each row in the index node contains the values of the (user-specified or system-generated) primary key and all the other columns of the table.

Secondary indexes in InnoDB tables are also B-trees, containing pairs of values: the index key and a pointer to a row in the clustered index. The pointer is in fact the value of the primary key of the table, which is used to access the clustered index if columns other than the index key and primary key are required. Secondary index records must always fit on a single B-tree page.

The compression of B-tree nodes (of both clustered and secondary indexes) is handled differently from compression of overflow pages used to store long VARCHAR, BLOB, or TEXT columns, as explained in the following sections.

Compression of B-Tree Pages

Because they are frequently updated, B-tree pages require special treatment. It is important to minimize the number of times B-tree nodes are split, as well as to minimize the need to uncompress and recompress their content.

One technique InnoDB uses is to maintain some system information in the B-tree node in uncompressed form, thus facilitating certain in-place updates. For example, this allows rows to be delete-marked and deleted without any compression operation.

In addition, InnoDB attempts to avoid unnecessary uncompression and recompression of index pages when they are changed. Within each B-tree page, the system keeps an uncompressed "modification log" to record changes made to the page. Updates and inserts of small records may be written to this modification log without requiring the entire page to be completely reconstructed.

When the space for the modification log runs out, InnoDB uncompresses the page, applies the changes and recompresses the page. If recompression fails (a situation known as a compression failure), the B-tree nodes are split and the process is repeated until the update or insert succeeds.
How Compression Works for InnoDB Tables

Generally, InnoDB requires that each B-tree page can accommodate at least two records. For compressed tables, this requirement has been relaxed. Leaf pages of B-tree nodes (whether of the primary key or secondary indexes) only need to accommodate one record, but that record must fit in uncompressed form, in the per-page modification log. Starting with InnoDB storage engine version 1.0.2, and if innodb_strict_mode is ON, the InnoDB storage engine checks the maximum row size during CREATE TABLE or CREATE INDEX. If the row does not fit, the following error message is issued: ERROR HY000: Too big row.

If you create a table when innodb_strict_mode is OFF, and a subsequent INSERT or UPDATE statement attempts to create an index entry that does not fit in the size of the compressed page, the operation fails with ERROR 42000: Row size too large. (This error message does not name the index for which the record is too large, or mention the length of the index record or the maximum record size on that particular index page.) To solve this problem, rebuild the table with ALTER TABLE and select a larger compressed page size (KEY_BLOCK_SIZE), shorten any column prefix indexes, or disable compression entirely with ROW_FORMAT=DYNAMIC or ROW_FORMAT=COMPACT.

Compressing BLOB, VARCHAR, and TEXT Columns

In an InnoDB table, BLOB, VARCHAR, and TEXT columns that are not part of the primary key may be stored on separately allocated overflow pages. We refer to these columns as off-page columns. Their values are stored on singly-linked lists of overflow pages.

For tables created in ROW_FORMAT=DYNAMIC or ROW_FORMAT=COMPRESSED, the values of BLOB, TEXT, or VARCHAR columns may be stored fully off-page, depending on their length and the length of the entire row. For columns that are stored off-page, the clustered index record only contains 20-byte pointers to the overflow pages, one per column. Whether any columns are stored off-page depends on the page size and the total size of the row. When the row is too long to fit entirely within the page of the clustered index, MySQL chooses the longest columns for off-page storage until the row fits on the clustered index page. As noted above, if a row does not fit by itself on a compressed page, an error occurs.

Note

For tables created in ROW_FORMAT=DYNAMIC or ROW_FORMAT=COMPRESSED, TEXT and BLOB columns that are less than or equal to 40 bytes are always stored in-line.

Tables created in older versions of InnoDB use the Antelope file format, which supports only ROW_FORMAT=REDUNDANT and ROW_FORMAT=COMPACT. In these formats, MySQL stores the first 768 bytes of BLOB, VARCHAR, and TEXT columns in the clustered index record along with the primary key. The 768-byte prefix is followed by a 20-byte pointer to the overflow pages that contain the rest of the column value.

When a table is in COMPRESSED format, all data written to overflow pages is compressed “as is”; that is, InnoDB applies the zlib compression algorithm to the entire data item. Other than the data, compressed overflow pages contain an uncompressed header and trailer comprising a page checksum and a link to the next overflow page, among other things. Therefore, very significant storage savings can be obtained for longer BLOB, TEXT, or VARCHAR columns if the data is highly compressible, as is often the case with text data. Image data, such as JPEG, is typically already compressed and so does not benefit much from being stored in a compressed table; the double compression can waste CPU cycles for little or no space savings.

The overflow pages are of the same size as other pages. A row containing ten columns stored off-page occupies ten overflow pages, even if the total length of the columns is only 8K bytes. In an uncompressed table, ten uncompressed overflow pages occupy 160K bytes. In a compressed table with an 8K page size, they occupy only 80K bytes. Thus, it is often more efficient to use compressed table format for tables with long column values.
Using a 16K compressed page size can reduce storage and I/O costs for \texttt{BLOB, VARCHAR, or TEXT} columns, because such data often compress well, and might therefore require fewer overflow pages, even though the B-tree nodes themselves take as many pages as in the uncompressed form.

**Compression and the InnoDB Buffer Pool**

In a compressed InnoDB table, every compressed page (whether 1K, 2K, 4K or 8K) corresponds to an uncompressed page of 16K bytes. To access the data in a page, InnoDB reads the compressed page from disk if it is not already in the buffer pool, then uncompresses the page to its original form. This section describes how InnoDB manages the buffer pool with respect to pages of compressed tables.

To minimize I/O and to reduce the need to uncompress a page, at times the buffer pool contains both the compressed and uncompressed form of a database page. To make room for other required database pages, InnoDB may evict from the buffer pool an uncompressed page, while leaving the compressed page in memory. Or, if a page has not been accessed in a while, the compressed form of the page might be written to disk, to free space for other data. Thus, at any given time, the buffer pool might contain both the compressed and uncompressed forms of the page, or only the compressed form of the page, or neither.

InnoDB keeps track of which pages to keep in memory and which to evict using a least-recently-used (LRU) list, so that hot (frequently accessed) data tends to stay in memory. When compressed tables are accessed, MySQL uses an adaptive LRU algorithm to achieve an appropriate balance of compressed and uncompressed pages in memory. This adaptive algorithm is sensitive to whether the system is running in an I/O-bound or CPU-bound manner. The goal is to avoid spending too much processing time uncompressing pages when the CPU is busy, and to avoid doing excess I/O when the CPU has spare cycles that can be used for uncompressing compressed pages (that may already be in memory). When the system is I/O-bound, the algorithm prefers to evict the uncompressed copy of a page rather than both copies, to make more room for other disk pages to become memory resident. When the system is CPU-bound, MySQL prefers to evict both the compressed and uncompressed page, so that more memory can be used for “hot” pages and reducing the need to uncompress data in memory only in compressed form.

**Compression and the InnoDB Redo Log Files**

Before a compressed page is written to a data file, MySQL writes a copy of the page to the redo log (if it has been recompressed since the last time it was written to the database). This is done to ensure that redo logs are usable for crash recovery, even in the unlikely case that the \texttt{zlib} library is upgraded and that change introduces a compatibility problem with the compressed data. Therefore, some increase in the size of log files, or a need for more frequent checkpoints, can be expected when using compression. The amount of increase in the log file size or checkpoint frequency depends on the number of times compressed pages are modified in a way that requires reorganization and recompression.

Note that compressed tables use a different file format for the redo log and the per-table tablespaces than in MySQL 5.1 and earlier. The MySQL Enterprise Backup product supports this latest Barracuda file format for compressed InnoDB tables.

### 14.12.6 SQL Compression Syntax Warnings and Errors

Specifying \texttt{ROW_FORMAT=COMPRESSED} or \texttt{KEY_BLOCK_SIZE} in \texttt{CREATE TABLE} or \texttt{ALTER TABLE} statements produces the following warnings if the Barracuda file format is not enabled. You can view them with the \texttt{SHOW WARNINGS} statement.

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>1478</td>
<td>InnoDB: KEY_BLOCK_SIZE requires innodb_file_per_table.</td>
</tr>
<tr>
<td>Warning</td>
<td>1478</td>
<td>InnoDB: KEY_BLOCK_SIZE requires innodb_file_format=1</td>
</tr>
</tbody>
</table>
SQL Compression Syntax Warnings and Errors

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>1478</td>
<td>InnoDB: ignoring KEY_BLOCK_SIZE=4.</td>
</tr>
<tr>
<td>Warning</td>
<td>1478</td>
<td>InnoDB: ROW_FORMAT=COMPRESSED requires innodb_file_per_table.</td>
</tr>
<tr>
<td>Warning</td>
<td>1478</td>
<td>InnoDB: assuming ROW_FORMAT=COMPACT.</td>
</tr>
</tbody>
</table>

Notes:

• By default, these messages are only warnings, not errors, and the table is created without compression, as if the options were not specified.

• When innodb_strict_mode is enabled, MySQL generates an error, not a warning, for these cases. The table is not created if the current configuration does not permit using compressed tables.

The “non-strict” behavior lets you import a mysqldump file into a database that does not support compressed tables, even if the source database contained compressed tables. In that case, MySQL creates the table in ROW_FORMAT=COMPACT instead of preventing the operation.

To import the dump file into a new database, and have the tables re-created as they exist in the original database, ensure the server has the proper settings for the configuration parameters innodb_file_format and innodb_file_per_table.

The attribute KEY_BLOCK_SIZE is permitted only when ROW_FORMAT is specified as COMPRESSED or is omitted. Specifying a KEY_BLOCK_SIZE with any other ROW_FORMAT generates a warning that you can view with SHOW WARNINGS. However, the table is non-compressed; the specified KEY_BLOCK_SIZE is ignored.

If you are running with innodb_strict_mode enabled, the combination of a KEY_BLOCK_SIZE with any ROW_FORMAT other than COMPRESSED generates an error, not a warning, and the table is not created.

Table 14.4, “ROW_FORMAT and KEY_BLOCK_SIZE Options” provides an overview the ROW_FORMAT and KEY_BLOCK_SIZE options that are used with CREATE TABLE or ALTER TABLE.

<table>
<thead>
<tr>
<th>Option</th>
<th>Usage Notes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW_FORMAT=REDUNDANT</td>
<td>Storage format used prior to MySQL 5.0.3</td>
<td>Less efficient than ROW_FORMAT=COMPACT; for backward compatibility</td>
</tr>
<tr>
<td>ROW_FORMAT=COMPACT</td>
<td>Default storage format since MySQL 5.0.3</td>
<td>Stores a prefix of 768 bytes of long column values in the clustered index page, with the remaining bytes stored in an overflow page</td>
</tr>
<tr>
<td>ROW_FORMAT=DYNAMIC</td>
<td>Available only with innodb_file_format=Barracuda</td>
<td>Store values within the clustered index page if they fit; if not, stores only a 20-byte pointer to an overflow page (no prefix)</td>
</tr>
<tr>
<td>ROW_FORMAT=COMPRESSED</td>
<td>Available only with innodb_file_format=Barracuda</td>
<td>Compresses the table and indexes using zlib to default compressed page size of 8K bytes</td>
</tr>
</tbody>
</table>
Table 14.5 “CREATE/ALTER TABLE Warnings and Errors when InnoDB Strict Mode is OFF” summarizes error conditions that occur with certain combinations of configuration parameters and options on the CREATE TABLE or ALTER TABLE statements, and how the options appear in the output of SHOW TABLE STATUS.

When innodb_strict_mode is OFF, InnoDB creates or alters the table, but ignores certain settings as shown below. You can see the warning messages in the MySQL error log. When innodb_strict_mode is ON, these specified combinations of options generate errors, and the table is not created or altered. To see the full description of the error condition, issue the SHOW ERRORS statement: example:

```sql
mysql> CREATE TABLE x (id INT PRIMARY KEY, c INT)
   
   -> ENGINE=INNODB KEY_BLOCK_SIZE=33333;
```

```sql
ERROR 1005 (HY000): Can't create table 'test.x' (errno: 1478)
```

```sql
mysql> SHOW ERRORS;
```

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error</td>
<td>1478</td>
<td>InnoDB: invalid KEY_BLOCK_SIZE=33333.</td>
</tr>
<tr>
<td>Error</td>
<td>1005</td>
<td>Can't create table 'test.x' (errno: 1478)</td>
</tr>
</tbody>
</table>

Table 14.5 CREATE/ALTER TABLE Warnings and Errors when InnoDB Strict Mode is OFF

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Warning or Error Condition</th>
<th>Resulting ROW_FORMAT, as shown in SHOW TABLE STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW_FORMAT=REDUNDANT</td>
<td>None</td>
<td>REDUNDANT</td>
</tr>
<tr>
<td>ROW_FORMAT=COMPRESSED</td>
<td>None</td>
<td>COMPRESSED</td>
</tr>
<tr>
<td>ROW_FORMAT=DYNAMIC or KEY_BLOCK_SIZE is specified</td>
<td>Ignored unless both innodb_file_format=Barracuda and innodb_file_per_table are enabled</td>
<td>COMPACT</td>
</tr>
<tr>
<td>Invalid KEY_BLOCK_SIZE is specified (not 1, 2, 4, 8 or 16)</td>
<td>KEY_BLOCK_SIZE is ignored</td>
<td>the specified row format, or COMPACT by default</td>
</tr>
<tr>
<td>ROW_FORMAT=COMPRESSED and valid KEY_BLOCK_SIZE are specified</td>
<td>None; KEY_BLOCK_SIZE specified is used, not the 8K default</td>
<td>COMPRESSED</td>
</tr>
<tr>
<td>KEY_BLOCK_SIZE is specified with REDUNDANT, COMPACT or DYNAMIC row format</td>
<td>KEY_BLOCK_SIZE is ignored</td>
<td>REDUNDANT, COMPACT or DYNAMIC</td>
</tr>
<tr>
<td>ROW_FORMAT is not one of REDUNDANT, COMPACT, DYNAMIC or COMPRESSED</td>
<td>Ignored if recognized by the MySQL parser. Otherwise, an error is issued.</td>
<td>COMPACT or N/A</td>
</tr>
</tbody>
</table>

When innodb_strict_mode is ON, the InnoDB storage engine rejects invalid ROW_FORMAT or KEY_BLOCK_SIZE parameters. For compatibility with earlier versions of MySQL, strict mode is not enabled by default; instead, MySQL issues warnings (not errors) for ignored invalid parameters.
Note that it is not possible to see the chosen `KEY_BLOCK_SIZE` using `SHOW TABLE STATUS`. The statement `SHOW CREATE TABLE` displays the `KEY_BLOCK_SIZE` (even if it was ignored when creating the table). The real compressed page size of the table cannot be displayed by MySQL.

### 14.13 InnoDB File-Format Management

As InnoDB evolves, data file formats that are not compatible with prior versions of InnoDB are sometimes required to support new features. To help manage compatibility in upgrade and downgrade situations, and systems that run different versions of MySQL, InnoDB uses named file formats. InnoDB currently supports two named file formats, Antelope and Barracuda.

- **Antelope** is the original InnoDB file format, which previously did not have a name. It supports COMPACT and REDUNDANT row formats for InnoDB tables and is the default file format in MySQL 5.5 to ensure maximum compatibility with earlier MySQL versions that do not support the Barracuda file format.

- **Barracuda** is the newest file format. It supports all InnoDB row formats including the newer COMPRESSED and DYNAMIC row formats. The features associated with COMPRESSED and DYNAMIC row formats include compressed tables and efficient storage of off-page columns. See Section 14.14, “InnoDB Row Formats”.

This section discusses enabling InnoDB file formats, verifying compatibility of different file formats between MySQL releases, identifying the file format in use, and downgrading the file format.

#### 14.13.1 Enabling File Formats

The `innodb_file_format` configuration option enables an InnoDB file format for file-per-table tablespaces.

Antelope is the default `innodb_file_format`.

To preclude the use of features supported by the Barracuda file that make your database inaccessible to the built-in InnoDB in MySQL 5.1 and prior releases, set `innodb_file_format` to Antelope. Alternatively, you can disable `innodb_file_per_table` to have new tables created in the system tablespace. The system tablespace is stored in the original Antelope file format.

You can set the value of `innodb_file_format` on the command line when you start `mysqld`, or in the option file (`my.cnf` on Unix, `my.ini` on Windows). You can also change it dynamically with a `SET GLOBAL` statement.

```sql
SET GLOBAL innodb_file_format=Barracuda;
```

Although Oracle recommends using the Barracuda format for new tables where practical, in MySQL 5.5 the default file format is Antelope, for maximum compatibility with replication configurations containing earlier MySQL releases.

#### 14.13.2 Verifying File Format Compatibility

InnoDB incorporates several checks to guard against the possible crashes and data corruptions that might occur if you run an old release of the MySQL server on InnoDB data files that use a newer file format. These checks take place when the server is started, and when you first access a table. This section describes these checks, how you can control them, and error and warning conditions that might arise.

**Backward Compatibility**

You only need to consider backward file format compatibility when using a recent version of InnoDB (the InnoDB Plugin, or MySQL 5.5 and higher with InnoDB) alongside an older version (MySQL 5.1 or earlier,
with the built-in InnoDB rather than the InnoDB Plugin). To minimize the chance of compatibility issues, you can standardize on the InnoDB Plugin for all your MySQL 5.1 and earlier database servers.

In general, a newer version of InnoDB may create a table or index that cannot safely be read or written with an older version of InnoDB without risk of crashes, hangs, wrong results or corruptions. MySQL 5.5 and higher with InnoDB includes a mechanism to guard against these conditions, and to help preserve compatibility among database files and versions of InnoDB. This mechanism lets you take advantage of some new features of an InnoDB release (such as performance improvements and bug fixes), and still preserve the option of using your database with a prior version of InnoDB, by preventing accidental use of new features that create downward-incompatible disk files.

If a version of InnoDB supports a particular file format (whether or not that format is the default), you can query and update any table that requires that format or an earlier format. Only the creation of new tables using new features is limited based on the particular file format enabled. Conversely, if a tablespace contains a table or index that uses a file format that is not supported, it cannot be accessed at all, even for read access.

The only way to “downgrade” an InnoDB tablespace to the earlier Antelope file format is to copy the data to a new table, in a tablespace that uses the earlier format. This can be done with the `ALTER TABLE` statement, as described in Section 14.13.4, “Downgrading the File Format”.

The easiest way to determine the file format of an existing InnoDB tablespace is to examine the properties of the table it contains, using the `SHOW TABLE STATUS` command or querying the table `INFORMATION_SCHEMA.TABLES`. If the `Row_format` of the table is reported as 'Compressed' or 'Dynamic', the tablespace containing the table uses the Barracuda format. Otherwise, it uses the prior InnoDB file format, Antelope.

**Internal Details**

Every InnoDB file-per-table tablespace (represented by a `.ibd` file) file is labeled with a file format identifier. The system tablespace (represented by the `ibdata` files) is tagged with the “highest” file format in use in a group of InnoDB database files, and this tag is checked when the files are opened.

Creating a compressed table, or a table with `ROW_FORMAT=DYNAMIC`, updates the file header of the corresponding file-per-table `.ibd` file and the table type in the InnoDB data dictionary with the identifier for the Barracuda file format. From that point forward, the table cannot be used with a version of InnoDB that does not support the Barracuda file format. To protect against anomalous behavior, InnoDB version 5.0.21 and later performs a compatibility check when the table is opened. (In many cases, the `ALTER TABLE` statement recreates a table and thus changes its properties. The special case of adding or dropping indexes without rebuilding the table is described in Section 14.16, “InnoDB Fast Index Creation”.)

**Definition of ib-file set**

To avoid confusion, for the purposes of this discussion we define the term “ib-file set” to mean the set of operating system files that InnoDB manages as a unit. The ib-file set includes the following files:

- The system tablespace (one or more `ibdata` files) that contain internal system information (including internal catalogs and undo information) and may include user data and indexes.
- Zero or more single-table tablespaces (also called “file per table” files, named `*.ibd` files).
- InnoDB log files; usually two, `ib_logfile0` and `ib_logfile1`. Used for crash recovery and in backups.

An “ib-file set” does not include the corresponding `.frm` files that contain metadata about InnoDB tables. The `.frm` files are created and managed by MySQL, and can sometimes get out of sync with the internal metadata in InnoDB.
Verifying File Format Compatibility

Multiple tables, even from more than one database, can be stored in a single “ib-file set”. (In MySQL, a “database” is a logical collection of tables, what other systems refer to as a “schema” or “catalog”.)

14.13.2.1 Compatibility Check When InnoDB Is Started

To prevent possible crashes or data corruptions when InnoDB opens an ib-file set, it checks that it can fully support the file formats in use within the ib-file set. If the system is restarted following a crash, or a “fast shutdown” (i.e., `innodb_fast_shutdown` is greater than zero), there may be on-disk data structures (such as redo or undo entries, or doublewrite pages) that are in a “too-new” format for the current software. During the recovery process, serious damage can be done to your data files if these data structures are accessed. The startup check of the file format occurs before any recovery process begins, thereby preventing consistency issues with the new tables or startup problems for the MySQL server.

Beginning with version InnoDB 1.0.1, the system tablespace records an identifier or tag for the “highest” file format used by any table in any of the tablespaces that is part of the ib-file set. Checks against this file format tag are controlled by the configuration parameter `innodb_file_format_check`, which is ON by default.

If the file format tag in the system tablespace is newer or higher than the highest version supported by the particular currently executing software and if `innodb_file_format_check` is ON, the following error is issued when the server is started:

```
InnoDB: Error: the system tablespace is in a file format that this version doesn't support
```

You can also set `innodb_file_format` to a file format name. Doing so prevents InnoDB from starting if the current software does not support the file format specified. It also sets the “high water mark” to the value you specify. The ability to set `innodb_file_format_check` is useful (with future releases) if you manually “downgrade” all of the tables in an ib-file set (as described in Section 14.4, “Downgrading the InnoDB Storage Engine”). You can then rely on the file format check at startup if you subsequently use an older version of InnoDB to access the ib-file set.

In some limited circumstances, you might want to start the server and use an ib-file set that is in a new file format that is not supported by the software you are using. If you set the configuration parameter `innodb_file_format_check` to OFF, InnoDB opens the database, but issues this warning message in the error log:

```
InnoDB: Warning: the system tablespace is in a file format that this version doesn't support
```

Note

This is a dangerous setting, as it permits the recovery process to run, possibly corrupting your database if the previous shutdown was a crash or “fast shutdown”. You should only set `innodb_file_format_check` to OFF if you are sure that the previous shutdown was done with `innodb_fast_shutdown=0`, so that essentially no recovery process occurs.

The parameter `innodb_file_format_check` affects only what happens when a database is opened, not subsequently. Conversely, the parameter `innodb_file_format` (which enables a specific format) only determines whether or not a new table can be created in the enabled format and has no effect on whether or not a database can be opened.

The file format tag is a “high water mark”, and as such it is increased after the server is started, if a table in a “higher” format is created or an existing table is accessed for read or write (assuming its format is supported). If you access an existing table in a format higher than the format the running software supports, the system tablespace tag is not updated, but table-level compatibility checking applies (and...
Identifying the File Format in Use

When a table is first accessed, InnoDB (including some releases prior to InnoDB 1.0) checks that the file format of the tablespace in which the table is stored is fully supported. This check prevents crashes or corruptions that would otherwise occur when tables using a “too new” data structure are encountered.

All tables using any file format supported by a release can be read or written (assuming the user has sufficient privileges). The setting of the system configuration parameter `innodb_file_format` can prevent creating a new table that uses a specific file format, even if the file format is supported by a given release. Such a setting might be used to preserve backward compatibility, but it does not prevent accessing any table that uses a supported format.

Versions of MySQL older than 5.0.21 cannot reliably use database files created by newer versions if a new file format was used when a table was created. To prevent various error conditions or corruptions, InnoDB checks file format compatibility when it opens a file (for example, upon first access to a table). If the currently running version of InnoDB does not support the file format identified by the table type in the InnoDB data dictionary, MySQL reports the following error:

```
ERROR 1146 (42S02): Table 'test.t1' doesn't exist
```

InnoDB also writes a message to the error log:

```
InnoDB: table test/t1: unknown table type 33
```

The table type should be equal to the tablespace flags, which contains the file format version as discussed in Section 14.13.3, “Identifying the File Format in Use”.

Versions of InnoDB prior to MySQL 4.1 did not include table format identifiers in the database files, and versions prior to MySQL 5.0.21 did not include a table format compatibility check. Therefore, there is no way to ensure proper operations if a table in a newer file format is used with versions of InnoDB prior to 5.0.21.

The file format management capability in InnoDB 1.0 and higher (tablespace tagging and run-time checks) allows InnoDB to verify as soon as possible that the running version of software can properly process the tables existing in the database.

If you permit InnoDB to open a database containing files in a format it does not support (by setting the parameter `innodb_file_format_check` to OFF), the table-level checking described in this section still applies.

Users are strongly urged not to use database files that contain Barracuda file format tables with releases of InnoDB older than the MySQL 5.1 with the InnoDB Plugin. It is possible to “downgrade” such tables to the Antelope format with the procedure described in Section 14.13.4, “Downgrading the File Format”.

14.13.3 Identifying the File Format in Use

If you enable a different file format using the `innodb_file_format` configuration option, the change only applies to newly created tables. Also, when you create a new table, the tablespace containing the table is tagged with the “earliest” or “simplest” file format that is required to support the table’s features. For example, if you enable the Barracuda file format, and create a new table that does not use the Dynamic
or Compressed row format, the new tablespace that contains the table is tagged as using the Antelope file format.

It is easy to identify the file format used by a given table. The table uses the Antelope file format if the row format reported by `SHOW TABLE STATUS` is either Compact or Redundant. The table uses the Barracuda file format if the row format reported by `SHOW TABLE STATUS` is either Compressed or Dynamic.

```
mysql> SHOW TABLE STATUS;
*************************** 1. row ***************************
 Name: t1
 Engine: InnoDB
 Version: 10
 Row_format: Compact
 Rows: 0
 Avg_row_length: 0
 Data_length: 16384
 Max_data_length: 0
 Index_length: 16384
 Data_free: 0
 Auto_increment: 1
 Create_time: 2014-11-03 13:32:10
 Update_time: NULL
 Check_time: NULL
 Collation: latin1_swedish_ci
 Checksum: NULL
 Create_options: 
 Comment: 
```

### 14.13.4 Downgrading the File Format

Each InnoDB tablespace file (with a name matching `*.ibd`) is tagged with the file format used to create its table and indexes. The way to downgrade the tablespace is to re-create the table and its indexes. The easiest way to recreate a table and its indexes is to use the command:

```
ALTER TABLE t ROW_FORMAT=COMPACT;
```

on each table that you want to downgrade. The COMPACT row format uses the file format Antelope. It was introduced in MySQL 5.0.3.

### 14.14 InnoDB Row Formats

The row format of a table determines how its rows are physically stored, which in turn can affect the performance of queries and DML operations. As more rows fit into a single disk page, queries and index lookups can work faster, less cache memory is required in the buffer pool, and less I/O is required to write out updated values.

The data in each table is divided into pages. The pages that make up each table are arranged in a tree data structure called a B-tree index. Table data and secondary indexes both use this type of structure. The B-tree index that represents an entire table is known as the clustered index, which is organized according to the primary key columns. The nodes of a clustered index data structure contain the values of all columns in the row. The nodes of a secondary index structure contain the values of index columns and primary key columns.

Variable-length columns are an exception to the rule that column values are stored in B-tree index nodes. Variable-length columns that are too long to fit on a B-tree page are stored on separately allocated disk pages called overflow pages. Such columns are referred to as off-page columns. The values of off-page columns are stored in singly-linked lists of overflow pages, with each such column having its own list of one or more overflow pages. Depending on column length, all or a prefix of variable-length column values are stored in the B-tree to avoid wasting storage and having to read a separate page.
The InnoDB storage engine supports four row formats: REDUNDANT, COMPACT, DYNAMIC, and COMPRESSED.

### Table 14.6 InnoDB Row Format Overview

<table>
<thead>
<tr>
<th>Row Format</th>
<th>Compact Storage Characteristics</th>
<th>Enhanced Variable-Length Column Storage</th>
<th>Large Index Key Prefix Support</th>
<th>Compression Support</th>
<th>Supported Tablespace Types</th>
<th>Required File Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>REDUNDANT</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>system, file-per-table</td>
<td>Antelope or Barracuda</td>
</tr>
<tr>
<td>COMPACT</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>system, file-per-table</td>
<td>Antelope or Barracuda</td>
</tr>
<tr>
<td>DYNAMIC</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>file-per-table</td>
<td>Barracuda</td>
</tr>
<tr>
<td>COMPRESSED</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>file-per-table</td>
<td>Barracuda</td>
</tr>
</tbody>
</table>

The topics that follow describe row format storage characteristics and how to define and determine the row format of a table.

- REDUNDANT Row Format
- COMPACT Row Format
- DYNAMIC Row Format
- COMPRESSED Row Format
- Defining the Row Format of a Table
- Determining the Row Format of a Table

### REDUNDANT Row Format

The REDUNDANT format provides compatibility with older versions of MySQL.

The REDUNDANT row format is supported by both InnoDB file formats (Antelope and Barracuda). For more information, see Section 14.13, “InnoDB File-Format Management”.

Tables that use the REDUNDANT row format store the first 768 bytes of variable-length column values (VARCHAR, VARBINARY, and BLOB and TEXT types) in the index record within the B-tree node, with the remainder stored on overflow pages. Fixed-length columns greater than or equal to 768 bytes are encoded as variable-length columns, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

If the value of a column is 768 bytes or less, an overflow page is not used, and some savings in I/O may result, since the value is stored entirely in the B-tree node. This works well for relatively short BLOB column values, but may cause B-tree nodes to fill with data rather than key values, reducing their efficiency. Tables with many BLOB columns could cause B-tree nodes to become too full, and contain too few rows, making the entire index less efficient than if rows were shorter or column values were stored off-page.

### REDUNDANT Row Format Storage Characteristics

The REDUNDANT row format has the following storage characteristics:

- Each index record contains a 6-byte header. The header is used to link together consecutive records, and for row-level locking.
Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.

If no primary key is defined for a table, each clustered index record also contains a 6-byte row ID field.

Each secondary index record contains all the primary key columns defined for the clustered index key that are not in the secondary index.

A record contains a pointer to each field of the record. If the total length of the fields in a record is less than 128 bytes, the pointer is one byte; otherwise, two bytes. The array of pointers is called the record directory. The area where the pointers point is the data part of the record.

Internally, fixed-length character columns such as `CHAR(10)` are stored in fixed-length format. Trailing spaces are not truncated from `VARCHAR` columns.

Fixed-length columns greater than or equal to 768 bytes are encoded as variable-length columns, which can be stored off-page. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.

An SQL NULL value reserves one or two bytes in the record directory. An SQL NULL value reserves zero bytes in the data part of the record if stored in a variable-length column. For a fixed-length column, the fixed length of the column is reserved in the data part of the record. Reserving fixed space for NULL values permits columns to be updated in place from NULL to non-NULL values without causing index page fragmentation.

COMPACT Row Format

The COMPACT row format reduces row storage space by about 20% compared to the REDUNDANT row format, at the cost of increasing CPU use for some operations. If your workload is a typical one that is limited by cache hit rates and disk speed, COMPACT format is likely to be faster. If the workload is limited by CPU speed, compact format might be slower.

The COMPACT row format is supported by both InnoDB file formats (Antelope and Barracuda). For more information, see Section 14.13, “InnoDB File-Format Management”.

Tables that use the COMPACT row format store the first 768 bytes of variable-length column values (VARCHAR, VARBINARY, and BLOB and TEXT types) in the index record within the B-tree node, with the remainder stored on overflow pages. Fixed-length columns greater than or equal to 768 bytes are encoded as variable-length columns, which can be stored off-page. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.

If the value of a column is 768 bytes or less, an overflow page is not used, and some savings in I/O may result, since the value is stored entirely in the B-tree node. This works well for relatively short BLOB column values, but may cause B-tree nodes to fill with data rather than key values, reducing their efficiency. Tables with many BLOB columns could cause B-tree nodes to become too full, and contain too few rows, making the entire index less efficient than if rows were shorter or column values were stored off-page.

COMPACT Row Format Storage Characteristics

The COMPACT row format has the following storage characteristics:

- Each index record contains a 5-byte header that may be preceded by a variable-length header. The header is used to link together consecutive records, and for row-level locking.

- The variable-length part of the record header contains a bit vector for indicating NULL columns. If the number of columns in the index that can be NULL is N, the bit vector occupies CEILING(N/8) bytes. (For example, if there are anywhere from 9 to 16 columns that can be NULL, the bit vector uses two
DYNAMIC Row Format

Columns that are **NULL** do not occupy space other than the bit in this vector. The variable-length part of the header also contains the lengths of variable-length columns. Each length takes one or two bytes, depending on the maximum length of the column. If all columns in the index are **NOT NULL** and have a fixed length, the record header has no variable-length part.

- For each non-**NULL** variable-length field, the record header contains the length of the column in one or two bytes. Two bytes are only needed if part of the column is stored externally in overflow pages or the maximum length exceeds 255 bytes and the actual length exceeds 127 bytes. For an externally stored column, the 2-byte length indicates the length of the internally stored part plus the 20-byte pointer to the externally stored part. The internal part is 768 bytes, so the length is 768+20. The 20-byte pointer stores the true length of the column.
- The record header is followed by the data contents of non-**NULL** columns.
- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.
- If no primary key is defined for a table, each clustered index record also contains a 6-byte row ID field.
- Each secondary index record contains all the primary key columns defined for the clustered index key that are not in the secondary index. If any of the primary key columns are variable length, the record header for each secondary index has a variable-length part to record their lengths, even if the secondary index is defined on fixed-length columns.
- Internally, for nonvariable-length character sets, fixed-length character columns such as **CHAR(10)** are stored in a fixed-length format.

Trailing spaces are not truncated from **VARCHAR** columns.

- Internally, for variable-length character sets such as **utf8mb3** and **utf8mb4**, InnoDB attempts to store **CHAR(N)** in \( N \) bytes by trimming trailing spaces. If the byte length of a **CHAR(N)** column value exceeds \( N \) bytes, trailing spaces are trimmed to a minimum of the column value byte length. The maximum length of a **CHAR(N)** column is the maximum character byte length \( \times N \).

A minimum of \( N \) bytes is reserved for **CHAR(N)**. Reserving the minimum space \( N \) in many cases enables column updates to be done in place without causing index page fragmentation. By comparison, **CHAR(N)** columns occupy the maximum character byte length \( \times N \) when using the **REDUNDANT** row format.

Fixed-length columns greater than or equal to 768 bytes are encoded as variable-length fields, which can be stored off-page. For example, a **CHAR(255)** column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with **utf8mb4**.

**DYNAMIC Row Format**

The **DYNAMIC** row format offers the same storage characteristics as the **COMPACT** row format but adds enhanced storage capabilities for long variable-length columns and supports large index key prefixes.

The **DYNAMIC** row format is supported by the **Barracuda** file format. For more information, see Section 14.13, “InnoDB File-Format Management”. To create tables that use the **DYNAMIC** row format, the **innodb_file_format** variable must be set to **Barracuda**, and the **innodb_file_per_table** variable must be enabled.

When a table is created with **ROW_FORMAT=DYNAMIC**, InnoDB can store long variable-length column values (for **VARCHAR**, **VARBINARY**, and **BLOB** and **TEXT** types) fully off-page, with the clustered index record containing only a 20-byte pointer to the overflow page. Fixed-length fields greater than or equal to
768 bytes are encoded as variable-length fields. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.

Whether columns are stored off-page depends on the page size and the total size of the row. When a row is too long, the longest columns are chosen for off-page storage until the clustered index record fits on the B-tree page. `TEXT` and `BLOB` columns that are less than or equal to 40 bytes are stored in line.

The `DYNAMIC` row format maintains the efficiency of storing the entire row in the index node if it fits (as do the `COMPACT` and `REDUNDANT` formats), but the `DYNAMIC` row format avoids the problem of filling B-tree nodes with a large number of data bytes of long columns. The `DYNAMIC` row format is based on the idea that if a portion of a long data value is stored off-page, it is usually most efficient to store the entire value off-page. With `DYNAMIC` format, shorter columns are likely to remain in the B-tree node, minimizing the number of overflow pages required for a given row.

The `DYNAMIC` row format supports index key prefixes up to 3072 bytes. This feature is controlled by the `innodb_large_prefix` variable, which is disabled by default. See the `innodb_large_prefix` variable description for more information.

**DYNAMIC Row Format Storage Characteristics**

The `DYNAMIC` row format is a variation of the `COMPACT` row format. For storage characteristics, see `COMPACT Row Format Storage Characteristics`.

**COMPRESSED Row Format**

The `COMPRESSED` row format offers the same the storage characteristics and capabilities as the `DYNAMIC` row format but adds support for table and index data compression.

The `COMPRESSED` row format is supported by the Barracuda file format. For more information, see Section 14.13, “InnoDB File-Format Management”. To create tables that use the `COMPRESSED` row format, the `innodb_file_format` variable must be set to `Barracuda`, and the `innodb_file_per_table` variable must be enabled.

The `COMPRESSED` row format uses similar internal details for off-page storage as the `DYNAMIC` row format, with additional storage and performance considerations from the table and index data being compressed and using smaller page sizes. With the `COMPRESSED` row format, the `KEY_BLOCK_SIZE` option controls how much column data is stored in the clustered index, and how much is placed on overflow pages. For more information about the `COMPRESSED` row format, see InnoDB Table Compression.

The `COMPRESSED` row format supports index key prefixes up to 3072 bytes. This feature is controlled by the `innodb_large_prefix` variable, which is disabled by default. See the `innodb_large_prefix` variable description for more information.

**Compressed Row Format Storage Characteristics**

The `COMPRESSED` row format is a variation of the `COMPACT` row format. For storage characteristics, see `COMPACT Row Format Storage Characteristics`.

**Defining the Row Format of a Table**

The default row format for InnoDB tables is `COMPACT`.

The row format of a table can be defined explicitly using the `ROW_FORMAT` table option in a `CREATE TABLE` or `ALTER TABLE` statement. For example:

```sql
CREATE TABLE t1 (c1 INT) ROW_FORMAT=COMPACT;
```
ROW_FORMAT options include REDUNDANT, COMPACT, DYNAMIC, and COMPRESSED.

To create tables that use the DYNAMIC or COMPRESSED row format, the innodb_file_format variable must be set to Barracuda, and the innodb_file_per_table variable must be enabled. Otherwise, if innodb_strict_mode is not enabled, InnoDB tables are created with the default COMPACT row format.

Oracle recommends enabling innodb_strict_mode when using the ROW_FORMAT table option in CREATE TABLE and ALTER TABLE statements.

Determining the Row Format of a Table

To determine the row format of a table, use SHOW TABLE STATUS:

mysql> SHOW TABLE STATUS IN test1\G
*************************** 1. row ***************************
Name: t1
Engine: InnoDB
Version: 10
Row_format: Compact
Rows: 0
Avg_row_length: 0
Data_length: 16384
Max_data_length: 0
Index_length: 16384
Data_free: 0
Auto_increment: 1
Create_time: 2014-10-31 16:02:01
Update_time: NULL
Check_time: NULL
Collation: latin1_swedish_ci
Checksum: NULL
Create_options: 
Comment: 

14.15 InnoDB Disk I/O and File Space Management

As a DBA, you must manage disk I/O to keep the I/O subsystem from becoming saturated, and manage disk space to avoid filling up storage devices. The ACID design model requires a certain amount of I/O that might seem redundant, but helps to ensure data reliability. Within these constraints, InnoDB tries to optimize the database work and the organization of disk files to minimize the amount of disk I/O. Sometimes, I/O is postponed until the database is not busy, or until everything needs to be brought to a consistent state, such as during a database restart after a fast shutdown.

This section discusses the main considerations for I/O and disk space with the default kind of MySQL tables (also known as InnoDB tables):

- Controlling the amount of background I/O used to improve query performance.
- Enabling or disabling features that provide extra durability at the expense of additional I/O.
- Organizing tables into many small files, a few larger files, or a combination of both.
- Balancing the size of redo log files against the I/O activity that occurs when the log files become full.
- How to reorganize a table for optimal query performance.

14.15.1 InnoDB Disk I/O

InnoDB uses asynchronous disk I/O where possible, by creating a number of threads to handle I/O operations, while permitting other database operations to proceed while the I/O is still in progress. On
File Space Management

Linux and Windows platforms, InnoDB uses the available OS and library functions to perform “native” asynchronous I/O. On other platforms, InnoDB still uses I/O threads, but the threads may actually wait for I/O requests to complete; this technique is known as “simulated” asynchronous I/O.

Read-Ahead

If InnoDB can determine there is a high probability that data might be needed soon, it performs read-ahead operations to bring that data into the buffer pool so that it is available in memory. Making a few large read requests for contiguous data can be more efficient than making several small, spread-out requests. There are two read-ahead heuristics in InnoDB:

- In sequential read-ahead, if InnoDB notices that the access pattern to a segment in the tablespace is sequential, it posts in advance a batch of reads of database pages to the I/O system.
- In random read-ahead, if InnoDB notices that some area in a tablespace seems to be in the process of being fully read into the buffer pool, it posts the remaining reads to the I/O system.

For information about configuring read-ahead heuristics, see Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)“.

Doublewrite Buffer

InnoDB uses a novel file flush technique involving a structure called the doublewrite buffer, which is enabled by default (innodb_doublewrite=ON). It adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for fsync() operations.

Before writing pages to a data file, InnoDB first writes them to a contiguous tablespace area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer has completed does InnoDB write the pages to their proper positions in the data file. If there is an operating system, storage subsystem, or mysqld process crash in the middle of a page write (causing a torn page condition), InnoDB can later find a good copy of the page from the doublewrite buffer during recovery.

14.15.2 File Space Management

The data files that you define in the configuration file using the innodb_data_file_path configuration option form the InnoDB system tablespace. The files are logically concatenated to form the system tablespace. There is no striping in use. You cannot define where within the system tablespace your tables are allocated. In a newly created system tablespace, InnoDB allocates space starting from the first data file.

To avoid the issues that come with storing all tables and indexes inside the system tablespace, you can enable the innodb_file_per_table configuration option, which stores each newly created table in a separate tablespace file (with extension .ibd). For tables stored this way, there is less fragmentation within the disk file, and when the table is truncated, the space is returned to the operating system rather than still being reserved by InnoDB within the system tablespace.

Pages, Extents, Segments, and Tablespaces

Each tablespace consists of database pages with a default size of 16KB. The pages are grouped into extents of size 1MB (64 consecutive pages). The “files” inside a tablespace are called segments in InnoDB. (These segments are different from the rollback segment, which actually contains many tablespace segments.)

When a segment grows inside the tablespace, InnoDB allocates the first 32 pages to it one at a time. After that, InnoDB starts to allocate whole extents to the segment. InnoDB can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.
Two segments are allocated for each index in InnoDB. One is for nonleaf nodes of the B-tree, the other is for the leaf nodes. Keeping the leaf nodes contiguous on disk enables better sequential I/O operations, because these leaf nodes contain the actual table data.

Some pages in the tablespace contain bitmaps of other pages, and therefore a few extents in an InnoDB tablespace cannot be allocated to segments as a whole, but only as individual pages.

When you ask for available free space in the tablespace by issuing a `SHOW TABLE STATUS` statement, InnoDB reports the extents that are definitely free in the tablespace. InnoDB always reserves some extents for cleanup and other internal purposes; these reserved extents are not included in the free space.

When you delete data from a table, InnoDB contracts the corresponding B-tree indexes. Whether the freed space becomes available for other users depends on whether the pattern of deletes frees individual pages or extents to the tablespace. Dropping a table or deleting all rows from it is guaranteed to release the space to other users, but remember that deleted rows are physically removed only by the `purge` operation, which happens automatically some time after they are no longer needed for transaction rollbacks or consistent reads. (See Section 14.6, “InnoDB Multi-Versioning”.)

To see information about the tablespace, use the Tablespace Monitor. See Section 14.20, “InnoDB Monitors”.

**How Pages Relate to Table Rows**

The maximum row length is slightly less than half a database page. For example, the maximum row length is slightly less than 8KB for the 16KB InnoDB page size.

If a row does not exceed the half page limit, all of it is stored locally within the page. If a row exceeds the half page limit, variable-length columns are chosen for external off-page storage until the row fits within half a page. External off-page storage for variable-length columns differs by row format:

- **COMPACT and REDUNDANT Row Formats**

  When a variable-length column is chosen for external off-page storage, InnoDB stores the first 768 bytes locally in the row, and the rest externally into overflow pages. Each such column has its own list of overflow pages. The 768-byte prefix is accompanied by a 20-byte value that stores the true length of the column and points into the overflow list where the rest of the value is stored. See Section 14.14, “InnoDB Row Formats”.

- **DYNAMIC and COMPRESSED Row Formats**

  When a variable-length column is chosen for external off-page storage, InnoDB stores a 20-byte pointer locally in the row, and the rest externally into overflow pages. See Section 14.14, “InnoDB Row Formats”.

**LONGBLOB** and **LONGTEXT** columns must be less than 4GB, and the total row length, including **BLOB** and **TEXT** columns, must be less than 4GB.

**14.15.3 InnoDB Checkpoints**

Making your log files very large may reduce disk I/O during checkpointing. It often makes sense to set the total size of the log files as large as the buffer pool or even larger. Although in the past large log files could make crash recovery take excessive time, starting with MySQL 5.5, performance enhancements to crash recovery make it possible to use large log files with fast startup after a crash. (Strictly speaking, this performance improvement is available for MySQL 5.1 with the InnoDB Plugin 1.0.7 and higher. It is with MySQL 5.5 that this improvement is available in the default InnoDB storage engine.)
How Checkpoint Processing Works

_InnoDB_ implements a checkpoint mechanism known as fuzzy checkpointing. _InnoDB_ flushes modified database pages from the buffer pool in small batches. There is no need to flush the buffer pool in one single batch, which would disrupt processing of user SQL statements during the checkpointing process.

During crash recovery, _InnoDB_ looks for a checkpoint label written to the log files. It knows that all modifications to the database before the label are present in the disk image of the database. Then _InnoDB_ scans the log files forward from the checkpoint, applying the logged modifications to the database.

_InnoDB_ writes to its log files on a rotating basis. It also writes checkpoint information to the first log file at each checkpoint. All committed modifications that make the database pages in the buffer pool different from the images on disk must be available in the log files in case _InnoDB_ has to do a recovery. This means that when _InnoDB_ starts to reuse a log file, it has to make sure that the database page images on disk contain the modifications logged in the log file that _InnoDB_ is going to reuse. In other words, _InnoDB_ must create a checkpoint and this often involves flushing of modified database pages to disk.

### 14.15.4 Defragmenting a Table

Random insertions into or deletions from a secondary index can cause the index to become fragmented. Fragmentation means that the physical ordering of the index pages on the disk is not close to the index ordering of the records on the pages, or that there are many unused pages in the 64-page blocks that were allocated to the index.

One symptom of fragmentation is that a table takes more space than it “should” take. How much that is exactly, is difficult to determine. All _InnoDB_ data and indexes are stored in B-trees, and their fill factor may vary from 50% to 100%. Another symptom of fragmentation is that a table scan such as this takes more time than it “should” take:

```sql
SELECT COUNT(*) FROM t WHERE non_indexed_column <> 12345;
```

The preceding query requires MySQL to perform a full table scan, the slowest type of query for a large table.

To speed up index scans, you can periodically perform a “null” ALTER TABLE operation, which causes MySQL to rebuild the table:

```sql
ALTER TABLE tbl_name ENGINE=INNODB
```

Another way to perform a defragmentation operation is to use `mysqldump` to dump the table to a text file, drop the table, and reload it from the dump file.

If the insertions into an index are always ascending and records are deleted only from the end, the _InnoDB_ filespace management algorithm guarantees that fragmentation in the index does not occur.

### 14.15.5 Reclaiming Disk Space with TRUNCATE TABLE

To reclaim operating system disk space when truncating an _InnoDB_ table, the table must be stored in its own .ibd file. For a table to be stored in its own .ibd file, _innodb_file_per_table_ must enabled when the table is created. Additionally, there cannot be a foreign key constraint between the table being truncated and other tables, otherwise the TRUNCATE TABLE operation fails. This is a change from previous behavior, which would transform the TRUNCATE operation to a DELETE operation that removes all rows and triggers ON DELETE operations on child tables. A foreign key constraint between two columns in the same table, however, is permitted.

When a table is truncated, it is dropped and re-created in a new .ibd file (previous versions of _InnoDB_ would keep the existing .ibd file), and the freed space is returned to the operating system. This is in
InnoDB Fast Index Creation

InnoDB tables that are stored within the InnoDB system tablespace (tables created when `innodb_file_per_table=OFF`), where only InnoDB can use the freed space after the table is truncated.

The ability to truncate tables and return disk space to the operating system also means that physical backups can be smaller. Truncating tables that are stored in the system tablespace (tables created when `innodb_file_per_table=OFF`) leaves blocks of unused space in the system tablespace.

14.16 InnoDB Fast Index Creation

In MySQL 5.5 and higher, or in MySQL 5.1 with the InnoDB Plugin, creating and dropping secondary indexes does not copy the contents of the entire table, making this operation much more efficient than with prior releases.

14.16.1 Overview of Fast Index Creation

With MySQL 5.5 and higher, creating and dropping secondary indexes for InnoDB tables is much faster than before. Historically, adding or dropping an index on a table with existing data could be very slow. The `CREATE INDEX` and `DROP INDEX` statements worked by creating a new, empty table defined with the requested set of indexes, then copying the existing rows to the new table one-by-one, updating the indexes as the rows are inserted. After all rows from the original table were copied, the old table was dropped and the copy was renamed with the name of the original table.

The performance speedup for fast index creation applies to secondary indexes, not to the primary key index. The rows of an InnoDB table are stored in a clustered index organized based on the primary key, forming what some database systems call an ‘index-organized table’. Because the table structure is so closely tied to the primary key, redefining the primary key still requires copying the data.

This new mechanism also means that you can generally speed the overall process of creating and loading an indexed table by creating the table with only the clustered index, and adding the secondary indexes after the data is loaded.

Although no syntax changes are required in the `CREATE INDEX` or `DROP INDEX` commands, some factors affect the performance, space usage, and semantics of this operation (see Section 14.16.6, “Limitations of Fast Index Creation”).

14.16.2 Examples of Fast Index Creation

It is possible to create multiple indexes on a table with one `ALTER TABLE` statement. This is relatively efficient, because the clustered index of the table needs to be scanned only once (although the data is sorted separately for each new index). For example:

```sql
CREATE TABLE T1(A INT PRIMARY KEY, B INT, C CHAR(1)) ENGINE=InnoDB;
INSERT INTO T1 VALUES (1,2,'a'), (2,3,'b'), (3,2,'c'), (4,3,'d'), (5,2,'e');
COMMIT;
ALTER TABLE T1 ADD INDEX (B), ADD UNIQUE INDEX (C);
```

The above statements create table `T1` with the clustered index (primary key) on column `A`, insert several rows, and then build two new indexes on columns `B` and `C`. If there were many rows inserted into `T1` before the `ALTER TABLE` statement, this approach is much more efficient than creating all the secondary indexes before loading the data.

You can also create the indexes one at a time, but then the clustered index of the table is scanned (as well as sorted) once for each `CREATE INDEX` statement. Thus, the following statements are not as efficient as the `ALTER TABLE` statement above, even though neither requires recreating the clustered index for table `T1`. 

1801
CREATE INDEX B ON T1 (B);
CREATE UNIQUE INDEX C ON T1 (C);

Dropping InnoDB secondary indexes also does not require any copying of table data. You can equally quickly drop multiple indexes with a single `ALTER TABLE` statement or multiple `DROP INDEX` statements:

```
ALTER TABLE T1 DROP INDEX B, DROP INDEX C;
```

or:

```
DROP INDEX B ON T1;
DROP INDEX C ON T1;
```

Restructuring the clustered index in InnoDB always requires copying the data in the table. For example, if you create a table without a primary key, InnoDB chooses one for you, which may be the first `UNIQUE` key defined on `NOT NULL` columns, or a system-generated key. Defining a `PRIMARY KEY` later causes the data to be copied, as in the following example:

```
CREATE TABLE T2 (A INT, B INT) ENGINE=InnoDB;
INSERT INTO T2 VALUES (NULL, 1);
ALTER TABLE T2 ADD PRIMARY KEY (B);
```

When you create a `UNIQUE` or `PRIMARY KEY` index, InnoDB must do some extra work. For `UNIQUE` indexes, InnoDB checks that the table contains no duplicate values for the key. For a `PRIMARY KEY` index, InnoDB also checks that none of the `PRIMARY KEY` columns contains a `NULL`. It is best to define the primary key when you create a table, so you need not rebuild the table later.

### 14.16.3 Implementation Details of Fast Index Creation

InnoDB has two types of indexes: the clustered index and secondary indexes. Since the clustered index contains the data values in its B-tree nodes, adding or dropping a clustered index does involve copying the data, and creating a new copy of the table. A secondary index, however, contains only the index key and the value of the primary key. This type of index can be created or dropped without copying the data in the clustered index. Because each secondary index contains copies of the primary key values (used to access the clustered index when needed), when you change the definition of the primary key, all secondary indexes are recreated as well.

Dropping a secondary index is simple. Only the internal InnoDB system tables and the MySQL data dictionary tables are updated to reflect the fact that the index no longer exists. InnoDB returns the storage used for the index to the tablespace that contained it, so that new indexes or additional table rows can use the space.

To add a secondary index to an existing table, InnoDB scans the table, and sorts the rows using memory buffers and temporary files in order by the values of the secondary index key columns. The B-tree is then built in key-value order, which is more efficient than inserting rows into an index in random order. Because the B-tree nodes are split when they fill, building the index in this way results in a higher fill-factor for the index, making it more efficient for subsequent access.

### 14.16.4 Concurrency Considerations for Fast Index Creation

While an InnoDB secondary index is being created or dropped, the table is locked in shared mode. Any writes to the table are blocked, but the data in the table can be read. When you alter the clustered index of a table, the table is locked in exclusive mode, because the data must be copied. Thus, during the creation of a new clustered index, all operations on the table are blocked.

A `CREATE INDEX` or `ALTER TABLE` statement for an InnoDB table always waits for currently executing transactions that are accessing the table to commit or roll back. `ALTER TABLE` statements that redefine an InnoDB primary key wait for all `SELECT` statements that access the table to complete, or their containing
transactions to commit. No transactions whose execution spans the creation of the index can be accessing the table, because the original table is dropped when the clustered index is restructured.

Once a `CREATE INDEX` or `ALTER TABLE` statement that creates an InnoDB secondary index begins executing, queries can access the table for read access, but cannot update the table. If an `ALTER TABLE` statement is changing the clustered index for an InnoDB table, all queries wait until the operation completes.

A newly-created InnoDB secondary index contains only the committed data in the table at the time the `CREATE INDEX` or `ALTER TABLE` statement begins to execute. It does not contain any uncommitted values, old versions of values, or values marked for deletion but not yet removed from the old index.

Because a newly-created index contains only information about data current at the time the index was created, queries that need to see data that was deleted or changed before the index was created cannot use the index. The only queries that could be affected by this limitation are those executing in transactions that began before the creation of the index was begun. For such queries, unpredictable results could occur. Newer queries can use the index.

### 14.16.5 How Crash Recovery Works with Fast Index Creation

Although no data is lost if the server crashes while an `ALTER TABLE` statement is executing, the crash recovery process is different for clustered indexes and secondary indexes.

If the server crashes while creating an InnoDB secondary index, upon recovery, MySQL drops any partially created indexes. You must re-run the `ALTER TABLE` or `CREATE INDEX` statement.

When a crash occurs during the creation of an InnoDB clustered index, recovery is more complicated, because the data in the table must be copied to an entirely new clustered index. Remember that all InnoDB tables are stored as clustered indexes. In the following discussion, we use the word table and clustered index interchangeably.

MySQL creates the new clustered index by copying the existing data from the original InnoDB table to a temporary table that has the desired index structure. Once the data is completely copied to this temporary table, the original table is renamed with a different temporary table name. The temporary table comprising the new clustered index is renamed with the name of the original table, and the original table is dropped from the database.

If a system crash occurs while creating a new clustered index, no data is lost, but you must complete the recovery process using the temporary tables that exist during the process. Since it is rare to re-create a clustered index or re-define primary keys on large tables, or to encounter a system crash during this operation, this manual does not provide information on recovering from this scenario. Contact MySQL support.

### 14.16.6 Limitations of Fast Index Creation

Take the following considerations into account when creating or dropping InnoDB indexes:

- During index creation, files are written to the temporary directory (`$TMPDIR` on Unix, `%TEMP%` on Windows, or the value of the `--tmpdir` configuration variable). Each temporary file is large enough to hold one column that makes up the new index, and each one is removed as soon as it is merged into the final index.

- An `ALTER TABLE` statement that contains `DROP INDEX` and `ADD INDEX` clauses that both name the same index uses a table copy, not Fast Index Creation.

- The table is copied, rather than using Fast Index Creation when you create an index on a `TEMPORARY TABLE`. This has been reported as MySQL Bug #39833.
• To avoid consistency issues between the InnoDB data dictionary and the MySQL data dictionary, the table is copied rather than using Fast Index Creation when renaming a column using `ALTER TABLE ... CHANGE` syntax.

• The statement `ALTER IGNORE TABLE t ADD UNIQUE INDEX` does not delete duplicate rows. This has been reported as MySQL Bug #40344. The `IGNORE` keyword is ignored. If any duplicate rows exist, the operation fails with the following error message:

```
ERROR 23000: Duplicate entry '347' for key 'pl'
```

• As noted above, a newly-created index contains only information about data current at the time the index was created. Therefore, you should not run queries in a transaction that might use a secondary index that did not exist at the beginning of the transaction. There is no way for InnoDB to access “old” data that is consistent with the rest of the data read by the transaction. See the discussion of locking in Section 14.16.4, “Concurrency Considerations for Fast Index Creation”.

Prior to InnoDB storage engine 1.0.4, unexpected results could occur if a query attempts to use an index created after the start of the transaction containing the query. If an old transaction attempts to access a “too new” index, InnoDB storage engine 1.0.4 and later reports an error:

```
ERROR HY000: Table definition has changed, please retry transaction
```

As the error message suggests, committing (or rolling back) the transaction, and restarting it, cures the problem.

• InnoDB storage engine 1.0.2 introduces some improvements in error handling when users attempt to drop indexes. See Section B.3.1, “Server Error Message Reference” for information related to errors 1025, 1553, and 1173.

• MySQL 5.5 does not support efficient creation or dropping of `FOREIGN KEY` constraints. Therefore, if you use `ALTER TABLE` to add or remove a `REFERENCES` constraint, the child table is copied, rather than using Fast Index Creation.

• `OPTIMIZE TABLE` for an InnoDB table is mapped to an `ALTER TABLE` operation to rebuild the table and update index statistics and free unused space in the clustered index. This operation does not use fast index creation. Secondary indexes are not created as efficiently because keys are inserted in the order they appeared in the primary key.

### 14.17 InnoDB Startup Options and System Variables

This section describes the InnoDB-related command options and system variables.

• System variables that are true or false can be enabled at server startup by naming them, or disabled by using a `--skip-` prefix. For example, to enable or disable InnoDB checksums, you can use `--innodb-checksums` or `--skip-innodb-checksums` on the command line, or `innodb_checksums` or `skip_innodb_checksums` in an option file.

• System variables that take a numeric value can be specified as `--var_name=value` on the command line or as `var_name=value` in option files.

• Many system variables can be changed at runtime (see Section 5.1.8.2, “Dynamic System Variables”).

• For information about `GLOBAL` and `SESSION` variable scope modifiers, refer to the `SET` statement documentation.

• Certain options control the locations and layout of the InnoDB data files. Section 14.11.1, “InnoDB Startup Configuration” explains how to use these options.
InnoDB Startup Options and System Variables

- Some options, which you might not use initially, help tune InnoDB performance characteristics based on machine capacity and your database workload.

- For more information on specifying options and system variables, see Section 4.2.2, “Specifying Program Options”.

Table 14.7 InnoDB Option and Variable Reference

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<th>Option File</th>
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## InnoDB Startup Options and System Variables

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</tr>
<tr>
<td>innodb_purge_batch_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_purge_threads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_random_read_ahead</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_read_ahead_threads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_read_io_threads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_replication_delay</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_rollback_on_timeout</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_rollback_segments</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>Innodb_row_lock_current_waits</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_row_lock_time</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_row_lock_time_avg</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_row_lock_time_max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_row_lock_waits</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_rows_deleted</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_rows_inserted</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_rows_read</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Innodb_rows_updated</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_spin_wait_delay</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_stats_method</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_stats_on_metadata</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_stats_sample_pages</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb-status-file</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Both</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_strict_mode</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Both</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_support_xa</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Both</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_sync_spin_loop</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_table_locks</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Both</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_thread_concurrency</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>Yes</td>
</tr>
</tbody>
</table>
InnoDB Command Options

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>innodb_thread_sleep_delay</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>InnoDB_truncated_status_writes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_truncated_status_writes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_trx_rseg_n_slots_debug</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>innodb_use_native_aio</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_use_sys_malloc</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_version</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>innodb_writer_io_threads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>timed_mutexes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>unique_checks</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
</tr>
</tbody>
</table>

InnoDB Command Options

- **--innodb=value**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb=value</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
<tr>
<td>Valid Values</td>
<td>OFF, ON, FORCE</td>
</tr>
</tbody>
</table>

Controls loading of the InnoDB storage engine, if the server was compiled with InnoDB support. This option has a tristate format, with possible values of OFF, ON, or FORCE. See Section 5.5.1, “Installing and Uninstalling Plugins”.

To disable InnoDB, use --innodb=OFF or --skip-innodb. In this case, because the default storage engine is InnoDB, the server will not start unless you also change the default_storage_engine system variable to set the default to some other available engine.

- **--innodb-status-file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-status-file=[OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

The --innodb-status-file startup option controls whether InnoDB creates a file named innodb_status.pid in the data directory and writes SHOW ENGINE INNODB STATUS output to it every 15 seconds, approximately.

The innodb_status.pid file is not created by default. To create it, start mysqld with the --innodb-status-file option. InnoDB removes the file when the server is shut down normally. If an abnormal shutdown occurs, the status file may have to be removed manually.
The `--innodb-status-file` option is intended for temporary use, as `SHOW ENGINE INNODB STATUS` output generation can affect performance, and the `innodb_status.pid` file can become quite large over time.

For related information, see Section 14.20.2, “Enabling InnoDB Monitors”.

- `--skip-innodb`
  Disable the InnoDB storage engine. See the description of `--innodb`.

### InnoDB System Variables

- **ignore_builtin_innodb**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ignore-built-in-innodb=[{OFF</td>
</tr>
<tr>
<td>Deprecated</td>
<td>5.5.22</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ignore_builtin_innodb</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

In MySQL 5.1, enabling this variable caused the server to behave as if the built-in InnoDB were not present, which enabled the InnoDB Plugin to be used instead. In MySQL 5.5, InnoDB is the default storage engine and InnoDB Plugin is not used, so this variable has no effect. As of MySQL 5.5.22, it is deprecated and its use results in a warning.

- **innodb_adaptive_flushing**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-adaptive-flushing=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_adaptive_flushing</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Specifies whether to dynamically adjust the rate of flushing dirty pages in the InnoDB buffer pool based on the workload. Adjusting the flush rate dynamically is intended to avoid bursts of I/O activity. This setting is enabled by default. See Section 14.11.2.4, “Configuring Buffer Pool Flushing” for more information. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- **innodb_adaptive_hash_index**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-adaptive-hash-index=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_adaptive_hash_index</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
Whether the InnoDB adaptive hash index is enabled or disabled. It may be desirable, depending on your workload, to dynamically enable or disable adaptive hash indexing to improve query performance. Because the adaptive hash index may not be useful for all workloads, conduct benchmarks with it both enabled and disabled, using realistic workloads. See Section 14.8.3, “Adaptive Hash Index” for details.

This variable is enabled by default. You can modify this parameter using the `SET GLOBAL` statement, without restarting the server. Changing the setting at runtime requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”. You can also use `--skip-innodb-adaptive-hash-index` at server startup to disable it.

Disabling the adaptive hash index empties the hash table immediately. Normal operations can continue while the hash table is emptied, and executing queries that were using the hash table access the index B-trees directly instead. When the adaptive hash index is re-enabled, the hash table is populated again during normal operation.

- `innodb_additional_mem_pool_size`

The size in bytes of a memory pool InnoDB uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you need to allocate here. If InnoDB runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 8MB.

This variable relates to the InnoDB internal memory allocator, which is unused if `innodb_use_sys_malloc` is enabled. For more information, see Section 14.11.3, “Configuring the Memory Allocator for InnoDB”.

- `innodb_autoextend_increment`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-autoextend-increment=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_autoextend_increment</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The size in bytes of a memory pool InnoDB uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you need to allocate here. If InnoDB runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 8MB.

This variable relates to the InnoDB internal memory allocator, which is unused if `innodb_use_sys_malloc` is enabled. For more information, see Section 14.11.3, “Configuring the Memory Allocator for InnoDB”.

- `innodb_autoextend_increment`
### InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The increment size (in megabytes) for extending the size of an auto-extending system tablespace file when it becomes full. The default value is 8. For related information, see System Tablespace Data File Configuration, and Resizing the System Tablespace.

The `innodb_autoextend_increment` setting does not affect file-per-table tablespace files. These files are auto-extending regardless of the `innodb_autoextend_increment` setting. The initial extensions are by small amounts, after which extensions occur in increments of 4MB.

- `innodb_autoinc_lock_mode`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-autoinc-lock-mode=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_autoinc_lock_mode</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Valid Values</td>
<td>0, 1, 2</td>
</tr>
</tbody>
</table>

The lock mode to use for generating auto-increment values. Permissible values are 0, 1, or 2, for traditional, consecutive, or interleaved, respectively. The default setting is 1 (consecutive). For the characteristics of each lock mode, see InnoDB AUTO_INCREMENT Lock Modes.

- `innodb_buffer_pool_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-buffer-pool-instances=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_buffer_pool_instances</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>64</td>
</tr>
</tbody>
</table>

The number of regions that the InnoDB buffer pool is divided into. For systems with buffer pools in the multi-gigabyte range, dividing the buffer pool into separate instances can improve concurrency.
InnoDB System Variables

reducing contention as different threads read and write to cached pages. Each page that is stored in or read from the buffer pool is assigned to one of the buffer pool instances randomly, using a hashing function. Each buffer pool manages its own free lists, flush lists, LRUs, and all other data structures connected to a buffer pool, and is protected by its own buffer pool mutex.

This option only takes effect when setting `innodb_buffer_pool_size` to a size of 1GB or more. The total size you specify is divided among all the buffer pools. For best efficiency, specify a combination of `innodb_buffer_pool_instances` and `innodb_buffer_pool_size` so that each buffer pool instance is at least 1GB.

- `innodb_buffer_pool_size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-buffer-pool-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_buffer_pool_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>134217728</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>5242880</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>$2^{64}-1$</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>$2^{32}-1$</td>
</tr>
</tbody>
</table>

The size in bytes of the buffer pool, the memory area where InnoDB caches table and index data. The default value is 134217728 bytes (128MB). The maximum value depends on the CPU architecture; the maximum is 4294967295 ($2^{32}-1$) on 32-bit systems and 18446744073709551615 ($2^{64}-1$) on 64-bit systems. On 32-bit systems, the CPU architecture and operating system may impose a lower practical maximum size than the stated maximum. When the size of the buffer pool is greater than 1GB, setting `innodb_buffer_pool_instances` to a value greater than 1 can improve the scalability on a busy server.

A larger buffer pool requires less disk I/O to access the same table data more than once. On a dedicated database server, you might set the buffer pool size to 80% of the machine’s physical memory size. Be aware of the following potential issues when configuring buffer pool size, and be prepared to scale back the size of the buffer pool if necessary.

- Competition for physical memory can cause paging in the operating system.
- InnoDB reserves additional memory for buffers and control structures, so that the total allocated space is approximately 10% greater than the specified buffer pool size.
- Address space for the buffer pool must be contiguous, which can be an issue on Windows systems with DLLs that load at specific addresses.
- The time to initialize the buffer pool is roughly proportional to its size. On instances with large buffer pools, initialization time might be significant.
### InnoDB System Variables

- **innodb_change_buffering**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-change-buffering=value</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_change_buffering</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>all</code></td>
</tr>
<tr>
<td>Valid Values</td>
<td><code>none</code> <code>inserts</code> <code>deletes</code> <code>changes</code> <code>purges</code> <code>all</code></td>
</tr>
</tbody>
</table>

Whether **InnoDB** performs **change buffering**, an optimization that delays write operations to secondary indexes so that the I/O operations can be performed sequentially. Permitted values are described in the following table.

**Table 14.8 Permitted Values for innodb_change_buffering**

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>Do not buffer any operations.</td>
</tr>
<tr>
<td>inserts</td>
<td>Buffer insert operations.</td>
</tr>
<tr>
<td>deletes</td>
<td>Buffer delete marking operations; strictly speaking, the writes that mark index records for later deletion during a purge operation.</td>
</tr>
<tr>
<td>changes</td>
<td>Buffer inserts and delete-marking operations.</td>
</tr>
<tr>
<td>purges</td>
<td>Buffer the physical deletion operations that happen in the background.</td>
</tr>
<tr>
<td>all</td>
<td>The default. Buffer inserts, delete-marking operations, and purges.</td>
</tr>
</tbody>
</table>

For more information, see Section 14.8.2, “Change Buffer”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- **innodb_change_buffering_debug**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-change-buffering-debug=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_change_buffering_debug</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>2</td>
</tr>
</tbody>
</table>

Sets a debug flag for InnoDB change buffering. A value of 1 forces all changes to the change buffer. A value of 2 causes a crash at merge. A default value of 0 indicates that the change buffering debug flag is not set. This option is only available when debugging support is compiled in using the `WITH_DEBUG CMake` option.

- **innodb_checkums**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-checkums=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_checkums</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

InnoDB can use checksum validation on all pages read from disk to ensure extra fault tolerance against broken hardware or data files. This validation is enabled by default. Under specialized circumstances (such as when running benchmarks) this safety feature can be disabled with `--skip-innodb-checkums`.

- **innodb_commit_concurrency**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-commit-concurrency=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_commit_concurrency</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The number of threads that can commit at the same time. A value of 0 (the default) permits any number of transactions to commit simultaneously.

The value of `innodb_commit_concurrency` cannot be changed at runtime from zero to nonzero or vice versa. The value can be changed from one nonzero value to another.

- **innodb_concurrency_tickets**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-concurrency-tickets=#</code></td>
</tr>
</tbody>
</table>
InnoDB System Variables

**innodb_concurrency_tickets**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Variable</strong></td>
<td>innodb_concurrency_tickets</td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>500</td>
</tr>
<tr>
<td><strong>Minimum Value</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Determines the number of threads that can enter InnoDB concurrently. A thread is placed in a queue when it tries to enter InnoDB if the number of threads has already reached the concurrency limit. When a thread is permitted to enter InnoDB, it is given a number of “tickets” equal to the value of innodb_concurrency_tickets, and the thread can enter and leave InnoDB freely until it has used up its tickets. After that point, the thread again becomes subject to the concurrency check (and possible queuing) the next time it tries to enter InnoDB. The default value is 500.

With a small innodb_concurrency_tickets value, small transactions that only need to process a few rows compete fairly with larger transactions that process many rows. The disadvantage of a small innodb_concurrency_tickets value is that large transactions must loop through the queue many times before they can complete, which extends the amount of time required to complete their task.

With a large innodb_concurrency_tickets value, large transactions spend less time waiting for a position at the end of the queue (controlled by innodb_thread_concurrency) and more time retrieving rows. Large transactions also require fewer trips through the queue to complete their task. The disadvantage of a large innodb_concurrency_tickets value is that too many large transactions running at the same time can starve smaller transactions by making them wait a longer time before executing.

With a nonzero innodb_thread_concurrency value, you may need to adjust the innodb_concurrency_tickets value up or down to find the optimal balance between larger and smaller transactions. The SHOW ENGINE INNODB STATUS report shows the number of tickets remaining for an executing transaction in its current pass through the queue. This data may also be obtained from the TRX_CONCURRENCY_TICKETS column of the INFORMATION_SCHEMA.INNODB_TRX table.

For more information, see Section 14.11.4, “Configuring Thread Concurrency for InnoDB”.

- innodb_data_file_path

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td>--innodb-data-file-path=file_name</td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td>innodb_data_file_path</td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>String</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>ibdata1:10M:autoextend</td>
</tr>
</tbody>
</table>

Defines the name, size, and attributes of InnoDB system tablespace data files. If you do not specify a value for innodb_data_file_path, the default behavior is to create a single auto-extending data file, slightly larger than 10MB, named ibdata1.

The full syntax for a data file specification includes the file name, file size, autoextend attribute, and max attribute:

```
file_name:file_size[:autoextend[:max:max_file_size]]
```

File sizes are specified in kilobytes, megabytes, or gigabytes by appending K, M or G to the size value. If specifying the data file size in kilobytes, do so in multiples of 1024. Otherwise, KB values are rounded to nearest megabyte (MB) boundary. The sum of file sizes must be, at a minimum, slightly larger than 12MB.

For additional configuration information, see System Tablespace Data File Configuration. For resizing instructions, see Resizing the System Tablespace.

- innodb_data_home_dir

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-data-home-dir=dir_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_data_home_dir</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The common part of the directory path for InnoDB system tablespace data files. This setting does not affect the location of file-per-table tablespaces when innodb_file_per_table is enabled. The default value is the MySQL data directory. If you specify the value as an empty string, you can specify an absolute file paths for innodb_data_file_path.

A trailing slash is required when specifying a value for innodb_data_home_dir. For example:

```
[mysqld]
innodb_data_home_dir = /path/to/myibdata/
```

For related information, see Section 14.11.1, “InnoDB Startup Configuration”.

- innodb_doublewrite

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-doublewrite[=(OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_doublewrite</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
When enabled (the default), InnoDB stores all data twice, first to the doublewrite buffer, and then to the actual data files. This variable can be turned off with --skip-innodb-doublewrite for benchmarks or cases when top performance is needed rather than concern for data integrity or possible failures.

For related information, see Section 14.9.5, “Doublewrite Buffer”.

- innodb_fast_shutdown

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-fast-shutdown=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_fast_shutdown</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Valid Values</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

The InnoDB shutdown mode. If the value is 0, InnoDB does a slow shutdown, a full purge and a change buffer merge before shutting down. If the value is 1 (the default), InnoDB skips these operations at shutdown, a process known as a fast shutdown. If the value is 2, InnoDB flushes its logs and shuts down cold, as if MySQL had crashed; no committed transactions are lost, but the crash recovery operation makes the next startup take longer.

The slow shutdown can take minutes, or even hours in extreme cases where substantial amounts of data are still buffered. Use the slow shutdown technique before upgrading or downgrading between MySQL major releases, so that all data files are fully prepared in case the upgrade process updates the file format.

Use innodb_fast_shutdown=2 in emergency or troubleshooting situations, to get the absolute fastest shutdown if data is at risk of corruption.

- innodb_file_format

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-file-format=value</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_file_format</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>Antelope</td>
</tr>
<tr>
<td>Valid Values</td>
<td>Antelope</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barracuda</td>
<td></td>
</tr>
</tbody>
</table>

Enables an InnoDB file format for file-per-table tablespaces. Supported file formats are Antelope and Barracuda. Antelope is the original InnoDB file format, which supports REDUNDANT and COMPACT row formats for InnoDB tables. Barracuda is the newer file format, which supports COMPRESSED and DYNAMIC row formats.

COMPRESSED and DYNAMIC row formats enable important storage features for InnoDB tables. See Section 14.14, “InnoDB Row Formats”.

To create tables that use COMPRESSED or DYNAMIC row format, the Barracuda file format and innodb_file_per_table must be enabled.

Changing the innodb_file_format setting does not affect the file format of existing InnoDB tablespace files.

For more information, see Section 14.13, “InnoDB File-Format Management”.

- innodb_file_format_check

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-file-format-check={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_file_format_check</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

This variable can be set to 1 or 0 at server startup to enable or disable whether InnoDB checks the file format tag in the system tablespace (for example, Antelope or Barracuda). If the tag is checked and is higher than that supported by the current version of InnoDB, an error occurs and InnoDB does not start. If the tag is not higher, InnoDB sets the value of innodb_file_format_max to the file format tag.

Note

Despite the default value sometimes being displayed as ON or OFF, always use the numeric values 1 or 0 to turn this option on or off in your configuration file or command line string.

For more information, see Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”.

- innodb_file_format_max

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-file-format-max=value</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_file_format_max</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>Antelope</td>
</tr>
<tr>
<td>Valid Values</td>
<td>Antelope</td>
</tr>
<tr>
<td></td>
<td>Barracuda</td>
</tr>
</tbody>
</table>

At server startup, InnoDB sets the value of this variable to the file format tag in the system tablespace (for example, Antelope or Barracuda). If the server creates or opens a table with a “higher” file format, it sets the value of innodb_file_format_max to that format.

For related information, see Section 14.13, “InnoDB File-Format Management”.

• **innodb_file_per_table**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-file-per-table={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_file_per_table</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When innodb_file_per_table is enabled, tables are created in file-per-table tablespaces. When disabled, tables are created in the system tablespace. For information about file-per-table tablespaces, see Section 14.9.3.2, “File-Per-Table Tablespaces”. For information about the InnoDB system tablespace, see Section 14.9.3.1, “The System Tablespace”.

The innodb_file_per_table variable can be configured at runtime using a SET GLOBAL statement, specified on the command line at startup, or specified in an option file. Configuration at runtime requires privileges sufficient to set global system variables (see Section 5.1.8.1, “System Variable Privileges”) and immediately affects the operation of all connections.

When a table that resides in a file-per-table tablespace is truncated or dropped, the freed space is returned to the operating system. Truncating or dropping a table that resides in the system tablespace only frees space in the system tablespace. Freed space in the system tablespace can be used again for InnoDB data but is not returned to the operating system, as system tablespace data files never shrink.

When innodb_file_per_table is enabled, a table-copying ALTER TABLE operation on a table that resides in the system tablespace implicitly re-creates the table in a file-per-table tablespace. To prevent this from occurring, disable innodb_file_per_table before executing table-copying ALTER TABLE operations on tables that reside in the system tablespace.

• **innodb_flush_log_at_trx_commit**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-flush-log-at-trx-commit=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_flush_log_at_trx_commit</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Valid Values</td>
<td>0, 1, 2</td>
</tr>
</tbody>
</table>

Controls the balance between strict ACID compliance for commit operations and higher performance that is possible when commit-related I/O operations are rearranged and done in batches. You can achieve better performance by changing the default value but then you can lose transactions in a crash.

- The default setting of 1 is required for full ACID compliance. Logs are written and flushed to disk at each transaction commit.
- With a setting of 0, logs are written and flushed to disk once per second. Transactions for which logs have not been flushed can be lost in a crash.
- With a setting of 2, logs are written after each transaction commit and flushed to disk once per second. Transactions for which logs have not been flushed can be lost in a crash.
- For settings 0 and 2, once-per-second flushing is not 100% guaranteed. Flushing may occur more frequently due to DDL changes and other internal InnoDB activities that cause logs to be flushed independently of the innodb_flush_log_at_trx_commit setting, and sometimes less frequently due to scheduling issues. If logs are flushed once per second, up to one second of transactions can be lost in a crash. If logs are flushed more or less frequently than once per second, the amount of transactions that can be lost varies accordingly.
- DDL changes and other internal InnoDB activities flush the log independently of the innodb_flush_log_at_trx_commit setting.
- InnoDB crash recovery works regardless of the innodb_flush_log_at_trx_commit setting. Transactions are either applied entirely or erased entirely.

For the greatest possible durability and consistency in a replication setup using InnoDB with transactions, use innodb_flush_log_at_trx_commit=1 and sync_binlog=1 in your master server my.cnf file.

Caution

Many operating systems and some disk hardware fool the flush-to-disk operation. They may tell mysqld that the flush has taken place, even though it has not. In this case, the durability of transactions is not guaranteed even with the recommended settings, and in the worst case, a power outage can corrupt InnoDB data. Using a battery-backed disk cache in the SCSI disk controller or in the disk itself speeds up file flushes, and makes the operation safer. You can also try to disable the caching of disk writes in hardware caches.

- innodb_flush_method

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-flush-method=value</td>
</tr>
</tbody>
</table>
### Innodb Flush Method

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><strong>innodb_flush_method</strong></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><strong>NULL</strong></td>
</tr>
<tr>
<td>Valid Values (Windows)</td>
<td><code>async_unbuffered</code></td>
</tr>
<tr>
<td></td>
<td><code>normal</code></td>
</tr>
<tr>
<td></td>
<td><code>unbuffered</code></td>
</tr>
<tr>
<td>Valid Values (Unix)</td>
<td><code>fsync</code></td>
</tr>
<tr>
<td></td>
<td><code>littlesync</code></td>
</tr>
<tr>
<td></td>
<td><code>nosync</code></td>
</tr>
<tr>
<td></td>
<td><code>O_DSYNC</code></td>
</tr>
<tr>
<td></td>
<td><code>O_DIRECT</code></td>
</tr>
</tbody>
</table>

Defines the method used to flush data to **InnoDB data files** and **log files**, which can affect I/O throughput.

If **innodb_flush_method** is set to **NULL** on a Unix-like system, the **fsync** option is used by default. If **innodb_flush_method** is set to **NULL** on Windows, the **async_unbuffered** option is used by default.

The **innodb_flush_method** options for Unix-like systems include:

- **fsync**: InnoDB uses the **fsync()** system call to flush both the data and log files. **fsync** is the default setting.

- **O_DSYNC**: InnoDB uses **O_SYNC** to open and flush the log files, and **fsync()** to flush the data files. InnoDB does not use **O_DSYNC** directly because there have been problems with it on many varieties of Unix.

- **littlesync**: This option is used for internal performance testing and is currently unsupported. Use at your own risk.

- **nosync**: This option is used for internal performance testing and is currently unsupported. Use at your own risk.
InnoDB System Variables

- **O_DIRECT**: InnoDB uses `O_DIRECT` (or `directio()` on Solaris) to open the data files, and uses `fsync()` to flush both the data and log files. This option is available on some GNU/Linux versions, FreeBSD, and Solaris.

The `innodb_flush_method` options for Windows systems include:

- **async_unbuffered**: InnoDB uses Windows asynchronous I/O and non-buffered I/O. `async_unbuffered` is the default setting on Windows systems.

  Running MySQL server on a 4K sector hard drive on Windows is not supported with `async_unbuffered`. The workaround is to use `innodb_flush_method=normal`.

- **normal**: InnoDB uses simulated asynchronous I/O and buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.

- **unbuffered**: InnoDB uses simulated asynchronous I/O and non-buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.

How each setting affects performance depends on hardware configuration and workload. Benchmark your particular configuration to decide which setting to use, or whether to keep the default setting. Examine the `Innodb_data_fsyncs` status variable to see the overall number of `fsync()` calls for each setting. The mix of read and write operations in your workload can affect how a setting performs. For example, on a system with a hardware RAID controller and battery-backed write cache, `O_DIRECT` can help to avoid double buffering between the InnoDB buffer pool and the operating system file system cache. On some systems where InnoDB data and log files are located on a SAN, the default value or `O_DSYNC` might be faster for a read-heavy workload with mostly `SELECT` statements. Always test this parameter with hardware and workload that reflect your production environment. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

Prior to MySQL 5.1.24, the default `innodb_flush_method` option was named `fdatasync`. When `fdatasync` was specified, InnoDB used the `fsync()` system call to flush both the data and log files. To avoid confusing the `fdatasync` option name with the `fdatasync()` system call, the option name was changed to `fsync` in MySQL 5.1.24.

- **innodb_force_load_corrupted**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-force-load-corrupted=[OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.18</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_force_load_corrupted</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Permits InnoDB to load tables at startup that are marked as corrupted. Use only during troubleshooting, to recover data that is otherwise inaccessible. When troubleshooting is complete, disable this setting and restart the server.
InnoDB System Variables

- **innodb_force_recovery**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-force-recovery=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_force_recovery</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>6</td>
</tr>
</tbody>
</table>

The crash recovery mode, typically only changed in serious troubleshooting situations. Possible values are from 0 to 6. For the meanings of these values and important information about `innodb_force_recovery`, see Section 14.23.2, “Forcing InnoDB Recovery”.

**Warning**

Only set this variable to a value greater than 0 in an emergency situation so that you can start InnoDB and dump your tables. As a safety measure, InnoDB prevents `INSERT`, `UPDATE`, or `DELETE` operations when `innodb_force_recovery` is greater than 0.

- **innodb_io_capacity**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-io-capacity=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_io_capacity</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>200</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>100</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>$2^{64}-1$</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>$2^{32}-1$</td>
</tr>
</tbody>
</table>

The `innodb_io_capacity` variable defines the number of I/O operations per second (IOPS) available to InnoDB background tasks, such as flushing pages from the buffer pool and merging data from the change buffer.

For information about configuring the `innodb_io_capacity` variable, see Section 14.11.7, “Configuring InnoDB I/O Capacity”. 
InnoDB System Variables

- **innodb_large_prefix**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-large-prefix=[{OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.14</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_large_prefix</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Enable this option to allow index key prefixes longer than 767 bytes (up to 3072 bytes), for InnoDB tables that use DYNAMIC or COMPRESSED row format. (Creating such tables also requires the option values `innodb_file_format=barracuda` and `innodb_file_per_table=true`.) See Section 14.24, “InnoDB Limits” for maximums associated with index key prefixes under various settings.

For tables that use REDUNDANT or COMPACT row format, this option does not affect the permitted index key prefix length. When this setting is enabled, attempting to create an index prefix with a key length greater than 3072 for a REDUNDANT or COMPACT table causes an `ER_INDEX_COLUMN_TOO_LONG` error.

- **innodb_limit_optimistic_insert_debug**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-limit-optimistic-insert-debug=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_limit_optimistic_insert_debug</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>$2^{32}-1$</td>
</tr>
</tbody>
</table>

Limits the number of records per B-tree page. A default value of 0 means that no limit is imposed. This option is only available if debugging support is compiled in using the `WITH_DEBUG` CMake option.

- **innodb_lock_wait_timeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-lock-wait-timeout=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_lock_wait_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>50</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>1073741824</td>
</tr>
</tbody>
</table>

The length of time in seconds an InnoDB transaction waits for a row lock before giving up. The default value is 50 seconds. A transaction that tries to access a row that is locked by another InnoDB transaction waits at most this many seconds for write access to the row before issuing the following error:

ERROR 1205 (HY000): Lock wait timeout exceeded; try restarting transaction

When a lock wait timeout occurs, the current statement is rolled back (not the entire transaction). To have the entire transaction roll back, start the server with the --innodb-rollback-on-timeout option. See also Section 14.23.4, "InnoDB Error Handling".

You might decrease this value for highly interactive applications or OLTP systems, to display user feedback quickly or put the update into a queue for processing later. You might increase this value for long-running back-end operations, such as a transform step in a data warehouse that waits for other large insert or update operations to finish.

innodb_lock_wait_timeout applies to InnoDB row locks only. A MySQL table lock does not happen inside InnoDB and this timeout does not apply to waits for table locks.

The lock wait timeout value does not apply to deadlocks, because InnoDB detects them immediately and rolls back one of the deadlocked transactions. See Section 14.10.5.2, "Deadlock Detection and Rollback".

innodb_lock_wait_timeout can be set at runtime with the SET GLOBAL or SET SESSION statement. Changing the GLOBAL setting requires privileges sufficient to set global system variables (see Section 5.1.8.1, "System Variable Privileges") and affects the operation of all clients that subsequently connect. Any client can change the SESSION setting for innodb_lock_wait_timeout, which affects only that client.

• innodb_locks_unsafe_for_binlog

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-locks-unsafe-for-binlog=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_locks_unsafe_for_binlog</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable affects how InnoDB uses gap locking for searches and index scans. Normally, InnoDB uses an algorithm called next-key locking that combines index-row locking with gap locking. InnoDB performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the gap before the index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one
session has a shared or exclusive lock on record R in an index, another session cannot insert a new index record in the gap immediately before R in the index order. See Section 14.10.1, “InnoDB Locking”.

By default, the value of innodb_locks_unsafe_for_binlog is 0 (disabled), which means that gap locking is enabled: InnoDB uses next-key locks for searches and index scans. To enable the variable, set it to 1. This causes gap locking to be disabled: InnoDB uses only index-record locks for searches and index scans.

Enabling innodb_locks_unsafe_for_binlog does not disable the use of gap locking for foreign-key constraint checking or duplicate-key checking.

The effects of enabling innodb_locks_unsafe_for_binlog are the same as setting the transaction isolation level to READ COMMITTED, with these exceptions:

• Enabling innodb_locks_unsafe_for_binlog is a global setting and affects all sessions, whereas the isolation level can be set globally for all sessions, or individually per session.

• innodb_locks_unsafe_for_binlog can be set only at server startup, whereas the isolation level can be set at startup or changed at runtime.

READ COMMITTED therefore offers finer and more flexible control than innodb_locks_unsafe_for_binlog. For more information about the effect of isolation level on gap locking, see Section 14.10.2.1, “Transaction Isolation Levels”.

Enabling innodb_locks_unsafe_for_binlog may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled. Suppose that there is an index on the id column of the child table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where the id is greater than 100. If the locks set on the index records in that range do not lock out inserts made in the gaps, another session can insert a new row into the table. Consequently, if you were to execute the same SELECT again within the same transaction, you would see a new row in the result set returned by the query. This also means that if new items are added to the database, InnoDB does not guarantee serializability. Therefore, if innodb_locks_unsafe_for_binlog is enabled, InnoDB guarantees at most an isolation level of READ COMMITTED. (Conflict serializability is still guaranteed.) For more information about phantoms, see Section 14.10.4, “Phantom Rows”.

Enabling innodb_locks_unsafe_for_binlog has additional effects:

• For UPDATE or DELETE statements, InnoDB holds locks only for rows that it updates or deletes. Record locks for nonmatching rows are released after MySQL has evaluated the WHERE condition. This greatly reduces the probability of deadlocks, but they can still happen.

• For UPDATE statements, if a row is already locked, InnoDB performs a “semi-consistent” read, returning the latest committed version to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE. If the row matches (must be updated), MySQL reads the row again and this time InnoDB either locks it or waits for a lock on it.

Consider the following example, beginning with this table:

```sql
CREATE TABLE t (a INT NOT NULL, b INT) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2),(2,3),(3,2),(4,3),(5,2);
```
InnoDB System Variables

COMMIT;

In this case, table has no indexes, so searches and index scans use the hidden clustered index for record locking (see Section 14.9.2.1, “Clustered and Secondary Indexes”).

Suppose that one client performs an UPDATE using these statements:

```
SET autocommit = 0;
UPDATE t SET b = 5 WHERE b = 3;
```

Suppose also that a second client performs an UPDATE by executing these statements following those of the first client:

```
SET autocommit = 0;
UPDATE t SET b = 4 WHERE b = 2;
```

As InnoDB executes each UPDATE, it first acquires an exclusive lock for each row, and then determines whether to modify it. If InnoDB does not modify the row and innodb_locks_unsafe_for_binlog is enabled, it releases the lock. Otherwise, InnoDB retains the lock until the end of the transaction. This affects transaction processing as follows.

If innodb_locks_unsafe_for_binlog is disabled, the first UPDATE acquires x-locks and does not release any of them:

```
x-lock(1,2); retain x-lock
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); retain x-lock
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); retain x-lock
```

The second UPDATE blocks as soon as it tries to acquire any locks (because the first update has retained locks on all rows), and does not proceed until the first UPDATE commits or rolls back:

```
x-lock(1,2); block and wait for first UPDATE to commit or roll back
```

If innodb_locks_unsafe_for_binlog is enabled, the first UPDATE acquires x-locks and releases those for rows that it does not modify:

```
x-lock(1,2); unlock(1,2)
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); unlock(3,2)
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); unlock(5,2)
```

For the second UPDATE, InnoDB does a “semi-consistent” read, returning the latest committed version of each row to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE:

```
x-lock(1,2); update(1,2) to (1,4); retain x-lock
x-lock(2,3); unlock(2,3)
x-lock(3,2); update(3,2) to (3,4); retain x-lock
x-lock(4,3); unlock(4,3)
x-lock(5,2); update(5,2) to (5,4); retain x-lock
```

• innodb_log_buffer_size

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-log-buffer-size=</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_log_buffer_size</code></td>
</tr>
</tbody>
</table>
The size in bytes of the buffer that InnoDB uses to write to the log files on disk. The default value is 8MB. A large log buffer enables large transactions to run without the need to write the log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O. For related information, see Memory Configuration, and Section 8.5.3, “Optimizing InnoDB Redo Logging”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_log_file_size`

The size in bytes of each log file in a log group. The combined size of log files ($\text{innodb_log_file_size} \times \text{innodb_log_files_in_group}$) cannot exceed a maximum value that is slightly less than 4GB. A pair of 2047 MB log files, for example, approaches the limit but does not exceed it. The default value is 5MB.

Generally, the combined size of the log files should be large enough that the server can smooth out peaks and troughs in workload activity, which often means that there is enough redo log space to handle more than an hour of write activity. The larger the value, the less checkpoint flush activity is required in the buffer pool, saving disk I/O. Larger log files also make crash recovery slower.

For related information, see Redo Log File Configuration. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_log_files_in_group`
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>2</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100</td>
</tr>
</tbody>
</table>

The number of log files in the log group. InnoDB writes to the files in a circular fashion. The default (and recommended) value is 2. The location of the files is specified by `innodb_log_group_home_dir`.

For related information, see Redo Log File Configuration.

- `innodb_log_group_home_dir`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-log-group-home-dir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_log_group_home_dir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

The directory path to the InnoDB redo log files, whose number is specified by `innodb_log_files_in_group`. If you do not specify any InnoDB log variables, the default is to create two files named `ib_logfile0` and `ib_logfile1` in the MySQL data directory. Log file size is given by the `innodb_log_file_size` system variable.

For related information, see Redo Log File Configuration.

- `innodb_max_dirty_pages_pct`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-max-dirty-pages-pct=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_max_dirty_pages_pct</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>75</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>99</td>
</tr>
</tbody>
</table>

InnoDB tries to flush data from the buffer pool so that the percentage of dirty pages does not exceed this value. Specify an integer in the range from 0 to 99. The default value is 75.

For additional information about this variable, see Section 14.11.2.4, “Configuring Buffer Pool Flushing”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

1829
• **innodb_max_purge_lag**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-max-purge-lag=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_max_purge_lag</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Defines the desired maximum purge lag. If this value is exceeded, a delay is imposed on **INSERT**, **UPDATE**, and **DELETE** operations to allow time for purge to catch up. The default value is 0, which means there is no maximum purge lag and no delay.

For more information, see Section 14.11.9, "Purge Configuration".

• **innodb_mirrored_log_groups**

Has no effect.

• **innodb_old_blocks_pct**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-old-blocks-pct=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_old_blocks_pct</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>37</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>5</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>95</td>
</tr>
</tbody>
</table>

Specifies the approximate percentage of the InnoDB buffer pool used for the old block sublist. The range of values is 5 to 95. The default value is 37 (that is, 3/8 of the pool).

For more information, see Section 14.11.2.2, "Making the Buffer Pool Scan Resistant". For information about buffer pool management, the LRU algorithm, and eviction policies, see Section 14.8.1, "Buffer Pool".

• **innodb_old_blocks_time**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-old-blocks-time=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_old_blocks_time</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>2**32-1</td>
</tr>
</tbody>
</table>

Non-zero values protect against the buffer pool being filled by data that is referenced only for a brief period, such as during a full table scan. Increasing this value offers more protection against full table scans interfering with data cached in the buffer pool.

Specifies how long in milliseconds a block inserted into the old sublist must stay there after its first access before it can be moved to the new sublist. If the value is 0, a block inserted into the old sublist moves immediately to the new sublist the first time it is accessed, no matter how soon after insertion the access occurs. If the value is greater than 0, blocks remain in the old sublist until an access occurs at least that many milliseconds after the first access. For example, a value of 1000 causes blocks to stay in the old sublist for 1 second after the first access before they become eligible to move to the new sublist.

This variable is often used in combination with innodb_old_blocks_pct. For more information, see Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”. For information about buffer pool management, the LRU algorithm, and eviction policies, see Section 14.8.1, “Buffer Pool”.

• innodb_open_files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-open-files=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_open_files</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>300</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>10</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This variable is only relevant if you use multiple InnoDB tablespaces. It specifies the maximum number of .ibd files that MySQL can keep open at one time. The minimum value is 10. The default value is 300.

The file descriptors used for .ibd files are for InnoDB tables only. They are independent of those specified by the open_files_limit system variable, and do not affect the operation of the table cache.

• innodb_print_all_deadlocks

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-print-all-deadlocks=[{OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.30</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_print_all_deadlocks</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>


InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When this option is enabled, information about all deadlocks in InnoDB user transactions is recorded in the *mysql* error log. Otherwise, you see information about only the last deadlock, using the `SHOW ENGINE INNODB STATUS` command. An occasional InnoDB deadlock is not necessarily an issue, because InnoDB detects the condition immediately and rolls back one of the transactions automatically. You might use this option to troubleshoot why deadlocks are occurring if an application does not have appropriate error-handling logic to detect the rollback and retry its operation. A large number of deadlocks might indicate the need to restructure transactions that issue DML or `SELECT ... FOR UPDATE` statements for multiple tables, so that each transaction accesses the tables in the same order, thus avoiding the deadlock condition.

For related information, see Section 14.10.5, “Deadlocks in InnoDB”.

- **innodb_purge_batch_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-purge-batch-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><em>innodb_purge_batch_size</em></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>20</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>5000</td>
</tr>
</tbody>
</table>

Defines the number of undo log pages that purge parses and processes in one batch from the history list. It also defines the number of undo log pages that purge frees after every 128 iterations through the undo logs.

The `innodb_purge_batch_size` option is intended for advanced performance tuning in combination with the `innodb_purge_threads` setting. Most users need not change `innodb_purge_batch_size` from its default value.

For related information, see Section 14.11.9, “Purge Configuration”.

- **innodb_purge_threads**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-purge-threads=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><em>innodb_purge_threads</em></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of background threads devoted to the InnoDB purge operation. Currently, the value can only be 0 (the default) or 1. The default value of 0 means that the purge operation is performed by the InnoDB master thread.

For related information, see Section 14.11.9, “Purge Configuration”.

• innodb_random_read_ahead

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-random-read-ahead=[{OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_random_read_ahead</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Enables the random read-ahead technique for optimizing InnoDB I/O. Random read-ahead functionality was removed from the InnoDB Plugin (version 1.0.4) and was therefore not included in MySQL 5.5 when InnoDB Plugin became the “built-in” version of InnoDB. Random read-ahead was reintroduced in MySQL 5.5.16 and higher along with the `innodb_random_read_ahead` configuration option, which is disabled by default.

For details about performance considerations for different types of read-ahead requests, see Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

• innodb_read_ahead_threshold

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-read-ahead-threshold=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_read_ahead_threshold</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>56</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>64</td>
</tr>
</tbody>
</table>

Controls the sensitivity of linear read-ahead that InnoDB uses to prefetch pages into the buffer pool. If InnoDB reads at least `innodb_read_ahead_threshold` pages sequentially from an extent (64 pages), it initiates an asynchronous read for the entire following extent. The permissible range of values...
is 0 to 64. The default is 56: InnoDB must read at least 56 pages sequentially from an extent to initiate an asynchronous read for the following extent.

Knowing how many pages are read through the read-ahead mechanism, and how many of these pages are evicted from the buffer pool without ever being accessed, can be useful when fine-tuning the innodb_read_ahead_threshold setting. SHOW ENGINE INNODB STATUS output displays counter information from the Innodb_buffer_pool_read_ahead and Innodb_buffer_pool_read_ahead_evicted global status variables, which report the number of pages brought into the buffer pool by read-ahead requests, and the number of such pages evicted from the buffer pool without ever being accessed, respectively. The status variables report global values since the last server restart.

SHOW ENGINE INNODB STATUS also shows the rate at which the read-ahead pages are read and the rate at which such pages are evicted without being accessed. The per-second averages are based on the statistics collected since the last invocation of SHOW ENGINE INNODB STATUS and are displayed in the BUFFER POOL AND MEMORY section of the SHOW ENGINE INNODB STATUS output.

For more information, see Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- **innodb_read_io_threads**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-read-io-threads=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_read_io_threads</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>64</td>
</tr>
</tbody>
</table>

The number of I/O threads for read operations in InnoDB. Its counterpart for write threads is innodb_write_io_threads. For more information, see Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

**Note**

On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for innodb_read_io_threads, innodb_write_io_threads, and the Linux aio-max-nr setting can exceed system limits. Ideally, increase the aio-max-nr setting; as a workaround, you might reduce the settings for one or both of the MySQL variables.

- **innodb_replication_delay**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-replication-delay=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_replication_delay</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The replication thread delay in milliseconds on a slave server if `innodb_thread_concurrency` is reached.

- `innodb_rollback_on_timeout`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-rollback-on-timeout[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_rollback_on_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

InnoDB rolls back only the last statement on a transaction timeout by default. If `--innodb-rollback-on-timeout` is specified, a transaction timeout causes InnoDB to abort and roll back the entire transaction (the same behavior as in MySQL 4.1).

**Note**

If the start-transaction statement was a `START TRANSACTION` or `BEGIN` statement, rollback does not cancel that statement. Further SQL statements become part of the transaction until the occurrence of `COMMIT`, `ROLLBACK`, or some SQL statement that causes an implicit commit.

For more information, see Section 14.23.4, “InnoDB Error Handling”.

- `innodb_rollback_segments`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-rollback-segments=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.11</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_rollback_segments</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>128</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>128</td>
</tr>
</tbody>
</table>

Defines the number of rollback segments used by InnoDB for transactions that generate undo records. Each rollback segment can support up to 1024 transactions, depending on the number of undo logs assigned to each transaction. For more information, see Section 14.9.7, “Undo Logs”.

This setting is appropriate for tuning performance if you observe mutex contention related to the undo logs.

Although you can increase or decrease the number of rollback segments used by InnoDB, the number of rollback segments physically present in the system never decreases. Thus, you might start with a low value and gradually increase it to avoid allocating rollback segments that are not required. The `innodb_rollback_segments` default and maximum value is 128.

For related information, see Section 14.6, “InnoDB Multi-Versioning”.

• `innodb_spin_wait_delay`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-spin-wait-delay=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_spin_wait_delay</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>6</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>$2^{64}-1$</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>$2^{32}-1$</td>
</tr>
</tbody>
</table>

The maximum delay between polls for a spin lock. The low-level implementation of this mechanism varies depending on the combination of hardware and operating system, so the delay does not correspond to a fixed time interval. For more information, see Section 14.11.8, “Configuring Spin Lock Polling”.

• `innodb_stats_method`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-stats-method=value</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.10</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_stats_method</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>nulls_equal</code></td>
</tr>
<tr>
<td>Valid Values</td>
<td><code>nulls_equal</code></td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nulls_unequal</td>
</tr>
<tr>
<td></td>
<td>nulls_ignored</td>
</tr>
</tbody>
</table>

How the server treats NULL values when collecting statistics about the distribution of index values for InnoDB tables. Permitted values are nulls_equal, nulls_unequal, and nulls_ignored. For nulls_equal, all NULL index values are considered equal and form a single value group with a size equal to the number of NULL values. For nulls_unequal, NULL values are considered unequal, and each NULL forms a distinct value group of size 1. For nulls_ignored, NULL values are ignored.

The method used to generate table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

- **innodb_stats_on_metadata**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-stats-on-metadata=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_stats_on_metadata</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

When this option is enabled (the default), InnoDB updates statistics when metadata statements such as SHOW TABLE STATUS or SHOW INDEX are run, or when accessing the INFORMATION_SCHEMA.TABLES or INFORMATION_SCHEMA.STATISTICS tables. (These updates are similar to what happens for ANALYZE TABLE.) When disabled, InnoDB does not update statistics during these operations. Disabling this variable can improve access speed for schemas that have a large number of tables or indexes. It can also improve the stability of execution plans for queries that involve InnoDB tables.

To change the setting, issue the statement SET GLOBAL innodb_stats_on_metadata=mode, where mode is either ON or OFF (or 1 or 0). Changing the setting requires privileges sufficient to set global system variables (see Section 5.1.8.1, “System Variable Privileges”) and immediately affects the operation of all connections.

- **innodb_stats_sample_pages**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-stats-sample-pages=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_stats_sample_pages</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>8</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>
The number of index pages to sample for index distribution statistics such as are calculated by `ANALYZE TABLE`. The default value is 8. For more information, see Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”.

Setting a high value for `innodb_stats_sample_pages` could result in lengthy `ANALYZE TABLE` execution time. To estimate the number of database pages accessed by `ANALYZE TABLE`, see Section 14.11.10.1, “Estimating `ANALYZE TABLE` Complexity for InnoDB Tables”.

- `innodb_strict_mode`
**InnoDB System Variables**

- **innodb_support_xa**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-support-xa=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_support_xa</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Enables **InnoDB** support for two-phase commit in **XA** transactions, causing an extra disk flush for transaction preparation. The XA mechanism is used internally and is essential for any server that has its binary log turned on and is accepting changes to its data from more than one thread. If you disable `innodb_support_xa`, transactions can be written to the binary log in a different order than the live database is committing them, which can produce different data when the binary log is replayed in disaster recovery or on a replication slave. Do not disable `innodb_support_xa` on a replication master server unless you have an unusual setup where only one thread is able to change data.

For a server that is accepting data changes from only one thread, it is safe and recommended to disable this option to improve performance for **InnoDB** tables. For example, you can turn it off on replication slaves where only the replication SQL thread is changing data.

You can also disable this option if you do not need it for safe binary logging or replication, and you also do not use an external XA transaction manager.

- **innodb_sync_spin_loops**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-sync-spin-loops=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_sync_spin_loops</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The number of times a thread waits for an **InnoDB** mutex to be freed before the thread is suspended.

- **innodb_table_locks**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--innodb-table-locks=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_table_locks</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
If `autocommit = 0`, InnoDB honors `LOCK TABLES;` MySQL does not return from `LOCK TABLES ... WRITE` until all other threads have released all their locks to the table. The default value of `innodb_table_locks` is 1, which means that `LOCK TABLES` causes InnoDB to lock a table internally if `autocommit = 0`.

`innodb_table_locks = 0` has no effect for tables locked explicitly with `LOCK TABLES ... WRITE`. It does have an effect for tables locked for read or write by `LOCK TABLES ... WRITE` implicitly (for example, through triggers) or by `LOCK TABLES ... READ`.

For related information, see Section 14.10, “InnoDB Locking and Transaction Model”.

• `innodb_thread_concurrency`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-thread-concurrency=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_thread_concurrency</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

InnoDB tries to keep the number of operating system threads concurrently inside InnoDB less than or equal to the limit given by this variable (InnoDB uses operating system threads to process user transactions). Once the number of threads reaches this limit, additional threads are placed into a wait state within a “First In, First Out” (FIFO) queue for execution. Threads waiting for locks are not counted in the number of concurrently executing threads.

The range of this variable is 0 to 1000. A value of 0 (the default) is interpreted as infinite concurrency (no concurrency checking). Disabling thread concurrency checking enables InnoDB to create as many threads as it needs. A value of 0 also disables the queries inside InnoDB and queries in queue counters in the `ROW OPERATIONS` section of `SHOW ENGINE INNODB STATUS` output.

Consider setting this variable if your MySQL instance shares CPU resources with other applications, or if your workload or number of concurrent users is growing. The correct setting depends on workload, computing environment, and the version of MySQL that you are running. You will need to test a range of values to determine the setting that provides the best performance. `innodb_thread_concurrency` is a dynamic variable, which allows you to experiment with different settings on a live test system. If a particular setting performs poorly, you can quickly set `innodb_thread_concurrency` back to 0.

Use the following guidelines to help find and maintain an appropriate setting:

• If the number of concurrent user threads for a workload is less than 64, set `innodb_thread_concurrency=0`.

• If your workload is consistently heavy or occasionally spikes, start by setting `innodb_thread_concurrency=128` and then lowering the value to 96, 80, 64, and so on, until you
find the number of threads that provides the best performance. Suppose that your system typically has 40 to 50 users, but periodically the number increases to 60, 70, or even 200. You find that performance is stable at 80 concurrent users but starts to show a regression above this number. In this case, you would set `innodb_thread_concurrency=80` to avoid impacting performance.

- If you do not want InnoDB to use more than a certain number of virtual CPUs for user threads (20 virtual CPUs, for example), set `innodb_thread_concurrency` to this number (or possibly lower, depending on performance results). If your goal is to isolate MySQL from other applications, you may consider binding the `mysqld` process exclusively to the virtual CPUs. Be aware, however, that exclusive binding could result in non-optimal hardware usage if the `mysqld` process is not consistently busy. In this case, you might bind the `mysqld` process to the virtual CPUs but also allow other applications to use some or all of the virtual CPUs.

**Note**

From an operating system perspective, using a resource management solution to manage how CPU time is shared among applications may be preferable to binding the `mysqld` process. For example, you could assign 90% of virtual CPU time to a given application while other critical processes are not running, and scale that value back to 40% when other critical processes are running.

- `innodb_thread_concurrency` values that are too high can cause performance regression due to increased contention on system internals and resources.

- In some cases, the optimal `innodb_thread_concurrency` setting can be smaller than the number of virtual CPUs.

- Monitor and analyze your system regularly. Changes to workload, number of users, or computing environment may require that you adjust the `innodb_thread_concurrency` setting.

For related information, see Section 14.11.4, “Configuring Thread Concurrency for InnoDB”.

- `innodb_thread_sleep_delay`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--innodb-thread-sleep-delay=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>innodb_thread_sleep_delay</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10000</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms, &lt;= 5.5.36)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms, &lt;= 5.5.36)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value (&gt;= 5.5.37)</td>
<td>1000000</td>
</tr>
</tbody>
</table>

Defines how long InnoDB threads sleep before joining the InnoDB queue, in microseconds. The default value is 10000. A value of 0 disables sleep.

For more information, see Section 14.11.4, “Configuring Thread Concurrency for InnoDB”.

- `innodb_use_native_aio`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-use-native-aio={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_use_native_aio</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Specifies whether to use the Linux asynchronous I/O subsystem. This variable applies to Linux systems only, and cannot be changed while the server is running. Normally, you do not need to configure this option, because it is enabled by default.

The asynchronous I/O capability that InnoDB has on Windows systems is available on Linux systems. (Other Unix-like systems continue to use synchronous I/O calls.) This feature improves the scalability of heavily I/O-bound systems, which typically show many pending reads/writes in `SHOW ENGINE INNODB STATUS\G` output.

Running with a large number of InnoDB I/O threads, and especially running multiple such instances on the same server machine, can exceed capacity limits on Linux systems. In this case, you may receive the following error:

```
EAGAIN: The specified maxevents exceeds the user's limit of available events.
```

You can typically address this error by writing a higher limit to `/proc/sys/fs/aio-max-nr`.

However, if a problem with the asynchronous I/O subsystem in the OS prevents InnoDB from starting, you can start the server with `innodb_use_native_aio=0`. This option may also be disabled automatically during startup if InnoDB detects a potential problem such as a combination of `tmpdir` location, `tmpfs` file system, and Linux kernel that does not support AIO on `tmpfs`.

For more information, see Section 14.11.6, “Using Asynchronous I/O on Linux”.

- `innodb_trx_purge_view_update_only_debug`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-trx-purge-view-update-only-debug={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_trx_purge_view_update_only_debug</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
InnoDB System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Pauses purging of delete-marked records while allowing the purge view to be updated. This option artificially creates a situation in which the purge view is updated but purges have not yet been performed. This option is only available if debugging support is compiled in using the WITH_DEBUG CMake option.

• **innodb_trx_rseg_n_slots_debug**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-trx-rseg-n-slots-debug=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_trx_rseg_n_slots_debug</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1024</td>
</tr>
</tbody>
</table>

Sets a debug flag that limits TRX_RSEG_N_SLOTS to a given value for the trx_rsegf_undo_find_free function that looks for free slots for undo log segments. This option is only available if debugging support is compiled in using the WITH_DEBUG CMake option.

• **innodb_use_sys_malloc**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-use-sys-malloc={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_use_sys_malloc</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Enables the operating system memory allocator. If disabled, InnoDB uses its own allocator. The default value is ON. For more information, see Section 14.11.3, "Configuring the Memory Allocator for InnoDB".

• **innodb_version**

The InnoDB version number. Starting in MySQL 5.5.30, separate version numbering for InnoDB is discontinued and this value is the same the version number of the server.

• **innodb_write_io_threads**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--innodb-write-io-threads=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>innodb_write_io_threads</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>
InnoDB INFORMATION_SCHEMA Tables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>4</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>64</td>
</tr>
</tbody>
</table>

The number of I/O threads for write operations in InnoDB. The default value is 4. Its counterpart for read threads is `innodb_read_io_threads`. For more information, see Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

**Note**

On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for `innodb_read_io_threads`, `innodb_write_io_threads`, and the Linux `aio-max-nr` setting can exceed system limits. Ideally, increase the `aio-max-nr` setting; as a workaround, you might reduce the settings for one or both of the MySQL variables.

Also take into consideration the value of `sync_binlog`, which controls synchronization of the binary log to disk.

For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

### 14.18 InnoDB INFORMATION_SCHEMA Tables

This section provides information and usage examples for InnoDB INFORMATION_SCHEMA tables.

InnoDB INFORMATION_SCHEMA tables provide metadata, status information, and statistics about various aspects of the InnoDB storage engine. You can view a list of InnoDB INFORMATION_SCHEMA tables by issuing a `SHOW TABLES` statement on the INFORMATION_SCHEMA database:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA LIKE 'INNODB%';
```

For table definitions, see Section 21.29, “INFORMATION_SCHEMA InnoDB Tables”. For general information regarding the MySQL INFORMATION_SCHEMA database, see Chapter 21, INFORMATION_SCHEMA Tables.

The InnoDB INFORMATION_SCHEMA tables are themselves plugins to the MySQL server. To see what plugins are installed, use the `SHOW PLUGINS` statement or query the INFORMATION_SCHEMA.PLUGINS table. Use `INSTALL PLUGIN` syntax to install an INFORMATION_SCHEMA table plugin. If INFORMATION_SCHEMA table plugins are installed, but the InnoDB storage engine plugin is not installed, the tables appear empty.

#### 14.18.1 InnoDB INFORMATION_SCHEMA Tables about Compression

There are two pairs of InnoDB INFORMATION_SCHEMA tables about compression that can provide insight into how well compression is working overall:

- `INNODB_CMP` and `INNODB_CMP_RESET` provide information about the number of compression operations and the amount of time spent performing compression.
- `INNODB_CMPMEM` and `INNODB_CMPMEM_RESET` provide information about the way memory is allocated for compression.
14.18.1.1 INNODB_CMP and INNODB_CMP_RESET

The INNODB_CMP and INNODB_CMP_RESET tables provide status information about operations related to compressed tables, which are described in Section 14.12, “InnoDB Table Compression”. The PAGE_SIZE column reports the compressed page size.

These two tables have identical contents, but reading from INNODB_CMP_RESET resets the statistics on compression and uncompression operations. For example, if you archive the output of INNODB_CMP_RESET every 60 minutes, you see the statistics for each hourly period. If you monitor the output of INNODB_CMP (making sure never to read INNODB_CMP_RESET), you see the cumulative statistics since InnoDB was started.

For the table definition, see Section 21.29.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”.

14.18.1.2 INNODB_CMPMEM and INNODB_CMPMEM_RESET

The INNODB_CMPMEM and INNODB_CMPMEM_RESET tables provide status information about compressed pages that reside in the buffer pool. Please consult Section 14.12, “InnoDB Table Compression” for further information on compressed tables and the use of the buffer pool. The INNODB_CMP and INNODB_CMP_RESET tables should provide more useful statistics on compression.

Internal Details

InnoDB uses a buddy allocator system to manage memory allocated to pages of various sizes, from 1KB to 16KB. Each row of the two tables described here corresponds to a single page size.

The INNODB_CMPMEM and INNODB_CMPMEM_RESET tables have identical contents, but reading from INNODB_CMPMEM_RESET resets the statistics on relocation operations. For example, if every 60 minutes you archived the output of INNODB_CMPMEM_RESET, it would show the hourly statistics. If you never read INNODB_CMPMEM_RESET and monitored the output of INNODB_CMPMEM instead, it would show the cumulative statistics since InnoDB was started.

For the table definition, see Section 21.29.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”.

14.18.1.3 Using the Compression Information Schema Tables

Example 14.1 Using the Compression Information Schema Tables

The following is sample output from a database that contains compressed tables (see Section 14.12, “InnoDB Table Compression”, INNODB_CMP, and INNODB_CMPMEM).

The following table shows the contents of INFORMATION_SCHEMA.INNODB_CMP under a light workload. The only compressed page size that the buffer pool contains is 8K. Compressing or uncompressing pages has consumed less than a second since the time the statistics were reset, because the columns COMPRESS_TIME and UNCOMPRESS_TIME are zero.

<table>
<thead>
<tr>
<th>page size</th>
<th>compress ops</th>
<th>compress ops ok</th>
<th>compress time</th>
<th>uncompress ops</th>
<th>uncompress time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1024</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2048</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
According to `INNODB_CMPMEM`, there are 6169 compressed 8KB pages in the buffer pool.

The following table shows the contents of `INFORMATION_SCHEMA.INNODB_CMPMEM` under a light workload. Some memory is unusable due to fragmentation of the InnoDB memory allocator for compressed pages: \( \text{SUM(PAGE_SIZE*PAGES_FREE)} = 6784 \). This is because small memory allocation requests are fulfilled by splitting bigger blocks, starting from the 16K blocks that are allocated from the main buffer pool, using the buddy allocation system. The fragmentation is this low because some allocated blocks have been relocated (copied) to form bigger adjacent free blocks. This copying of \( \text{SUM(PAGE_SIZE*RELOCATION_OPS)} \) bytes has consumed less than a second (\( \text{SUM(RELOCATION_TIME)} = 0 \)).

<table>
<thead>
<tr>
<th>page size</th>
<th>compress ops</th>
<th>compress ops ok</th>
<th>compress time</th>
<th>uncompress ops</th>
<th>uncompress time</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8192</td>
<td>1048</td>
<td>921</td>
<td>0</td>
<td>61</td>
<td>0</td>
</tr>
<tr>
<td>16384</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

14.18.2 InnoDB INFORMATION_SCHEMA Transaction and Locking Information

Three InnoDB INFORMATION_SCHEMA tables enable you to monitor transactions and diagnose potential locking problems:

- `INNODB_TRX`: Provides information about every transaction currently executing inside InnoDB, including the transaction state (for example, whether it is running or waiting for a lock), when the transaction started, and the particular SQL statement the transaction is executing.

- `INNODB_LOCKS`: Each transaction in InnoDB that is waiting for another transaction to release a lock (`INNODB_TRX.TRX_STATE` is `LOCK WAIT`) is blocked by exactly one blocking lock request. That blocking lock request is for a row or table lock held by another transaction in an incompatible mode. A lock that blocks a transaction is always held in a mode incompatible with the mode of requested lock (read vs. write, shared vs. exclusive). The blocked transaction cannot proceed until the other transaction commits or rolls back, thereby releasing the requested lock. For every blocked transaction, `INNODB_LOCKS` contains one row that describes each lock the transaction has requested, and for which it is waiting. `INNODB_LOCKS` also contains one row for each lock that is blocking another transaction, whatever the state of the transaction that holds the lock (`INNODB_TRX.TRX_STATE` is `RUNNING`, `LOCK WAIT`, `ROLLING BACK` or `COMMITTING`).

- `INNODB_LOCK_WAITS`: This table indicates which transactions are waiting for a given lock, or for which lock a given transaction is waiting. This table contains one or more rows for each blocked transaction, indicating the lock it has requested and any locks that are blocking that request. The `REQUESTED_LOCK_ID` value refers to the lock requested by a transaction, and the `BLOCKING_LOCK_ID` value refers to the lock (held by another transaction) that prevents the first transaction from proceeding. For any given blocked transaction, all rows in `INNODB_LOCK_WAITS` have the same value for `REQUESTED_LOCK_ID` and different values for `BLOCKING_LOCK_ID`. 

<table>
<thead>
<tr>
<th>page size</th>
<th>pages used</th>
<th>pages free</th>
<th>relocation ops</th>
<th>relocation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1024</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2048</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4096</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8192</td>
<td>6169</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>16384</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
14.18.2.1 Using InnoDB Transaction and Locking Information

Identifying Blocking Transactions

It is sometimes helpful to identify which transaction blocks another. The tables that contain information about InnoDB transactions and data locks enable you to determine which transaction is waiting for another, and which resource is being requested. (For descriptions of these tables, see Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”.)

Suppose that three sessions are running concurrently. Each session corresponds to a MySQL thread, and executes one transaction after another. Consider the state of the system when these sessions have issued the following statements, but none has yet committed its transaction:

- **Session A:**

  ```sql
  BEGIN;
  SELECT a FROM t FOR UPDATE;
  SELECT SLEEP(100);
  ```

- **Session B:**

  ```sql
  SELECT b FROM t FOR UPDATE;
  ```

- **Session C:**

  ```sql
  SELECT c FROM t FOR UPDATE;
  ```

In this scenario, use the following query to see which transactions are waiting and which transactions are blocking them:

```sql
SELECT
  r.trx_id waiting_trx_id,
  r.trx_mysql_thread_id waiting_thread,
  r.trx_query waiting_query,
  b.trx_id blocking_trx_id,
  b.trx_mysql_thread_id blocking_thread,
  b.trx_query blocking_query
FROM       information_schema.innodb_lock_waits w
INNER JOIN information_schema.innodb_trx b
  ON b.trx_id = w.blocking_trx_id
INNER JOIN information_schema.innodb_trx r
  ON r.trx_id = w.requesting_trx_id;
```

<table>
<thead>
<tr>
<th>waitingtrx id</th>
<th>waitingthread</th>
<th>waitingquery</th>
<th>blockingtrx id</th>
<th>blockingthread</th>
<th>blockingquery</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4</td>
<td>6</td>
<td>SELECT b FROM t FOR UPDATE</td>
<td>A3</td>
<td>5</td>
<td>SELECT SLEEP(100)</td>
</tr>
<tr>
<td>A5</td>
<td>7</td>
<td>SELECT c FROM t FOR UPDATE</td>
<td>A3</td>
<td>5</td>
<td>SELECT SLEEP(100)</td>
</tr>
<tr>
<td>A5</td>
<td>7</td>
<td>SELECT c FROM t FOR UPDATE</td>
<td>A4</td>
<td>6</td>
<td>SELECT b FROM t FOR UPDATE</td>
</tr>
</tbody>
</table>

In the preceding table, you can identify sessions by the “waiting query” or “blocking query” columns. As you can see:

- **Session B** (trx id **A4**, thread 6) and **Session C** (trx id **A5**, thread 7) are both waiting for **Session A** (trx id **A3**, thread 5).
InnoDB INFORMATION_SCHEMA Transaction and Locking Information

- Session C is waiting for Session B as well as Session A.

You can see the underlying data in the tables `INNODB_TRX`, `INNODB_LOCKS`, and `INNODB_LOCK_WAITS`.

The following table shows some sample contents of `INFORMATION_SCHEMA.INNODB_TRX`.

<table>
<thead>
<tr>
<th>trx id</th>
<th>trx state</th>
<th>trx started</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>RUNNING</td>
<td>2008-01-15 16:44:54</td>
</tr>
<tr>
<td>A4</td>
<td>LOCK WAIT</td>
<td>2008-01-15 16:45:09</td>
</tr>
<tr>
<td>A5</td>
<td>LOCK WAIT</td>
<td>2008-01-15 16:45:14</td>
</tr>
</tbody>
</table>

The following table shows some sample contents of `INFORMATION_SCHEMA.INNODB_LOCKS`.

<table>
<thead>
<tr>
<th>lock id</th>
<th>lock trx id</th>
<th>lock mode</th>
<th>lock type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3:1:3:2</td>
<td>A3</td>
<td>X</td>
<td>RECORD</td>
</tr>
<tr>
<td>A4:1:3:2</td>
<td>A4</td>
<td>X</td>
<td>RECORD</td>
</tr>
<tr>
<td>A5:1:3:2</td>
<td>A5</td>
<td>X</td>
<td>RECORD</td>
</tr>
</tbody>
</table>

The following table shows some sample contents of `INFORMATION_SCHEMA.INNODB_LOCK_WAITS`.

<table>
<thead>
<tr>
<th>requesting trx id</th>
<th>requested lock id</th>
<th>blocking trx id</th>
<th>blocking lock id</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5</td>
<td>A5:1:3:2</td>
<td>A3</td>
<td>A3:1:3:2</td>
</tr>
<tr>
<td>A5</td>
<td>A5:1:3:2</td>
<td>A4</td>
<td>A4:1:3:2</td>
</tr>
</tbody>
</table>

Correlating InnoDB Transactions with MySQL Sessions

Sometimes it is useful to correlate internal InnoDB locking information with the session-level information maintained by MySQL. For example, you might like to know, for a given InnoDB transaction ID, the corresponding MySQL session ID and name of the session that may be holding a lock, and thus blocking other transactions.

The following output from the `INFORMATION_SCHEMA` tables is taken from a somewhat loaded system. As can be seen, there are several transactions running.

The following `INNODB_LOCKS` and `INNODB_LOCK_WAITS` tables show that:

- Transaction 77F (executing an `INSERT`) is waiting for transactions 77E, 77D, and 77B to commit.
- Transaction 77E (executing an `INSERT`) is waiting for transactions 77D and 77B to commit.
- Transaction 77D (executing an `INSERT`) is waiting for transaction 77B to commit.
- Transaction 77B (executing an `INSERT`) is waiting for transaction 77A to commit.
- Transaction 77A is running, currently executing `SELECT`.
- Transaction E56 (executing an `INSERT`) is waiting for transaction E55 to commit.
- Transaction E55 (executing an `INSERT`) is waiting for transaction 19C to commit.
InnoDB INFORMATION_SCHEMA Transaction and Locking Information

- Transaction 19C is running, currently executing an INSERT.

**Note**

There may be inconsistencies between queries shown in the `INFORMATION_SCHEMA.PROCESSLIST` and `INNODB_TRX` tables. For an explanation, see Section 14.18.2.3, "Persistence and Consistency of InnoDB Transaction and Locking Information".

The following table shows the contents of `INFORMATION_SCHEMA.PROCESSLIST` for a system running a heavy workload.

<table>
<thead>
<tr>
<th>ID</th>
<th>USER</th>
<th>HOST</th>
<th>DB</th>
<th>COMMAND</th>
<th>TIME</th>
<th>STATE</th>
<th>INFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>384</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>10s</td>
<td>update</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>257</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>3s</td>
<td>update</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>130</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>0s</td>
<td>update</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>61</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>1s</td>
<td>update</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>8</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>1s</td>
<td>update</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>4</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Query</td>
<td>0s</td>
<td>prepare</td>
<td>INSERT INTO t2 VALUES …</td>
</tr>
<tr>
<td>2</td>
<td>root</td>
<td>localhost</td>
<td>test</td>
<td>Sleep</td>
<td>566s</td>
<td>update</td>
<td></td>
</tr>
</tbody>
</table>
The following table shows the contents of `INFORMATION_SCHEMA.INNODB_LOCK_WAITS` for a system running a heavy workload.

<table>
<thead>
<tr>
<th>requesting trx id</th>
<th>requested lock id</th>
<th>blocking trx id</th>
<th>blocking lock id</th>
</tr>
</thead>
<tbody>
<tr>
<td>77F</td>
<td>77F:806</td>
<td>77E</td>
<td>77E:806</td>
</tr>
<tr>
<td>77F</td>
<td>77F:806</td>
<td>77D</td>
<td>77D:806</td>
</tr>
<tr>
<td>77E</td>
<td>77E:806</td>
<td>77D</td>
<td>77D:806</td>
</tr>
<tr>
<td>77D</td>
<td>77D:806</td>
<td>77B</td>
<td>77B:806</td>
</tr>
<tr>
<td>77B</td>
<td>77B:733:12:1</td>
<td>77A</td>
<td>77A:733:12:1</td>
</tr>
</tbody>
</table>

The following table shows the contents of `INFORMATION_SCHEMA.INNODB_LOCKS` for a system running a heavy workload.

<table>
<thead>
<tr>
<th>lock id</th>
<th>lock trx id</th>
<th>lock mode</th>
<th>lock type</th>
<th>lock table</th>
<th>lock index</th>
<th>lock data</th>
</tr>
</thead>
<tbody>
<tr>
<td>77F:806</td>
<td>77F</td>
<td>AUTO_INC</td>
<td>TABLE</td>
<td>test.t09</td>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>77E:806</td>
<td>77E</td>
<td>AUTO_INC</td>
<td>TABLE</td>
<td>test.t09</td>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>77D:806</td>
<td>77D</td>
<td>AUTO_INC</td>
<td>TABLE</td>
<td>test.t09</td>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>77B:806</td>
<td>77B</td>
<td>AUTO_INC</td>
<td>TABLE</td>
<td>test.t09</td>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>77B:733:12:1</td>
<td>77B</td>
<td>X</td>
<td>RECORD</td>
<td>test.t09</td>
<td>PRIMARY</td>
<td>supremum pseudo-record</td>
</tr>
<tr>
<td>77A:733:12:1</td>
<td>77A</td>
<td>X</td>
<td>RECORD</td>
<td>test.t09</td>
<td>PRIMARY</td>
<td>supremum pseudo-record</td>
</tr>
<tr>
<td>E56:743:6:2</td>
<td>E56</td>
<td>S</td>
<td>RECORD</td>
<td>test.t2</td>
<td>PRIMARY</td>
<td>0, 0</td>
</tr>
<tr>
<td>E55:743:6:2</td>
<td>E55</td>
<td>X</td>
<td>RECORD</td>
<td>test.t2</td>
<td>PRIMARY</td>
<td>0, 0</td>
</tr>
<tr>
<td>E55:743:38:2</td>
<td>E55</td>
<td>S</td>
<td>RECORD</td>
<td>test.t2</td>
<td>PRIMARY</td>
<td>1922, 1922</td>
</tr>
<tr>
<td>19C:743:38:2</td>
<td>19C</td>
<td>X</td>
<td>RECORD</td>
<td>test.t2</td>
<td>PRIMARY</td>
<td>1922, 1922</td>
</tr>
</tbody>
</table>

### 14.18.2.2 InnoDB Lock and Lock-Wait Information

When a transaction updates a row in a table, or locks it with `SELECT FOR UPDATE`, InnoDB establishes a list or queue of locks on that row. Similarly, InnoDB maintains a list of locks on a table for table-level locks. If a second transaction wants to update a row or lock a table already locked by a prior transaction in an incompatible mode, InnoDB adds a lock request for the row to the corresponding queue. For a lock to be acquired by a transaction, all incompatible lock requests previously entered into the lock queue for that row or table must be removed (which occurs when the transactions holding or requesting those locks either commit or roll back).

A transaction may have any number of lock requests for different rows or tables. At any given time, a transaction may request a lock that is held by another transaction, in which case it is blocked by that other
transaction. The requesting transaction must wait for the transaction that holds the blocking lock to commit or roll back. If a transaction is not waiting for a lock, it is in a **RUNNING** state. If a transaction is waiting for a lock, it is in a **LOCK WAIT** state. (The **INFORMATION_SCHEMA INNODB_TRX** table indicates transaction state values.)

The **INNODB_LOCKS** table holds one or more rows for each **LOCK WAIT** transaction, indicating any lock requests that prevent its progress. This table also contains one row describing each lock in a queue of locks pending for a given row or table. The **INNODB_LOCK_WAITS** table shows which locks already held by a transaction are blocking locks requested by other transactions.

### 14.18.2.3 Persistence and Consistency of InnoDB Transaction and Locking Information

The data exposed by the transaction and locking tables (**INNODB_TRX**, **INNODB_LOCKS**, and **INNODB_LOCK_WAITS**) represents a glimpse into fast-changing data. This is not like user tables, where the data changes only when application-initiated updates occur. The underlying data is internal system-managed data, and can change very quickly.

For performance reasons, and to minimize the chance of misleading joins between the transaction and locking tables, **InnoDB** collects the required transaction and locking information into an intermediate buffer whenever a **SELECT** on any of the tables is issued. This buffer is refreshed only if more than 0.1 seconds has elapsed since the last time the buffer was read. The data needed to fill the three tables is fetched atomically and consistently and is saved in this global internal buffer, forming a point-in-time “snapshot”. If multiple table accesses occur within 0.1 seconds (as they almost certainly do when MySQL processes a join among these tables), then the same snapshot is used to satisfy the query.

A correct result is returned when you join any of these tables together in a single query, because the data for the three tables comes from the same snapshot. Because the buffer is not refreshed with every query of any of these tables, if you issue separate queries against these tables within a tenth of a second, the results are the same from query to query. On the other hand, two separate queries of the same or different tables issued more than a tenth of a second apart may see different results, since the data come from different snapshots.

Because **InnoDB** must temporarily stall while the transaction and locking data is collected, too frequent queries of these tables can negatively impact performance as seen by other users.

As these tables contain sensitive information (at least **INNODB_LOCKS.LOCK_DATA** and **INNODB_TRX.TRX_QUERY**), for security reasons, only the users with the **PROCESS** privilege are allowed to **SELECT** from them.

As described previously, the data that fills the transaction and locking tables (**INNODB_TRX**, **INNODB_LOCKS** and **INNODB_LOCK_WAITS**) is fetched automatically and saved to an intermediate buffer that provides a “point-in-time” snapshot. The data across all three tables is consistent when queried from the same snapshot. However, the underlying data changes so fast that similar glimpses at other, similarly fast-changing data, may not be in synchrony. Thus, you should be careful when comparing data in the **InnoDB** transaction and locking tables with data in the **PROCESSLIST** table. The data from the **PROCESSLIST** table does not come from the same snapshot as the data about locking and transactions. Even if you issue a single **SELECT** (joining **INNODB_TRX** and **PROCESSLIST**, for example), the content of those tables is generally not consistent. **INNODB_TRX** may reference rows that are not present in **PROCESSLIST** or the currently executing SQL query of a transaction shown in **INNODB_TRX.TRX_QUERY** may differ from the one in **PROCESSLIST.INFO**.

### 14.18.3 InnoDB INFORMATION_SCHEMA Buffer Pool Tables

The **InnoDB INFORMATION_SCHEMA** buffer pool tables provide buffer pool status information and metadata about the pages within the **InnoDB** buffer pool.
The **InnoDB INFORMATION_SCHEMA** buffer pool tables include those listed below:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA LIKE 'INNODB_BUFFER%';
+-----------------------------------------------+
| Tables_in_INFORMATION_SCHEMA (INNODB_BUFFER%) |
+-----------------------------------------------+
| INNODB_BUFFER_PAGE_LRU                        |
| INNODB_BUFFER_PAGE                            |
| INNODB_BUFFER_POOL_STATS                      |
+-----------------------------------------------+
```

**Table Overview**

- **INNODB_BUFFER_PAGE**: Holds information about each page in the InnoDB buffer pool.

- **INNODB_BUFFER_PAGE_LRU**: Holds information about the pages in the InnoDB buffer pool, in particular how they are ordered in the LRU list that determines which pages to evict from the buffer pool when it becomes full. The **INNODB_BUFFER_PAGE_LRU** table has the same columns as the **INNODB_BUFFER_PAGE** table, except that the **INNODB_BUFFER_PAGE_LRU** table has an **LRU_POSITION** column instead of a **BLOCK_ID** column.

- **INNODB_BUFFER_POOL_STATS**: Provides buffer pool status information. Much of the same information is provided by **SHOW ENGINE INNODB STATUS** output, or may be obtained using InnoDB buffer pool server status variables.

**Warning**

Querying the **INNODB_BUFFER_PAGE** or **INNODB_BUFFER_PAGE_LRU** table can affect performance. Do not query these tables on a production system unless you are aware of the performance impact and have determined it to be acceptable. To avoid impacting performance on a production system, reproduce the issue you want to investigate and query buffer pool statistics on a test instance.

**Example 14.2 Querying System Data in the INNODB_BUFFER_PAGE Table**

This query provides an approximate count of pages that contain system data by excluding pages where the **TABLE_NAME** value is either **NULL** or includes a slash / or period . in the table name, which indicates a user-defined table.

```
mysql> SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
      WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0);
+----------+
| COUNT(*) |
+----------+
|      381 |
+----------+
```

This query returns the approximate number of pages that contain system data, the total number of buffer pool pages, and an approximate percentage of pages that contain system data.

```
mysql> SELECT
      (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
       WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0)) AS system_pages,
     (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
      ) AS total_pages,
     (SELECT ROUND((system_pages/total_pages) * 100) AS system_page_percentage;
```

1852
The type of system data in the buffer pool can be determined by querying the `PAGE_TYPE` value. For example, the following query returns eight distinct `PAGE_TYPE` values among the pages that contain system data:

```sql
mysql> SELECT DISTINCT PAGE_TYPE FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
    WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0);
```

```
+-------------------+
| PAGE_TYPE         |
+-------------------+
| IBUF_BITMAP       |
| SYSTEM            |
| INDEX             |
| UNDO_LOG          |
| FILE_SPACE_HEADER |
| UNKNOWN           |
| INODE             |
| EXTENT_DESCRIPTOR |
+-------------------+
```

**Example 14.3 Querying User Data in the INNODB_BUFFER_PAGE Table**

This query provides an approximate count of pages containing user data by counting pages where the `TABLE_NAME` value is not `NULL`.

```sql
mysql> SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
    WHERE TABLE_NAME IS NOT NULL;
```

```
+----------+
| COUNT(*) |
+----------+
| 7811     |
+----------+
```

This query returns the approximate number of pages that contain user data, the total number of buffer pool pages, and an approximate percentage of pages that contain user data.

```sql
mysql> SELECT
    (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
     WHERE TABLE_NAME IS NOT NULL AND (INSTR(TABLE_NAME, '/') > 0 OR INSTR(TABLE_NAME, '.') > 0)) AS user_pages,
    (SELECT COUNT(*)
     FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
    ) AS total_pages,
    (SELECT ROUND((user_pages/total_pages) * 100)
     AS user_page_percentage;
```

```
+------------+-------------+----------------------+
| user_pages | total_pages | user_page_percentage |
+------------+-------------+----------------------+
| 7811       | 8192        | 95                   |
+------------+-------------+----------------------+
```

This query identifies user-defined tables with pages in the buffer pool:

```sql
mysql> SELECT DISTINCT TABLE_NAME
    FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
    WHERE TABLE_NAME IS NOT NULL
    AND (INSTR(TABLE_NAME, '/') > 0 OR INSTR(TABLE_NAME, '.') > 0);
```
### Example 14.4 Querying Index Data in the INNODB_BUFFER_PAGE Table

For information about index pages, query the `INDEX_NAME` column using the name of the index. For example, the following query returns the number of pages and total data size of pages for the `emp_no` index that is defined on the `employees.salaries` table:

```
mysql> SELECT INDEX_NAME, COUNT(*) AS Pages,
       
   ROUND(SUM(IF(COMPRESSED_SIZE = 0, 16384, COMPRESSED_SIZE))/1024/1024) AS 'Total Data (MB)'  
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE INDEX_NAME='emp_no' AND TABLE_NAME = 'employees/salaries';
```

<table>
<thead>
<tr>
<th>INDEX_NAME</th>
<th>Pages</th>
<th>Total Data (MB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>emp_no</td>
<td>1244</td>
<td>19</td>
</tr>
</tbody>
</table>

This query returns the number of pages and total data size of pages for all indexes defined on the `employees.salaries` table:

```
mysql> SELECT INDEX_NAME, COUNT(*) AS Pages,
       
   ROUND(SUM(IF(COMPRESSED_SIZE = 0, 16384, COMPRESSED_SIZE))/1024/1024) AS 'Total Data (MB)'
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME = 'employees/salaries'
GROUP BY INDEX_NAME;
```

<table>
<thead>
<tr>
<th>INDEX_NAME</th>
<th>Pages</th>
<th>Total Data (MB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>emp_no</td>
<td>1244</td>
<td>19</td>
</tr>
<tr>
<td>PRIMARY</td>
<td>6086</td>
<td>95</td>
</tr>
</tbody>
</table>

### Example 14.5 Querying LRU_POSITION Data in the INNODB_BUFFER_PAGE_LRU Table

The `INNODB_BUFFER_PAGE_LRU` table holds information about the pages in the InnoDB buffer pool, in particular how they are ordered that determines which pages to evict from the buffer pool when it becomes full. The definition for this page is the same as for `INNODB_BUFFER_PAGE`, except this table has an `LRU_POSITION` column instead of a `BLOCK_ID` column.

This query counts the number of positions at a specific location in the LRU list occupied by pages of the `employees.employees` table.

```
mysql> SELECT COUNT(LRU_POSITION) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE_LRU
WHERE TABLE_NAME='employees/employees' AND LRU_POSITION < 3072;
```

```
+---------------------+
<table>
<thead>
<tr>
<th>COUNT(LRU_POSITION)</th>
</tr>
</thead>
<tbody>
<tr>
<td>481</td>
</tr>
</tbody>
</table>
```

### Example 14.6 Querying the INNODB_BUFFER_POOL_STATS Table

The `INNODB_BUFFER_POOL_STATS` table provides information similar to `SHOW ENGINE INNODB STATUS` and InnoDB buffer pool status variables.

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_POOL_STATS \
G
```

```
*************************** 1. row ***************************
1854
```
For comparison, `SHOW ENGINE INNODB STATUS` output and InnoDB buffer pool status variable output is shown below, based on the same data set.

For more information about `SHOW ENGINE INNODB STATUS` output, see Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”.

For status variable descriptions, see Section 5.1.9, “Server Status Variables”.

```sql
mysql> SHOW ENGINE INNODB STATUS \G
...  
BUFFER POOL AND MEMORY
--------------
Total memory allocated 137363456; in additional pool allocated 0
Dictionary memory allocated 71426
Buffer pool size  8192
Free buffers  1
Database pages  7942
Old database pages 2911
Modified db pages  0
Pending reads  0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 8358, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 7045, created 12382, written 15790
0.00 reads/s, 0.00 creates/s, 0.00 writes/s
No buffer pool page gets since the last printout
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 7942, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
...  
```

```sql
mysql> SHOW STATUS LIKE 'Innodb_buffer';
```

1855
### 14.19 InnoDB Integration with MySQL Performance Schema

This section provides a brief introduction to InnoDB integration with Performance Schema. For comprehensive Performance Schema documentation, see Chapter 22, *MySQL Performance Schema*.

Starting with InnoDB 1.1 with MySQL 5.5, you can profile certain internal InnoDB operations using the MySQL Performance Schema feature. This type of tuning is primarily for expert users who evaluate optimization strategies to overcome performance bottlenecks. DBAs can also use this feature for capacity planning, to see whether their typical workload encounters any performance bottlenecks with a particular combination of CPU, RAM, and disk storage; and if so, to judge whether performance can be improved by increasing the capacity of some part of the system.

To use this feature to examine InnoDB performance:

- You must be running MySQL 5.5 or higher with the Performance Schema feature available and enabled, as described in Section 22.2, “Performance Schema Build Configuration”, and Section 22.3, “Performance Schema Startup Configuration”. Since the Performance Schema feature introduces some performance overhead, you should use it on a test or development system rather than on a production system.

- You must be running InnoDB 1.1 or higher.

- You must be generally familiar with how to use the Performance Schema feature. For example, you should know how enable instruments and consumers, and how to query *performance_schema* tables to retrieve data. For an introductory overview, see Section 22.1, “Performance Schema Quick Start”.

- You should be familiar with Performance Schema instruments that are available for InnoDB. To view InnoDB-related instruments, you can query the *setup_instruments* table for instrument names that contain `'innodb'`.

```sql
mysql> SELECT * FROM performance_schema.setup_instruments WHERE NAME LIKE '%innodb%';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/innodb/commit_cond_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/innobase_share_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/prepare_commit_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/autoinc_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/btr_search_enabled_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

---

**Table:**

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innodb_buffer_pool_pages_data</td>
<td>7942</td>
</tr>
<tr>
<td>Innodb_buffer_pool_bytes_data</td>
<td>130121728</td>
</tr>
<tr>
<td>Innodb_buffer_pool_pages_dirty</td>
<td>0</td>
</tr>
<tr>
<td>Innodb_buffer_pool_bytes_dirty</td>
<td>0</td>
</tr>
<tr>
<td>Innodb_buffer_pool_pages_flushed</td>
<td>15790</td>
</tr>
<tr>
<td>Innodb_buffer_pool_pages_free</td>
<td>1</td>
</tr>
<tr>
<td>Innodb_buffer_pool_pages_misc</td>
<td>249</td>
</tr>
<tr>
<td>Innodb_buffer_pool_pages_total</td>
<td>8192</td>
</tr>
<tr>
<td>Innodb_buffer_pool_read_ahead_rnd</td>
<td>0</td>
</tr>
<tr>
<td>Innodb_buffer_pool_read_ahead</td>
<td>2934</td>
</tr>
<tr>
<td>Innodb_buffer_pool_read_ahead_evicted</td>
<td>23</td>
</tr>
<tr>
<td>Innodb_buffer_pool_read_requests</td>
<td>28731589</td>
</tr>
<tr>
<td>Innodb_buffer_pool_reads</td>
<td>4112</td>
</tr>
<tr>
<td>Innodb_buffer_pool_wait_free</td>
<td>0</td>
</tr>
<tr>
<td>Innodb_buffer_pool_write_requests</td>
<td>11965146</td>
</tr>
</tbody>
</table>
### InnoDB Integration with MySQL Performance Schema

| wait/synch/mutex/innodb/buf_pool_mutex | YES | YES |
| wait/synch/mutex/innodb/buf_pool_zip_mutex | YES | YES |
| wait/synch/mutex/innodb/cache_last_read_mutex | YES | YES |
| wait/synch/mutex/innodb/dict_foreign_err_mutex | YES | YES |
| wait/synch/mutex/innodb/dict_sys_mutex | YES | YES |
| wait/synch/mutex/innodb/file_format_max_mutex | YES | YES |
| wait/synch/rwlock/innodb/btr_search_latch | YES | YES |
| wait/synch/rwlock/innodb/dict_operation_lock | YES | YES |
| wait/synch/rwlock/innodb/fil_space_latch | YES | YES |
| wait/synch/rwlock/innodb/checkpoint_lock | YES | YES |
| wait/synch/rwlock/innodb/trx_i_s_cache_lock | YES | YES |
| wait/synch/rwlock/innodb/index_tree_rw_lock | YES | YES |
| wait/synch/rwlock/innodb/dict_table_stats | YES | YES |
| wait/synch/cond/innodb/commit_cond | YES | YES |
| wait/io/file/innodb/innodb_data_file | YES | YES |
| wait/io/file/innodb/innodb_log_file | YES | YES |
| wait/io/file/innodb/innodb_temp_file | YES | YES |

For additional information about the instrumented InnoDB objects, you can query Performance Schema instances tables, which provide additional information about instrumented objects. Instance tables relevant to InnoDB include:

- The mutex_instances table
- The rwlock_instances table
- The cond_instances table
- The file_instances table

**Note**

Mutexes and RW-locks related to the InnoDB buffer pool are not included in this coverage; the same applies to the output of the `SHOW ENGINE INNODB MUTEX` command.

For example, to view information about instrumented InnoDB file objects seen by the Performance Schema when executing file I/O instrumentation, you might issue the following query:

```sql
mysql> SELECT *
    > FROM performance_schema.file_instances
    > WHERE EVENT_NAME LIKE '%innodb%'
```

- You should be familiar with performance_schema tables that store InnoDB event data. Tables relevant to InnoDB-related events include:
  - The Wait Event tables, which store wait events.
Monitoring InnoDB Mutex Waits Using Performance Schema

- The Summary tables, which provide aggregated information for terminated events over time. Summary tables include file I/O summary tables, which aggregate information about I/O operations.

If you are only interested in InnoDB-related objects, use the clause WHERE EVENT_NAME LIKE '%innodb%' or WHERE NAME LIKE '%innodb%' (as required) when querying these tables.


A mutex is a synchronization mechanism used in the code to enforce that only one thread at a given time can have access to a common resource. When two or more threads executing in the server need to access the same resource, the threads compete against each other. The first thread to obtain a lock on the mutex causes the other threads to wait until the lock is released.

For InnoDB mutexes that are instrumented, mutex waits can be monitored using Performance Schema. Wait event data collected in Performance Schema tables can help identify mutexes with the most waits or the greatest total wait time, for example.

The following example demonstrates how to view InnoDB mutex wait instruments, how to verify that associated consumers are enabled, and how to query wait event data. It is assumed that Performance Schema was enabled at server startup. For information about enabling Performance Schema, see Section 22.1, “Performance Schema Quick Start”.

1. To view available InnoDB mutex wait instruments, query the Performance Schema setup_instruments table, as shown below. Instruments are enabled by default.

```sql
mysql> SELECT *
FROM performance_schema.setup_instruments
WHERE NAME LIKE '%wait/synch/mutex/innodb%';

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/innodb/commit_cond_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/innobase_share_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/prepare_commit_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/autoinc_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/btr_search_enabled_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/buf_pool_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/buf_pool_zip_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/cache_last_read_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/dict_foreign_err_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/dict_sys_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/file_format_max_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/fil_system_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/flush_list_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/log_flush_order_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/hash_table_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_bitmap_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/kernel_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/log_sys_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/mem_pool_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/mutex_list_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/purge_sys_bh_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/recv_sys_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/rseg_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/rw_lock_list_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/rw_lock_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_dict_tmpfile_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_innodb_monitor_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_misc_tmpfile_mutex</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
```
2. Verify that wait event consumers are enabled by querying the `setup_consumers` table. The `events_waits_current`, `events_waits_history`, and `events_waits_history_long` consumers should be enabled by default.

```sql
mysql> SELECT * FROM performance_schema.setup_consumers;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>events_waits_current</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_history</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_history_long</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_thread_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_instance</td>
<td>YES</td>
</tr>
<tr>
<td>file_summary_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>file_summary_by_instance</td>
<td>YES</td>
</tr>
</tbody>
</table>

8 rows in set (0.00 sec)

3. Run the workload that you want to monitor. In this example, the `mysqlslap` load emulation client is used to simulate a workload.

```shell
shell> ./mysqlslap --auto-generate-sql --concurrency=100 --iterations=10 --number-of-queries=1000 --number-char-cols=6 --number-int-cols=6;
```

4. Query the wait event data. In this example, wait event data is queried from the `events_waits_summary_global_by_event_name` table which aggregates data found in the `events_waits_current`, `events_waits_history`, and `events_waits_history_long` tables. Data is summarized by event name (EVENT_NAME), which is the name of the instrument that produced the event. Summarized data includes:

- **COUNT_STAR**
  
  The number of summarized wait events.

- **SUM_TIMER_WAIT**
  
  The total wait time of the summarized timed wait events.

- **MIN_TIMER_WAIT**
  
  The minimum wait time of the summarized timed wait events.

- **AVG_TIMER_WAIT**
  
  The average wait time of the summarized timed wait events.

- **MAX_TIMER_WAIT**
  
  The maximum wait time of the summarized timed wait events.

The following query returns the instrument name (EVENT_NAME), the number of wait events (COUNT_STAR), and the total wait time for the events for that instrument (SUM_TIMER_WAIT). Because waits are timed in picoseconds (trillionths of a second) by default, wait times are divided by...
InnoDB Monitors

1000000000 to show wait times in milliseconds. Data is presented in descending order, by the number of summarized wait events (COUNT_STAR). You can adjust the ORDER BY clause to order the data by total wait time.

```
mysql> SELECT EVENT_NAME, COUNT_STAR, SUM_TIMER_WAIT/1000000000 SUM_TIMER_WAIT_MS
    FROM performance_schema.events_waits_summary_global_by_event_name
    WHERE SUM_TIMER_WAIT > 0 AND EVENT_NAME LIKE 'wait/synch/mutex/innodb/%'
    ORDER BY COUNT_STAR DESC;
```

<table>
<thead>
<tr>
<th>EVENT_NAME</th>
<th>COUNT_STAR</th>
<th>SUM_TIMER_WAIT_MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/innodb/buf_pool_mutex</td>
<td>154477</td>
<td>6258.6407</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/kernel_mutex</td>
<td>54294</td>
<td>1747.1980</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/log_sys_mutex</td>
<td>40578</td>
<td>3167.6126</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/dict_sys_mutex</td>
<td>34261</td>
<td>26.4183</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/log_flush_order_mutex</td>
<td>24463</td>
<td>0.5867</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/rseg_mutex</td>
<td>18204</td>
<td>0.4750</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/flush_list_mutex</td>
<td>15949</td>
<td>0.7182</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/mutex_list_mutex</td>
<td>10439</td>
<td>0.2239</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_innodb_monitor_mutex</td>
<td>9815</td>
<td>0.5027</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/rw_lock_list_mutex</td>
<td>8292</td>
<td>0.1763</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/innobase_share_mutex</td>
<td>6070</td>
<td>0.2339</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/file_format_max_mutex</td>
<td>1994</td>
<td>0.0761</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/file_format_max_mutex</td>
<td>1007</td>
<td>0.0245</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_mutex</td>
<td>387</td>
<td>0.0214</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/recv_sys_mutex</td>
<td>186</td>
<td>0.0047</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_mutex</td>
<td>121</td>
<td>0.0030</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex</td>
<td>99</td>
<td>0.0033</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_innodb_monitor_mutex</td>
<td>40</td>
<td>0.0011</td>
</tr>
<tr>
<td>wait/synch/mutex/innodb/srv_innodb_monitor_mutex</td>
<td>3</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

19 rows in set (0.00 sec)

Note

The preceding result set includes wait event data produced during the startup process. To exclude this data, you can truncate the `events_waits_summary_global_by_event_name` table immediately after startup and before running your workload. However, the truncate operation itself may produce a negligible amount wait event data.

```
mysql> TRUNCATE performance_schema.events_waits_summary_global_by_event_name;
```

14.20 InnoDB Monitors

InnoDB monitors provide information about the InnoDB internal state. This information is useful for performance tuning.

14.20.1 InnoDB Monitor Types

There are four types of InnoDB monitors:

- The standard InnoDB Monitor displays the following types of information:
  - Work done by the main background thread
  - Semaphore waits
  - Data about the most recent foreign key and deadlock errors
  - Lock waits for transactions
Enabling InnoDB Monitors

- Table and record locks held by active transactions
- Pending I/O operations and related statistics
- Insert buffer and adaptive hash index statistics
- Redo log data
- Buffer pool statistics
- Row operation data

The InnoDB Lock Monitor prints additional lock information as part of the standard InnoDB Monitor output.

The InnoDB Tablespace Monitor prints a list of file segments in the shared tablespace and validates the tablespace allocation data structures.

The InnoDB Table Monitor prints the contents of the InnoDB internal data dictionary.

For additional information about InnoDB table and tablespace monitors, see Mark Leith: InnoDB Table and Tablespace Monitors.

14.20.2 Enabling InnoDB Monitors

When InnoDB monitors are enabled for periodic output, InnoDB writes the output to mysqld server standard error output (stderr) every 15 seconds, approximately.

InnoDB sends the monitor output to stderr rather than to stdout or fixed-size memory buffers to avoid potential buffer overflows.

On Windows, stderr is directed to the default log file unless configured otherwise. If you want to direct the output to the console window rather than to the error log, start the server from a command prompt in a console window with the --console option. For more information, see Section 5.4.2.1, “Error Logging on Windows”.

On Unix and Unix-like systems, stderr is typically directed to the terminal unless configured otherwise. For more information, see Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”.

InnoDB monitors should only be enabled when you actually want to see monitor information because output generation causes some performance decrement. Also, if monitor output is directed to the error log, the log may become quite large if you forget to disable the monitor later by dropping the monitor table.

Note

To assist with troubleshooting, InnoDB temporarily enables standard InnoDB Monitor output under certain conditions. For more information, see Section 14.23, “InnoDB Troubleshooting”.

Each monitor begins with a header containing a timestamp and the monitor name. For example:

```
141016 15:41:44 INNODB MONITOR OUTPUT
```

The header for the standard InnoDB Monitor (INNODB MONITOR OUTPUT) is also used for the Lock Monitor because the latter produces the same output with the addition of extra lock information.
Enabling InnoDB Monitors

Enabling an InnoDB monitor for periodic output involves using a CREATE TABLE statement to create a specially named InnoDB table that is associated with the monitor. For example, to enable the standard InnoDB Monitor, you would create an InnoDB table named innodb_monitor.

Using CREATE TABLE syntax is just a way to pass a command to the InnoDB engine through MySQL’s SQL parser. The only things that matter are the table name and that it be an InnoDB table. The structure of the table and the database where the table is created are not relevant. If you shut down the server, the monitor does not restart automatically when you restart the server. Drop the monitor table and issue a new CREATE TABLE statement to start the monitor.

The PROCESS privilege is required to enable or disable InnoDB Monitors.

Enabling the Standard InnoDB Monitor

To enable the standard InnoDB Monitor for periodic output, create the innodb_monitor table:

```
CREATE TABLE innodb_monitor (a INT) ENGINE=INNODB;
```

To disable the standard InnoDB Monitor, drop the table:

```
DROP TABLE innodb_monitor;
```

Enabling the InnoDB Lock Monitor

To enable the InnoDB Lock Monitor for periodic output, create the innodb_lock_monitor table:

```
CREATE TABLE innodb_lock_monitor (a INT) ENGINE=INNODB;
```

To disable the InnoDB Lock Monitor, drop the table:

```
DROP TABLE innodb_lock_monitor;
```

Obtaining Standard InnoDB Monitor Output On Demand

As an alternative to enabling the standard InnoDB Monitor for periodic output, you can obtain standard InnoDB Monitor output on demand using the SHOW ENGINE INNODB STATUS SQL statement, which fetches the output to your client program. If you are using the mysql interactive client, the output is more readable if you replace the usual semicolon statement terminator with \G:

```
mysql> SHOW ENGINE INNODB STATUS\G
```

SHOW ENGINE INNODB STATUS output also includes InnoDB Lock Monitor data if the InnoDB Lock Monitor is enabled.

Directing Standard InnoDB Monitor Output to a Status File

Standard InnoDB Monitor output can be enabled and directed to a status file by specifying the --innodb-status-file option at startup. When this option is used, InnoDB creates a file named innodb_status.pid in the data directory and writes output to it every 15 seconds, approximately.

InnoDB removes the status file when the server is shut down normally. If an abnormal shutdown occurs, the status file may have to be removed manually.

The --innodb-status-file option is intended for temporary use, as output generation can affect performance, and the innodb_status.pid file can become quite large over time.

Enabling the InnoDB Tablespace Monitor

To enable the InnoDB Tablespace Monitor for periodic output, create the innodb_tablespace_monitor table:
InnoDB Standard Monitor and Lock Monitor Output

CREATE TABLE innodb_tablespace_monitor (a INT) ENGINE=INNODB;

To disable the standard InnoDB Tablespace Monitor, drop the table:

DROP TABLE innodb_tablespace_monitor;

Enabling the InnoDB Table Monitor

To enable the InnoDB Table Monitor for periodic output, create the innodb_table_monitor table:

CREATE TABLE innodb_table_monitor (a INT) ENGINE=INNODB;

To disable the InnoDB Table Monitor, drop the table:

DROP TABLE innodb_table_monitor;

14.20.3 InnoDB Standard Monitor and Lock Monitor Output

The Lock Monitor is the same as the Standard Monitor except that it includes additional lock information. Enabling either monitor for periodic output turns on the same output stream, but the stream includes extra information if the Lock Monitor is enabled. For example, if you enable the Standard Monitor and Lock Monitor, that turns on a single output stream. The stream includes extra lock information until you disable the Lock Monitor.

Standard Monitor output is limited to 1MB when produced using the SHOW ENGINE INNODB STATUS statement. This limit does not apply to output written to server standard error output (stderr).

Example Standard Monitor output:

```sql
mysql> SHOW ENGINE INNODB STATUS\G
*************************** 1. row ***************************
Type: InnoDB
Name:
Status: 141016 15:41:44 INNODB MONITOR OUTPUT
Per second averages calculated from the last 6 seconds
-----------------
BACKGROUND THREAD
-----------------
srv_master_thread loops: 49 1_second, 48 sleeps, 3 10_second, 18 background, 18 flush
srv_master_thread log flush and writes: 48
-----------------
SEMAPHORES
-----------------
OS WAIT ARRAY INFO: reservation count 46, signal count 45
Mutex spin waits 30, rounds 900, OS waits 27
RW-shared spins 14, rounds 420, OS waits 14
RW-excl spins 0, rounds 150, OS waits 5
Spin rounds per wait: 30.00 mutex, 30.00 RW-shared, 150.00 RW-excl
-----------------
LATEST FOREIGN KEY ERROR
-----------------
141016 15:37:30 Transaction:
TRANSACTION 3D005, ACTIVE 0 sec inserting
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1248, 3 row lock(s), undo log entries 3
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 70 localhost root
update
INSERT INTO child VALUES
(NULL, 1), (NULL, 2), (NULL, 3)
```
Foreign key constraint fails for table `mysql`.`child`:

```
CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`) REFERENCES `parent` (`id`)
ON DELETE CASCADE ON UPDATE CASCADE
```

Trying to add in child table, in index `par_ind` tuple:

DATA TUPLE: 2 fields;
0: len 4; hex 80000003; asc     ;
1: len 4; hex 80000003; asc     ;

But in parent table `mysql`.`parent`, in index `PRIMARY`,
the closest match we can find is record:

PHYSICAL RECORD: n_fields 3; compact format; info bits 0
0: len 4; hex 80000004; asc     ;
1: len 6; hex 00000003d002; asc     ;
2: len 7; hex 8300001d480137; asc     ;

LATEST DETECTED DEADLOCK
------------------------
141016 15:39:58
*** (1) TRANSACTION:
TRANSACTION 3D009, ACTIVE 19 sec starting index read
mysql tables in use 1, locked 1
LOCK WAIT 2 lock struct(s), heap size 376, 1 row lock(s)
MySQL thread id 2, OS thread handle 0x7f0ee43cd700, query id 78 localhost root
updating
DELETE FROM t WHERE i = 1
*** (1) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table `mysql`.`t` trx id 3D009 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
0: len 6; hex 000000000700; asc     ;
1: len 6; hex 00000003d007; asc     ;
2: len 7; hex 87000009560110; asc     ;
3: len 4; hex 80000001; asc     ;

*** (2) TRANSACTION:
TRANSACTION 3D008, ACTIVE 69 sec starting index read
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1248, 3 row lock(s)
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 79 localhost root
updating
DELETE FROM t WHERE i = 1
*** (2) HOLDS THE LOCK(S):
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table `mysql`.`t` trx id 3D008 lock_mode S
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
0: len 6; hex 000000000700; asc     ;
1: len 6; hex 00000003d007; asc     ;
2: len 7; hex 87000009560110; asc     ;
3: len 4; hex 80000001; asc     ;

*** (2) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table `mysql`.`t` trx id 3D008 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
0: len 6; hex 000000000700; asc     ;
1: len 6; hex 00000003d007; asc     ;
2: len 7; hex 87000009560110; asc     ;
3: len 4; hex 80000001; asc     ;
*** WE ROLL BACK TRANSACTION (1)

---

TRANSACTIONS

---

Trx id counter 3D038
Purge done fortrx's n:o < 3D02A undo n:o < 0
History list length 1047
Total number of lock structs in row lock hash table 0

LIST OF TRANSACTIONS FOR EACH SESSION:

---TRANSACTION 3D009, not started
MySQL thread id 2, OS thread handle 0x7f0ee43cd700, query id 78 localhost root

---TRANSACTION 3D008, not started
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 113 localhost root

SHOW ENGINE INNODB STATUS

---TRANSACTION 3D037, ACTIVE 1 sec inserting
mysql tables in use 1, locked 1
1 lock struct(s), heap size 376, 0 row lock(s), undo log entries 11940
MySQL thread id 3, OS thread handle 0x7f0ee438c700, query id 112 localhost root
update
INSERT INTO `employees` VALUES (413215,'1962-07-08','Ronghao','Molberg','F',
'1985-06-20'),(413216,'1954-05-25','Masaru','Lieberherr','M',
'1992-04-08'),(413217,'1953-03-17','Phule','Waschkowski','F',
'1988-07-28'),(413218,'1964-10-07','Vitaly','Negota','M',
'1986-01-13'),(413219,'1957-03-31','Danil','Kalafatis','F',
'1985-04-12'),(413220,'1958-07-25','Jianwen','Radwan','M',
'1986-09-03'),(413221,'1964-04-08','Paloma','Bach','M',
'1985-05-03'),(413222,'1955-06-10','Stafford','Muhlberg','M',
'1989-03-22'),(413223,'1963-10-27','Aichiro','Benzmuller','M',
'1987-12-02'),(413224,'1955-10-02','Giordano','N'
TABLE LOCK table `employees` trx id 3D037 lock mode IX

---

FILE I/O

---

I/O thread 0 state: waiting for completed aio requests (insert buffer thread)
I/O thread 1 state: waiting for completed aio requests (log thread)
I/O thread 2 state: waiting for completed aio requests (read thread)
I/O thread 3 state: waiting for completed aio requests (read thread)
I/O thread 4 state: waiting for completed aio requests (read thread)
I/O thread 5 state: waiting for completed aio requests (read thread)
I/O thread 6 state: waiting for completed aio requests (write thread)
I/O thread 7 state: waiting for completed aio requests (write thread)
I/O thread 8 state: waiting for completed aio requests (write thread)
I/O thread 9 state: waiting for completed aio requests (write thread)
Pending normal aio reads: 0 [0, 0, 0, 0] , aio writes: 0 [0, 0, 0, 0] ,
ibuf aio reads: 0, log i/o's: 0, sync i/o's: 0
Pending flushes (fsync) log: 0; buffer pool: 0
439 OS file reads, 917 OS file writes, 199 OS fsyncs
0.00 reads/s, 0 avg bytes/read, 56.32 writes/s, 7.67 fsyncs/s

---

INSERT BUFFER AND ADAPTIVE HASH INDEX

---

Ibuf: size 1, free list len 0, seg size 2, 0 merges
merged operations:
insert 0, delete mark 0, delete 0
discarded operations:
insert 0, delete mark 0, delete 0
Hash table size 4425293, used cells 32, node heap has 1 buffer(s)
13577.57 hash searches/s, 202.47 non-hash searches/s
---

LOG

---

Log sequence number 794838329
Log flushed up to 793815740
Last checkpoint at 788417971
0 pending log writes, 0 pending chkp writes
96 log i/o's done, 3.50 log i/o's/second
---

BUFFER POOL AND MEMORY

---

1865
Total memory allocated 2217738240; in additional pool allocated 0
Dictionary memory allocated 121719
Buffer pool size  131072
Free buffers     129937
Database pages   1134
Old database pages 211
Modified db pages 187
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 426, created 706, written 768
0.00 reads/s, 40.99 creates/s, 50.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 1134, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]

INDIVIDUAL BUFFER POOL INFO

---BUFFER POOL 0
Buffer pool size  65536
Free buffers     65029
Database pages   506
Old database pages 0
Modified db pages 95
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 137, created 369, written 412
0.00 reads/s, 20.16 creates/s, 18.00 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 506, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
---BUFFER POOL 1
Buffer pool size  65536
Free buffers     64908
Database pages   628
Old database pages 211
Modified db pages 92
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 289, created 339, written 356
0.00 reads/s, 20.83 creates/s, 32.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 628, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]

ROW OPERATIONS

0 queries inside InnoDB, 0 queries in queue
1 read views open inside InnoDB
Number of rows inserted 225354, updated 0, deleted 3, read 4
13690.55 inserts/s, 0.00 updates/s, 0.00 deletes/s, 0.00 reads/s

END OF INNODB MONITOR OUTPUT
Standard Monitor Output Sections

For a description of each metric reported by the Standard Monitor, refer to the Metrics chapter in the Oracle Enterprise Manager for MySQL Database User's Guide.

• **Status**

  This section shows the timestamp, the monitor name, and the number of seconds that per-second averages are based on. The number of seconds is the elapsed time between the current time and the last time InnoDB Monitor output was printed.

• **BACKGROUND THREAD**

  The srv_master_thread lines show work done by the main background thread.

• **SEMAPHORES**

  This section reports threads waiting for a semaphore and statistics on how many times threads have needed a spin or a wait on a mutex or a rw-lock semaphore. A large number of threads waiting for semaphores may be a result of disk I/O, or contention problems inside InnoDB. Contention can be due to heavy parallelism of queries or problems in operating system thread scheduling. Setting the innodb_thread_concurrency system variable smaller than the default value might help in such situations. The Spin rounds per wait line shows the number of spinlock rounds per OS wait for a mutex.

• **LATEST FOREIGN KEY ERROR**

  This section provides information about the most recent foreign key constraint error. It is not present if no such error has occurred. The contents include the statement that failed as well as information about the constraint that failed and the referenced and referencing tables.

• **LATEST DETECTED DEADLOCK**

  This section provides information about the most recent deadlock. It is not present if no deadlock has occurred. The contents show which transactions are involved, the statement each was attempting to execute, the locks they have and need, and which transaction InnoDB decided to roll back to break the deadlock. The lock modes reported in this section are explained in Section 14.10.1, “InnoDB Locking”.

• **TRANSACTIONS**

  If this section reports lock waits, your applications might have lock contention. The output can also help to trace the reasons for transaction deadlocks.

• **FILE I/O**

  This section provides information about threads that InnoDB uses to perform various types of I/O. The first few of these are dedicated to general InnoDB processing. The contents also display information for pending I/O operations and statistics for I/O performance.

  The number of these threads are controlled by the innodb_read_io_threads and innodb_write_io_threads parameters. See Section 14.17, “InnoDB Startup Options and System Variables”.

• **INSERT BUFFER AND ADAPTIVE HASH INDEX**

  This section shows the status of the InnoDB insert buffer (also referred to as the change buffer) and the adaptive hash index.
For related information, see Section 14.8.2, “Change Buffer”, and Section 14.8.3, “Adaptive Hash Index”.

• **LOG**

This section displays information about the InnoDB log. The contents include the current log sequence number, how far the log has been flushed to disk, and the position at which InnoDB last took a checkpoint. (See Section 14.15.3, “InnoDB Checkpoints”.) The section also displays information about pending writes and write performance statistics.

• **BUFFER POOL AND MEMORY**

This section gives you statistics on pages read and written. You can calculate from these numbers how many data file I/O operations your queries currently are doing.

For buffer pool statistics descriptions, see Monitoring the Buffer Pool Using the InnoDB Standard Monitor. For additional information about the operation of the buffer pool, see Section 14.8.1, “Buffer Pool”.

• **ROW OPERATIONS**

This section shows what the main thread is doing, including the number and performance rate for each type of row operation.

In MySQL 5.5, output from the standard InnoDB Monitor includes additional sections compared to the output for previous versions. For details, see Diagnostic and Monitoring Capabilities.

### 14.20.4 InnoDB Tablespace Monitor Output

The InnoDB Tablespace Monitor prints information about the file segments in the shared tablespace and validates the tablespace allocation data structures. The Tablespace Monitor does not describe file-per-table tablespaces created with the `innodb_file_per_table` option.

Example InnoDB Tablespace Monitor output:

```
090408 21:28:09 INNODB TABLESPACE MONITOR OUTPUT
====================================================================
FILE SPACE INFO: id 0
  size 13440, free limit 3136, free extents 28
  not full frag extents 2; used pages 78, full frag extents 3
  first seg id not used 0 23845
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
  fragm pages 32; free extents 0; not full extents 1; pages 14
SEGMENT id 0 2 space 0; page 2; res 1 used 1; full ext 0
  fragm pages 1; free extents 0; not full extents 0; pages 0
SEGMENT id 0 3 space 0; page 2; res 1 used 1; full ext 0
  fragm pages 1; free extents 0; not full extents 0; pages 0
... SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
  fragm pages 32; free extents 0; not full extents 0; pages 0
SEGMENT id 0 488 space 0; page 2; res 1 used 1; full ext 0
  fragm pages 1; free extents 0; not full extents 0; pages 0
SEGMENT id 0 17 space 0; page 2; res 1 used 1; full ext 0
  fragm pages 1; free extents 0; not full extents 0; pages 0
... SEGMENT id 0 171 space 0; page 2; res 592 used 481; full ext 7
  fragm pages 16; free extents 0; not full extents 2; pages 17
SEGMENT id 0 172 space 0; page 2; res 1 used 1; full ext 0
  fragm pages 1; free extents 0; not full extents 0; pages 0
SEGMENT id 0 173 space 0; page 2; res 96 used 44; full ext 0
```

1868
The Tablespace Monitor output includes information about the shared tablespace as a whole, followed by a list containing a breakdown for each segment within the tablespace.

In this example using the default page size, the tablespace consists of database pages that are 16KB each. The pages are grouped into extents of size 1MB (64 consecutive pages).

The initial part of the output that displays overall tablespace information has this format:

```
FILE SPACE INFO: id 0
size 13440, free limit 3136, free extents 28
not full frag extents 2: used pages 78, full frag extents 3
first seg id not used 0 23845
```

Overall tablespace information includes these values:

- **id**
  The tablespace ID. A value of 0 refers to the shared tablespace.

- **size**
  The current tablespace size in pages.

- **free limit**
  The minimum page number for which the free list has not been initialized. Pages at or above this limit are free.

- **free extents**
  The number of free extents.

- **not full frag extents, used pages**
  The number of fragment extents that are not completely filled, and the number of pages in those extents that have been allocated.

- **full frag extents**
  The number of completely full fragment extents.

- **first seg id not used**
  The first unused segment ID.

Individual segment information has this format:

```
SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
fragm pages 32; free extents 0; not full extents 0: pages 0
```
Segment information includes these values:

- **id**
  The segment ID.

- **space, page**
  The tablespace number and page within the tablespace where the segment “inode” is located. A tablespace number of 0 indicates the shared tablespace. **InnoDB** uses inodes to keep track of segments in the tablespace. The other fields displayed for a segment (**id, res, and so forth**) are derived from information in the inode.

- **res**
  The number of pages allocated (reserved) for the segment.

- **used**
  The number of allocated pages in use by the segment.

- **full ext**
  The number of extents allocated for the segment that are completely used.

- **fragm pages**
  The number of initial pages that have been allocated to the segment.

- **free extents**
  The number of extents allocated for the segment that are completely unused.

- **not full extents**
  The number of extents allocated for the segment that are partially used.

- **pages**
  The number of pages used within the not-full extents.

When a segment grows, it starts as a single page, and **InnoDB** allocates the first pages for it one at a time, up to 32 pages (this is the **fragm pages** value). After that, **InnoDB** allocates complete extents. **InnoDB** can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.

For the example segment shown earlier, it has 32 fragment pages, plus 2 full extents (64 pages each), for a total of 160 pages used out of 160 pages allocated. The following segment has 32 fragment pages and one partially full extent using 14 pages for a total of 46 pages used out of 96 pages allocated:

```
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
  fragm pages 32; free extents 0; not full extents 1: pages 14
```

It is possible for a segment that has extents allocated to it to have a **fragm pages** value less than 32 if some of the individual pages have been deallocated subsequent to extent allocation.

### 14.20.5 InnoDB Table Monitor Output

The **InnoDB** Table Monitor prints the contents of the **InnoDB** internal data dictionary.
InnoDB Table Monitor Output

The output contains one section per table. The `SYS_FOREIGN` and `SYS_FOREIGN_COLS` sections are for internal data dictionary tables that maintain information about foreign keys. There are also sections for the Table Monitor table and each user-created InnoDB table. Suppose that the following two tables have been created in the test database:

```
CREATE TABLE parent
(
    par_id INT NOT NULL,
    fname CHAR(20),
    lname CHAR(20),
    PRIMARY KEY (par_id),
    UNIQUE INDEX (lname, fname)
) ENGINE = INNODB;

CREATE TABLE child
(
    par_id INT NOT NULL,
    child_id INT NOT NULL,
    name VARCHAR(40),
    birth DATE,
    weight DECIMAL(10,2),
    misc_info VARCHAR(255),
    last_update TIMESTAMP,
    PRIMARY KEY (par_id, child_id),
    INDEX (name),
    FOREIGN KEY (par_id) REFERENCES parent (par_id)
    ON DELETE CASCADE
    ON UPDATE CASCADE
) ENGINE = INNODB;
```

Then the Table Monitor output will look something like this (reformatted slightly):

```
090420 12:09:32 INNODB TABLE MONITOR OUTPUT

TABLE: name SYS_FOREIGN, id 0 11, columns 7, indexes 3, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
  FOR_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
  REF_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
  N_COLS: DATA_INT len 4;
  DB_ROW_ID: DATA_SYS prtype 256 len 6;
  DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name ID_IND, id 0 11, fields 1/6, uniq 1, type 3
  root page 46, appr.key vals 1, leaf pages 1, size pages 1
  FIELDS:  ID POS DB_TRX_ID DB_ROLL_PTR FOR_NAME REF_NAME N_COLS

TABLE: name SYS_FOREIGN_COLS, id 0 12, columns 7, indexes 1, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
  POS: DATA_INT len 4;
  FOR_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
  REF_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
  DB_ROW_ID: DATA_SYS prtype 256 len 6;
  DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name ID_IND, id 0 12, fields 1/2, uniq 2, type 0
  root page 47, appr.key vals 1, leaf pages 1, size pages 1
  FIELDS:  FOR_COL_NAME ID

TABLE: name test/child, id 0 14, columns 10, indexes 2, appr.rows 201
  COLUMNS: par_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
```
InnoDB Table Monitor Output

For each table, Table Monitor output contains a section that displays general information about the table and specific information about its columns, indexes, and foreign keys.

The general information for each table includes the table name (in db_name/tbl_name format except for internal tables), its ID, the number of columns and indexes, and an approximate row count.

The columns part of a table section lists each column in the table. Information for each column indicates its name and data type characteristics. Some internal columns are added by InnoDB, such as DB_ROW_ID (row ID), DB_TRX_ID (transaction ID), and DB_ROLL_PTR (a pointer to the rollback/undo data).

- **DATA_xxx**
  These symbols indicate the data type. There may be multiple DATA_xxx symbols for a given column.

- **prtype**
  The column’s “precise” type. This field includes information such as the column data type, character set code, nullability, signedness, and whether it is a binary string. This field is described in the innobase/include/data0type.h source file.

- **len**
InnoDB Table Monitor Output

The column length in bytes.

Each **INDEX** part of the table section provides the name and characteristics of one table index:

- **name**
  The index name. If the name is **PRIMARY**, the index is a primary key. If the name is **GEN_CLUST_INDEX**, the index is the clustered index that is created automatically if the table definition doesn't include a primary key or non-**NULL** unique index. See Section 14.9.2.1, “Clustered and Secondary Indexes”.

- **id**
  The index ID.

- **fields**
  The number of fields in the index, as a value in $m/n$ format:
  - $m$ is the number of user-defined columns; that is, the number of columns you would see in the index definition in a `CREATE TABLE` statement.
  - $n$ is the total number of index columns, including those added internally. For the clustered index, the total includes the other columns in the table definition, plus any columns added internally. For a secondary index, the total includes the columns from the primary key that are not part of the secondary index.

- **uniq**
  The number of leading fields that are enough to determine index values uniquely.

- **type**
  The index type. This is a bit field. For example, 1 indicates a clustered index and 2 indicates a unique index, so a clustered index (which always contains unique values), will have a `type` value of 3. An index with a `type` value of 0 is neither clustered nor unique. The flag values are defined in the `innobase/include/dict0mem.h` source file.

- **root page**
  The index root page number.

- **appr. key vals**
  The approximate index cardinality.

- **leaf pages**
  The approximate number of leaf pages in the index.

- **size pages**
  The approximate total number of pages in the index.

- **FIELDS**
  The names of the fields in the index. For a clustered index that was generated automatically, the field list begins with the internal **DB_ROW_ID** (row ID) field. **DB_TRX_ID** and **DB_ROLL_PTR** are always added.
InnoDB Backup and Recovery

Internally to the clustered index, following the fields that comprise the primary key. For a secondary index, the final fields are those from the primary key that are not part of the secondary index.

The end of the table section lists the FOREIGN KEY definitions that apply to the table. This information appears whether the table is a referencing or referenced table.

14.21 InnoDB Backup and Recovery

This section covers topics related to InnoDB backup and recovery.

- For information about backup techniques applicable to InnoDB, see Section 14.21.1, “InnoDB Backup”.
- For information about point-in-time recovery, recovery from disk failure or corruption, and how InnoDB performs crash recovery, see Section 14.21.2, "InnoDB Recovery".

14.21.1 InnoDB Backup

The key to safe database management is making regular backups. Depending on your data volume, number of MySQL servers, and database workload, you can use these backup techniques, alone or in combination: hot backup with MySQL Enterprise Backup; cold backup by copying files while the MySQL server is shut down; logical backup with mysqldump for smaller data volumes or to record the structure of schema objects. Hot and cold backups are physical backups that copy actual data files, which can be used directly by the mysqld server for faster restore.

Using MySQL Enterprise Backup is the recommended method for backing up InnoDB data.

Note

InnoDB does not support databases that are restored using third-party backup tools.

Hot Backups

The mysqlbackup command, part of the MySQL Enterprise Backup component, lets you back up a running MySQL instance, including InnoDB tables, with minimal disruption to operations while producing a consistent snapshot of the database. When mysqlbackup is copying InnoDB tables, reads and writes to InnoDB can continue. MySQL Enterprise Backup can also create compressed backup files, and back up subsets of tables and databases. In conjunction with the MySQL binary log, users can perform point-in-time recovery. MySQL Enterprise Backup is part of the MySQL Enterprise subscription. For more details, see Section 25.2, “MySQL Enterprise Backup Overview”.

Cold Backups

If you can shut down the MySQL server, you can make a physical backup that consists of all files used by InnoDB to manage its tables. Use the following procedure:

1. Perform a slow shutdown of the MySQL server and make sure that it stops without errors.
2. Copy all InnoDB data files (ibdata files and .ibd files) into a safe place.
3. Copy all the .frm files for InnoDB tables to a safe place.
4. Copy all InnoDB log files (ib_logfile files) to a safe place.
5. Copy your my.cnf configuration file or files to a safe place.
Logical Backups Using mysqldump

In addition to physical backups, it is recommended that you regularly create logical backups by dumping your tables using `mysqldump`. A binary file might be corrupted without you noticing it. Dumped tables are stored into text files that are human-readable, so spotting table corruption becomes easier. Also, because the format is simpler, the chance for serious data corruption is smaller. `mysqldump` also has a `--single-transaction` option for making a consistent snapshot without locking out other clients. See Section 7.3.1, “Establishing a Backup Policy”.

Replication works with InnoDB tables, so you can use MySQL replication capabilities to keep a copy of your database at database sites requiring high availability. See Section 14.22, “InnoDB and MySQL Replication”.

14.21.2 InnoDB Recovery

This section describes InnoDB recovery. Topics include:

- Point-in-Time Recovery
- Recovery from Data Corruption or Disk Failure
- InnoDB Crash Recovery

Point-in-Time Recovery

To recover an InnoDB database to the present from the time at which the physical backup was made, you must run MySQL server with binary logging enabled, even before taking the backup. To achieve point-in-time recovery after restoring a backup, you can apply changes from the binary log that occurred after the backup was made. See Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

Recovery from Data Corruption or Disk Failure

If your database becomes corrupted or disk failure occurs, you must perform the recovery using a backup. If the case of corruption, first find a backup that is not corrupted. After restoring the base backup, do a point-in-time recovery from the binary log files using `mysqlbinlog` and `mysql` to restore the changes that occurred after the backup was made.

In some cases of database corruption, it is enough to dump, drop, and re-create one or a few corrupt tables. You can use the `CHECK TABLE` statement to check whether a table is corrupt, although `CHECK TABLE` naturally cannot detect every possible kind of corruption. You can use the Tablespace Monitor to check the integrity of the file space management inside the tablespace files.

In some cases, apparent database page corruption is actually due to the operating system corrupting its own file cache, and the data on disk may be okay. It is best to try restarting the computer first. Doing so may eliminate errors that appeared to be database page corruption. If MySQL still has trouble starting because of InnoDB consistency problems, see Section 14.23.2, “Forcing InnoDB Recovery” for steps to start the instance in recovery mode, which permits you to dump the data.

InnoDB Crash Recovery

To recover from a MySQL server crash, the only requirement is to restart the MySQL server. InnoDB automatically checks the logs and performs a roll-forward of the database to the present. InnoDB automatically rolls back uncommitted transactions that were present at the time of the crash. During recovery, `mysql` displays output similar to this:
The **InnoDB crash recovery** process consists of several steps:

- **Redo log application**

  Redo log application is the first step and is performed during initialization, before accepting any connections. If all changes are flushed from the buffer pool to the tablespaces (ibdata* and *.ibd files) at the time of the shutdown or crash, redo log application is skipped. **InnoDB** also skips redo log application if redo log files are missing at startup.

  Removing redo logs to speed up recovery is not recommended, even if some data loss is acceptable. Removing redo logs should only be considered after a clean shutdown, with **innodb_fast_shutdown** set to 0 or 1.

- **Roll back of incomplete transactions**

  Incomplete transactions are any transactions that were active at the time of crash or fast shutdown. The time it takes to roll back an incomplete transaction can be three or four times the amount of time a transaction is active before it is interrupted, depending on server load.

  You cannot cancel transactions that are being rolled back. In extreme cases, when rolling back transactions is expected to take an exceptionally long time, it may be faster to start **InnoDB** with an **innodb_force_recovery** setting of 3 or greater. See Section 14.23.2, “Forcing InnoDB Recovery”.

- **Change buffer merge**

  Applying changes from the change buffer (part of the system tablespace) to leaf pages of secondary indexes, as the index pages are read to the buffer pool.

- **Purge**

  Deleting delete-marked records that are no longer visible to active transactions.

The steps that follow redo log application do not depend on the redo log (other than for logging the writes) and are performed in parallel with normal processing. Of these, only rollback of incomplete transactions is special to crash recovery. The insert buffer merge and the purge are performed during normal processing.
InnoDB and MySQL Replication

After redo log application, **InnoDB** attempts to accept connections as early as possible, to reduce downtime. As part of crash recovery, **InnoDB** rolls back transactions that were not committed or in **XA PREPARE** state when the server crashed. The rollback is performed by a background thread, executed in parallel with transactions from new connections. Until the rollback operation is completed, new connections may encounter locking conflicts with recovered transactions.

In most situations, even if the MySQL server was killed unexpectedly in the middle of heavy activity, the recovery process happens automatically and no action is required of the DBA. If a hardware failure or severe system error corrupted **InnoDB** data, MySQL might refuse to start. In this case, see Section 14.23.2, “Forcing InnoDB Recovery”.

For information about the binary log and **InnoDB** crash recovery, see Section 5.4.4, “The Binary Log”.

### 14.22 InnoDB and MySQL Replication

MySQL replication works for **InnoDB** tables as it does for **MyISAM** tables. It is also possible to use replication in a way where the storage engine on the slave is not the same as the original storage engine on the master. For example, you can replicate modifications to an **InnoDB** table on the master to a **MyISAM** table on the slave. For more information see, Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.

For information about setting up a new slave for a master, see Section 17.1.1.8, “Setting Up Replication with Existing Data”. To make a new slave without taking down the master or an existing slave, use the MySQL Enterprise Backup product.

Transactions that fail on the master do not affect replication at all. MySQL replication is based on the binary log where MySQL writes SQL statements that modify data. A transaction that fails (for example, because of a foreign key violation, or because it is rolled back) is not written to the binary log, so it is not sent to slaves. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”.

#### Replication and CASCADE.

Cascading actions for **InnoDB** tables on the master are replicated on the slave only if the tables sharing the foreign key relation use **InnoDB** on both the master and slave. This is true whether you are using statement-based or row-based replication. Suppose that you have started replication, and then create two tables on the master using the following **CREATE TABLE** statements:

```sql
CREATE TABLE fc1 (  
i INT PRIMARY KEY,  
j INT  
) ENGINE = InnoDB;

CREATE TABLE fc2 (  
m INT PRIMARY KEY,  
n INT,  
FOREIGN KEY ni (n) REFERENCES fc1 (i)  
ON DELETE CASCADE  
) ENGINE = InnoDB;
```

Suppose that the slave does not have **InnoDB** support enabled. If this is the case, then the tables on the slave are created, but they use the **MyISAM** storage engine, and the **FOREIGN KEY** option is ignored. Now we insert some rows into the tables on the master:

```sql
master> INSERT INTO fc1 VALUES (1, 1), (2, 2);  
Query OK, 2 rows affected (0.09 sec)  
Records: 2  Duplicates: 0  Warnings: 0

master> INSERT INTO fc2 VALUES (1, 1), (2, 2), (3, 1);  
Query OK, 3 rows affected (0.19 sec)  
Records: 3  Duplicates: 0  Warnings: 0
```
At this point, on both the master and the slave, table \texttt{fc1} contains 2 rows, and table \texttt{fc2} contains 3 rows, as shown here:

\begin{verbatim}
master> SELECT * FROM fc1;
+---+---+
| i | j |
+---+---+
| 1 | 1 |
| 2 | 2 |
+---+---+
2 rows in set (0.00 sec)
master> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 1 | 1 |
| 2 | 2 |
| 3 | 1 |
+---+---+
3 rows in set (0.00 sec)
slave> SELECT * FROM fc1;
+---+---+
| i | j |
+---+---+
| 1 | 1 |
| 2 | 2 |
+---+---+
2 rows in set (0.00 sec)
slave> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 1 | 1 |
| 2 | 2 |
| 3 | 1 |
+---+---+
3 rows in set (0.00 sec)
\end{verbatim}

Now suppose that you perform the following \texttt{DELETE} statement on the master:

\begin{verbatim}
master> DELETE FROM fc1 WHERE i=1;
Query OK, 1 row affected (0.09 sec)
\end{verbatim}

Due to the cascade, table \texttt{fc2} on the master now contains only 1 row:

\begin{verbatim}
master> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 2 | 2 |
+---+---+
1 row in set (0.00 sec)
\end{verbatim}

However, the cascade does not propagate on the slave because on the slave the \texttt{DELETE} for \texttt{fc1} deletes no rows from \texttt{fc2}. The slave's copy of \texttt{fc2} still contains all of the rows that were originally inserted:

\begin{verbatim}
slave> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 1 | 1 |
| 3 | 1 |
| 2 | 2 |
+---+---+
3 rows in set (0.00 sec)
\end{verbatim}
This difference is due to the fact that the cascading deletes are handled internally by the InnoDB storage engine, which means that none of the changes are logged.

14.23 InnoDB Troubleshooting

The following general guidelines apply to troubleshooting InnoDB problems:

- When an operation fails or you suspect a bug, look at the MySQL server error log (see Section 5.4.2, “The Error Log”). Section B.3.1, “Server Error Message Reference” provides troubleshooting information for some of the common InnoDB-specific errors that you may encounter.

- If the failure is related to a deadlock, run with the innodb_print_all_deadlocks option enabled so that details about each deadlock are printed to the MySQL server error log. For information about deadlocks, see Section 14.10.5, “Deadlocks in InnoDB”.

- Issues relating to the InnoDB data dictionary include failed CREATE TABLE statements (orphan table files), inability to open InnoDB files, and system cannot find the path specified errors. For information about these sorts of problems and errors, see Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”.

- When troubleshooting, it is usually best to run the MySQL server from the command prompt, rather than through mysqld_safe or as a Windows service. You can then see what mysqld prints to the console, and so have a better grasp of what is going on. On Windows, start mysqld with the --console option to direct the output to the console window.

- Enable the InnoDB Monitors to obtain information about a problem (see Section 14.20, “InnoDB Monitors”). If the problem is performance-related, or your server appears to be hung, you should enable the standard Monitor to print information about the internal state of InnoDB. If the problem is with locks, enable the Lock Monitor. If the problem is in creation of tables or other data dictionary operations, enable the Table Monitor to print the contents of the InnoDB internal data dictionary. To see tablespace information enable the Tablespace Monitor.

   InnoDB temporarily enables standard InnoDB Monitor output under the following conditions:

   - A long semaphore wait
   - InnoDB cannot find free blocks in the buffer pool
   - Over 67% of the buffer pool is occupied by lock heaps or the adaptive hash index
   - If you suspect that a table is corrupt, run CHECK TABLE on that table.

14.23.1 Troubleshooting InnoDB I/O Problems

The troubleshooting steps for InnoDB I/O problems depend on when the problem occurs: during startup of the MySQL server, or during normal operations when a DML or DDL statement fails due to problems at the file system level.

Initialization Problems

If something goes wrong when InnoDB attempts to initialize its tablespace or its log files, delete all files created by InnoDB: all ibdata files and all ib_logfile files. If you already created some InnoDB tables, also delete the corresponding .frm files for these tables, and any .ibd files if you are using
multiple tablespaces, from the MySQL database directories. Then try the `InnoDB` database creation again. For easiest troubleshooting, start the MySQL server from a command prompt so that you see what is happening.

### Runtime Problems

If `InnoDB` prints an operating system error during a file operation, usually the problem has one of the following solutions:

- Make sure the `InnoDB` data file directory and the `InnoDB` log directory exist.
- Make sure `mysqld` has access rights to create files in those directories.
- Make sure `mysqld` can read the proper `my.cnf` or `my.ini` option file, so that it starts with the options that you specified.
- Make sure the disk is not full and you are not exceeding any disk quota.
- Make sure that the names you specify for subdirectories and data files do not clash.
- Doublecheck the syntax of the `innodb_data_home_dir` and `innodb_data_file_path` values. In particular, any `MAX` value in the `innodb_data_file_path` option is a hard limit, and exceeding that limit causes a fatal error.

### 14.23.2 Forcing InnoDB Recovery

To investigate database page corruption, you might dump your tables from the database with `SELECT ... INTO OUTFILE`. Usually, most of the data obtained in this way is intact. Serious corruption might cause `SELECT * FROM tbl_name` statements or `InnoDB` background operations to crash or assert, or even cause `InnoDB` roll-forward recovery to crash. In such cases, you can use the `innodb_force_recovery` option to force the `InnoDB` storage engine to start up while preventing background operations from running, so that you can dump your tables. For example, you can add the following line to the `[mysqld]` section of your option file before restarting the server:

```
[mysqld]
innoadb_force_recovery = 1
```

For information about using option files, see Section 4.2.2.2, “Using Option Files”.

---

**Warning**

Only set `innodb_force_recovery` to a value greater than 0 in an emergency situation, so that you can start `InnoDB` and dump your tables. Before doing so, ensure that you have a backup copy of your database in case you need to recreate it. Values of 4 or greater can permanently corrupt data files. Only use an `innodb_force_recovery` setting of 4 or greater on a production server instance after you have successfully tested the setting on a separate physical copy of your database. When forcing `InnoDB` recovery, you should always start with `innodb_force_recovery=1` and only increase the value incrementally, as necessary.

`innodb_force_recovery` is 0 by default (normal startup without forced recovery). The permissible nonzero values for `innodb_force_recovery` are 1 to 6. A larger value includes the functionality of lesser values. For example, a value of 3 includes all of the functionality of values 1 and 2.

If you are able to dump your tables with an `innodb_force_recovery` value of 3 or less, then you are relatively safe that only some data on corrupt individual pages is lost. A value of 4 or greater is considered
dangerous because data files can be permanently corrupted. A value of 6 is considered drastic because
database pages are left in an obsolete state, which in turn may introduce more corruption into B-trees and
other database structures.

As a safety measure, InnoDB prevents INSERT, UPDATE, or DELETE operations when
innodb_force_recovery is greater than 0.

• 1 (SRV_FORCE_IGNORE_CORRUPT)
  Lets the server run even if it detects a corrupt page. Tries to make SELECT * FROM tbl_name jump
  over corrupt index records and pages, which helps in dumping tables.

• 2 (SRV_FORCE_NO_BACKGROUND)
  Prevents the master thread and any purge threads from running. If a crash would occur during the purge
  operation, this recovery value prevents it.

• 3 (SRV_FORCE_NO_TRX_UNDO)
  Does not run transaction rollbacks after crash recovery.

• 4 (SRV_FORCE_NO_IBUF_MERGE)
  Prevents insert buffer merge operations. If they would cause a crash, does not do them. Does not
  calculate table statistics. This value can permanently corrupt data files. After using this value, be
  prepared to drop and recreate all secondary indexes.

• 5 (SRV_FORCE_NO_UNDO_LOG_SCAN)
  Does not look at undo logs when starting the database: InnoDB treats even incomplete transactions as
  committed. This value can permanently corrupt data files.

• 6 (SRV_FORCE_NO_LOG_REDO)
  Does not do the redo log roll-forward in connection with recovery. This value can permanently corrupt
  data files. Leaves database pages in an obsolete state, which in turn may introduce more corruption into
  B-trees and other database structures.

You can SELECT from tables to dump them, or DROP or CREATE tables even if forced recovery is used. If
you know that a given table is causing a crash on rollback, you can drop it. You can also use this to stop
a runaway rollback caused by a failing mass import or ALTER TABLE: kill the mysql process and set
innodb_force_recovery to 3 to bring the database up without the rollback, then DROP the table that is
causing the runaway rollback.

If corruption within the table data prevents you from dumping the entire table contents, a query with an
ORDER BY primary_key DESC clause might be able to dump the portion of the table after the corrupted
part.

If a high innodb_force_recovery value is required to start InnoDB, there may be corrupted data
structures that could cause complex queries (queries containing WHERE, ORDER BY, or other clauses) to
fail. In this case, you may only be able to run basic SELECT * FROM t queries.

14.23.3 Troubleshooting InnoDB Data Dictionary Operations

Information about table definitions is stored both in the .frm files, and in the InnoDB data dictionary. If you
move .frm files around, or if the server crashes in the middle of a data dictionary operation, these sources
of information can become inconsistent.
If a data dictionary corruption or consistency issue prevents you from starting InnoDB, see Section 14.23.2, "Forcing InnoDB Recovery" for information about manual recovery.

CREATE TABLE Failure Due to Orphan Table

A symptom of an out-of-sync data dictionary is that a CREATE TABLE statement fails. If this occurs, look in the server's error log. If the log says that the table already exists inside the InnoDB internal data dictionary, you have an orphan table inside the InnoDB tablespace files that has no corresponding .frm file. The error message looks like this:

```
InnoDB: Error: table test/parent already exists in InnoDB internal
InnoDB: data dictionary. Have you deleted the .frm file
InnoDB: and not used DROP TABLE? Have you used DROP DATABASE
InnoDB: for InnoDB tables in MySQL version <= 3.23.43?
InnoDB: See the Restrictions section of the InnoDB manual.
InnoDB: You can drop the orphaned table inside InnoDB by
InnoDB: creating an InnoDB table with the same name in another
InnoDB: database and moving the .frm file to the current database.
InnoDB: Then MySQL thinks the table exists, and DROP TABLE will
InnoDB: succeed.
```

You can drop the orphan table by following the instructions given in the error message. If you are still unable to use DROP TABLE successfully, the problem may be due to name completion in the mysql client. To work around this problem, start the mysql client with the --skip-auto-rehash option and try DROP TABLE again. (With name completion on, mysql tries to construct a list of table names, which fails when a problem such as just described exists.)

Cannot Open File Error

Another symptom of an out-of-sync data dictionary is that MySQL prints an error that it cannot open an InnoDB file:

```
ERROR 1016: Can't open file: 'child2.ibd'. (errno: 1)
```

In the error log you can find a message like this:

```
InnoDB: Cannot find table test/child2 from the internal data dictionary
InnoDB: of InnoDB though the .frm file for the table exists. Maybe you
InnoDB: have deleted and recreated InnoDB data files but have forgotten
InnoDB: to delete the corresponding .frm files of InnoDB tables?
```

This means that there is an orphan .frm file without a corresponding table inside InnoDB. You can drop the orphan .frm file by deleting it manually.

Orphan Temporary Tables

If MySQL exits in the middle of an ALTER TABLE operation, you may be left with an orphan temporary table that takes up space on your system. This section describes how to identify and remove orphan temporary tables.

Orphan temporary table names begin with an #sql- prefix (e.g., #sql-540_3). The accompanying .frm file has the same base name as the orphan temporary table.

**Note**

If there is no .frm file, you can recreate it. The .frm file must have the same table schema as the orphan temporary table (it must have the same columns and indexes) and must be placed in the database directory of the orphan temporary table.
InnoDB Error Handling

To identify orphan temporary tables on your system, you can view Table Monitor output. Look for table names that begin with `#sql`. If the original table resides in a file-per-table tablespace, the tablespace file (the `#sql-* .ibd` file) for the orphan temporary table should be visible in the database directory.

To remove an orphan temporary table, drop the table by issuing a `DROP TABLE` statement, prefixing the name of the table with `#mysql50#` and enclosing the table name in backticks. For example:

```
mysql> DROP TABLE `#mysql50##sql-540_3`;
```

The `#mysql50#` prefix tells MySQL to ignore `file name safe encoding` introduced in MySQL 5.1. Enclosing the table name in backticks is required to perform SQL statements on table names with special characters such as “#”.

Tablespace Does Not Exist

With `innodb_file_per_table` enabled, the following message might occur if the `.frm` or `.ibd` files (or both) are missing:

```
InnoDB: in InnoDB data dictionary has tablespace id N,
InnoDB: but tablespace with that id or name does not exist. Have
InnoDB: you deleted or moved .ibd files?
InnoDB: This may also be a table created with CREATE TEMPORARY TABLE
InnoDB: whose .ibd and .frm files MySQL automatically removed, but the
InnoDB: table still exists in the InnoDB internal data dictionary.
```

If this occurs, try the following procedure to resolve the problem:

1. Create a matching `.frm` file in some other database directory and copy it to the database directory where the orphan table is located.
2. Issue `DROP TABLE` for the original table. That should successfully drop the table and InnoDB should print a warning to the error log that the `.ibd` file was missing.

14.23.4 InnoDB Error Handling

The following items describe how InnoDB performs error handling. InnoDB sometimes rolls back only the statement that failed, other times it rolls back the entire transaction.

- If you run out of file space in a tablespace, a MySQL Table is full error occurs and InnoDB rolls back the SQL statement.

- A transaction deadlock causes InnoDB to roll back the entire transaction. Retry the whole transaction when this happens.

A lock wait timeout causes InnoDB to roll back only the single statement that was waiting for the lock and encountered the timeout. (To have the entire transaction roll back, start the server with the `--innodb-rollback-on-timeout` option.) Retry the statement if using the current behavior, or the entire transaction if using `--innodb-rollback-on-timeout`.

Both deadlocks and lock wait timeouts are normal on busy servers and it is necessary for applications to be aware that they may happen and handle them by retrying. You can make them less likely by doing as little work as possible between the first change to data during a transaction and the commit, so the locks are held for the shortest possible time and for the smallest possible number of rows. Sometimes splitting work between different transactions may be practical and helpful.

When a transaction rollback occurs due to a deadlock or lock wait timeout, it cancels the effect of the statements within the transaction. But if the start-transaction statement was a `START TRANSACTION` or
BEGIN statement, rollback does not cancel that statement. Further SQL statements become part of the transaction until the occurrence of COMMIT, ROLLBACK, or some SQL statement that causes an implicit commit.

- A duplicate-key error rolls back the SQL statement, if you have not specified the IGNORE option in your statement.
- A row too long error rolls back the SQL statement.
- Other errors are mostly detected by the MySQL layer of code (above the InnoDB storage engine level), and they roll back the corresponding SQL statement. Locks are not released in a rollback of a single SQL statement.

During implicit rollbacks, as well as during the execution of an explicit ROLLBACK SQL statement, SHOW PROCESSLIST displays Rolling back in the State column for the relevant connection.

14.24 InnoDB Limits

This section describes limits for InnoDB tables, indexes, tablespaces, and other aspects of the InnoDB storage engine.

- A table can contain a maximum of 1000 columns.
- A table can contain a maximum of 64 secondary indexes.
- By default, the index key prefix length limit is 767 bytes. See Section 13.1.13, “CREATE INDEX Statement”. For example, you might hit this limit with a column prefix index of more than 255 characters on a TEXT or VARCHAR column, assuming a utf8mb3 character set and the maximum of 3 bytes for each character. When the innodb_large_prefix configuration option is enabled, the index key prefix length limit is raised to 3072 bytes for InnoDB tables that use the DYNAMIC or COMPRESSED row format.

If you specify an index key prefix length that exceeds the limit, the length is silently reduced to the maximum length.

When innodb_large_prefix is enabled, attempting to create an index key prefix with a length greater than 3072 bytes for a DYNAMIC or COMPRESSED table causes an ER_INDEX_COLUMN_TOO_LONG error.

The limits that apply to index key prefixes also apply to full-column index keys.

- A maximum of 16 columns is permitted for multicolumn indexes. Exceeding the limit returns an error.

ERROR 1070 (42000): Too many key parts specified; max 16 parts allowed

- The maximum row size, excluding any variable-length columns that are stored off-page, is slightly less than half of a page. That is, the maximum row size is about 8000 bytes. LONGBLOB and LONGTEXT columns must be less than 4GB, and the total row size, including BLOB and TEXT columns must be less than 4GB.

If a row is less than half a page long, all of it is stored locally within the page. If it exceeds half a page, variable-length columns are chosen for off-page storage until the row fits within half a page, as described in Section 14.15.2, “File Space Management”.

The row size for BLOB columns that are chosen for off-page storage should not exceed 10% of the combined redo log file size. If the row size exceeds 10% of the combined redo log file size, InnoDB could overwrite the most recent checkpoint which may result in lost data during crash recovery. (Bug#69477).
• Although InnoDB supports row sizes larger than 65,535 bytes internally, MySQL itself imposes a row-size limit of 65,535 for the combined size of all columns. See Section 8.4.7, “Limits on Table Column Count and Row Size”.

• On some older operating systems, files must be less than 2GB. This is not an InnoDB limitation. If you require a large system tablespace, configure it using several smaller data files rather than one large data file, or distribute table data across file-per-table data files.

• The combined maximum size for InnoDB log files is 4GB.

• The minimum tablespace size is slightly larger than 10MB. The maximum tablespace size is 64TB, which is also the maximum size for a table.

• Tablespace files cannot exceed 4GB on Windows 32-bit systems (Bug #80149).

• The path of a tablespace file, including the file name, cannot exceed the MAX_PATH limit on Windows. Prior to Windows 10, the MAX_PATH limit is 260 characters. As of Windows 10, version 1607, MAX_PATH limitations are removed from common Win32 file and directory functions, but you must enable the new behavior.

• For limits associated with concurrent read-write transactions, see Section 14.9.7, “Undo Logs”.

14.25 InnoDB Restrictions and Limitations

This section describes restrictions and limitations of the InnoDB storage engine.

• You cannot create a table with a column name that matches the name of an internal InnoDB column (including DB_ROW_ID, DB_TRX_ID, and DB_ROLL_PTR). This restriction applies to use of the names in any lettercase.

  mysql> CREATE TABLE t1 (c1 INT, db_row_id INT) ENGINE=INNODB;
  ERROR 1166 (42000): Incorrect column name 'db_row_id'

• SHOW TABLE STATUS does not provide accurate statistics for InnoDB tables except for the physical size reserved by the table. The row count is only a rough estimate used in SQL optimization.

• InnoDB does not keep an internal count of rows in a table because concurrent transactions might “see” different numbers of rows at the same time. Consequently, SELECT COUNT(*) statements only count rows visible to the current transaction.

  For information about how InnoDB processes SELECT COUNT(*) statements, refer to the COUNT() description in Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”.

• Changing the page size is not a supported operation and there is no guarantee that InnoDB functions normally with a page size other than 16KB. Problems compiling or running InnoDB may occur. In particular, ROW_FORMAT=COMPRESSED in the Barracuda file format assumes that the page size is at most 16KB and uses 14-bit pointers.

• A version of InnoDB built for one page size cannot use data files or log files from a version built for a different page size. This limitation could affect restore or downgrade operations using data from MySQL 5.6, which does support page sizes other than 16KB.

• InnoDB does not support FULLTEXT indexes.

• InnoDB does not support indexes on spatial data type columns.

• For limitations associated with fast index creation, see Section 14.16.6, “Limitations of Fast Index Creation”.
Chapter 15 Alternative Storage Engines

Table of Contents

15.1 Setting the Storage Engine ................................................................. 1891
15.2 Overview of MySQL Storage Engine Architecture ................................. 1892
  15.2.1 Pluggable Storage Engine Architecture ........................................ 1892
  15.2.2 The Common Database Server Layer .............................................. 1893
15.3 The MyISAM Storage Engine .............................................................. 1893
  15.3.1 MyISAM Startup Options .............................................................. 1896
  15.3.2 Space Needed for Keys ................................................................. 1898
  15.3.3 MyISAM Table Storage Formats ..................................................... 1898
  15.3.4 MyISAM Table Problems .............................................................. 1901
15.4 The MEMORY Storage Engine ............................................................ 1902
15.5 The CSV Storage Engine ................................................................. 1907
  15.5.1 Repairing and Checking CSV Tables .............................................. 1908
  15.5.2 CSV Limitations ......................................................................... 1908
15.6 The ARCHIVE Storage Engine ........................................................... 1909
15.7 The BLACKHOLE Storage Engine ....................................................... 1910
15.8 The MERGE Storage Engine ............................................................... 1913
  15.8.1 MERGE Table Advantages and Disadvantages .................................. 1915
  15.8.2 MERGE Table Problems .............................................................. 1916
15.9 The FEDERATED Storage Engine ....................................................... 1918
  15.9.1 FEDERATED Storage Engine Overview ........................................... 1918
  15.9.2 How to Create FEDERATED Tables ............................................... 1919
  15.9.3 FEDERATED Storage Engine Notes and Tips ................................... 1922
  15.9.4 FEDERATED Storage Engine Resources ........................................ 1923
15.10 The EXAMPLE Storage Engine ......................................................... 1923
15.11 Other Storage Engines .................................................................... 1924

Storage engines are MySQL components that handle the SQL operations for different table types. MySQL storage engines include both those that handle transaction-safe tables and those that handle nontransaction-safe tables. InnoDB is the default storage engine as of MySQL 5.5.5 (The CREATE TABLE statement in MySQL 5.5 creates InnoDB tables by default.)

MySQL uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

To determine which storage engines your server supports, use the SHOW ENGINES statement. The value in the Support column indicates whether an engine can be used. A value of YES, NO, or DEFAULT indicates that an engine is available, not available, or available and currently set as the default storage engine.

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
    Engine: PERFORMANCE_SCHEMA
    Support: YES
    Comment: Performance Schema
   Transactions: NO
    XA: NO
   Savepoints: NO
*************************** 2. row ***************************
    Engine: InnoDB
    Support: DEFAULT
```
MySQL 5.5 Supported Storage Engines

<table>
<thead>
<tr>
<th>Engine</th>
<th>Support</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRG_MYISAM</td>
<td>YES</td>
<td>Collection of identical MyISAM tables</td>
</tr>
<tr>
<td>BLACKHOLE</td>
<td>YES</td>
<td>/dev/null storage engine (anything you write to it disappears)</td>
</tr>
<tr>
<td>MyISAM</td>
<td>YES</td>
<td>MyISAM storage engine</td>
</tr>
<tr>
<td>Memory</td>
<td>YES</td>
<td>Stores all data in RAM for extremely fast access</td>
</tr>
<tr>
<td>Merge</td>
<td>YES</td>
<td>Enables a MySQL DBA or developer to logically group</td>
</tr>
<tr>
<td>Archive</td>
<td>YES</td>
<td>Provides the perfect solution for storing and retrieving</td>
</tr>
</tbody>
</table>

This chapter covers use cases for special-purpose MySQL storage engines. It does not cover the default InnoDB storage engine or the NDB storage engine which are covered in Chapter 14, *The InnoDB Storage Engine* and Chapter 18, *MySQL NDB Cluster 7.2*. For advanced users, this chapter also contains a description of the pluggable storage engine architecture (see Section 15.2, “Overview of MySQL Storage Engine Architecture”).

For information about features offered in commercial MySQL Server binaries, see *MySQL Editions*, on the MySQL website. The storage engines available might depend on which edition of MySQL you are using.

For answers to some commonly asked questions about MySQL storage engines, see Section A.2, “MySQL 5.5 FAQ: Storage Engines”.

**MySQL 5.5 Supported Storage Engines**

- **InnoDB**: The default storage engine as of MySQL 5.5.5. InnoDB is a transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. InnoDB row-level locking (without escalation to coarser granularity locks) and Oracle-style consistent nonlocking reads increase multi-user concurrency and performance. InnoDB stores user data in clustered indexes to reduce I/O for common queries based on primary keys. To maintain data integrity, InnoDB also supports FOREIGN KEY referential-integrity constraints. For more information about InnoDB, see Chapter 14, *The InnoDB Storage Engine*.
- **MyISAM**: The MySQL storage engine that is used the most in Web, data warehousing, and other application environments. MyISAM is supported in all MySQL configurations, and is the default storage engine prior to MySQL 5.5.5.
- **Memory**: Stores all data in RAM for extremely fast access in environments that require quick lookups of reference and other like data. This engine was formerly known as the HEAP engine.
- **Merge**: Enables a MySQL DBA or developer to logically group a series of identical MyISAM tables and reference them as one object. Good for VLDB environments such as data warehousing.
- **Archive**: Provides the perfect solution for storing and retrieving large amounts of seldom-referenced historical, archived, or security audit information.
MySQL 5.5 Supported Storage Engines

- **Federated**: Offers the ability to link separate MySQL servers to create one logical database from many physical servers. Very good for distributed or data mart environments.

- **NDB** (also known as **NDBCLUSTER**)—This clustered database engine is particularly suited for applications that require the highest possible degree of uptime and availability.

  **Note**

  The NDB storage engine is not supported in standard MySQL 5.5 releases. Currently supported NDB Cluster releases include MySQL NDB Cluster 7.0 and MySQL NDB Cluster 7.1, which are based on MySQL 5.1, and MySQL NDB Cluster 7.2, which is based on MySQL 5.5. While based on MySQL Server, these releases also contain support for NDB.

- **CSV**: The CSV storage engine stores data in text files using comma-separated values format. You can use the CSV engine to easily exchange data between other software and applications that can import and export in CSV format.

- **Blackhole**: The Blackhole storage engine accepts but does not store data and retrievals always return an empty set. The functionality can be used in distributed database design where data is automatically replicated, but not stored locally.

- **Example**: The Example storage engine is “stub” engine that does nothing. You can create tables with this engine, but no data can be stored in them or retrieved from them. The purpose of this engine is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.

It is important to remember that you are not restricted to using the same storage engine for an entire server or schema: you can use a different storage engine for each table in your schema.

### Choosing a Storage Engine

The various storage engines provided with MySQL are designed with different use cases in mind. The following table provides an overview of some storage engines provided with MySQL, with clarifying notes following the table.

#### Table 15.1 Storage Engines Feature Summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>MyISAM</th>
<th>Memory</th>
<th>InnoDB</th>
<th>Archive</th>
<th>NDB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B-tree indexes</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Backup/point-in-time recovery</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Cluster database support</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Clustered indexes</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Compressed data</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

1. Note
2. Note
### MySQL 5.5 Supported Storage Engines

<table>
<thead>
<tr>
<th>Feature</th>
<th>MyISAM</th>
<th>Memory</th>
<th>InnoDB</th>
<th>Archive</th>
<th>NDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data caches</td>
<td>No</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Encrypted data</td>
<td>Yes (note 3)</td>
<td>Yes (note 3)</td>
<td>Yes (note 4)</td>
<td>Yes (note 3)</td>
<td>Yes (note 3)</td>
</tr>
<tr>
<td>Foreign key support</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes (note 5)</td>
</tr>
<tr>
<td>Full-text search indexes</td>
<td>Yes</td>
<td>No</td>
<td>Yes (note 6)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Geospatial data type support</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Geospatial indexing support</td>
<td>No</td>
<td>Yes (note 7)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hash indexes</td>
<td>No</td>
<td>Yes</td>
<td>No (note 8)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Index caches</td>
<td>Yes</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Locking granularity</td>
<td>Table</td>
<td>Table</td>
<td>Row</td>
<td>Row</td>
<td>Row</td>
</tr>
<tr>
<td>MVCC</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Replication support (note 1)</td>
<td>Yes</td>
<td>Limited (note 9)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Storage limits</td>
<td>256TB</td>
<td>RAM</td>
<td>64TB</td>
<td>None</td>
<td>384EB</td>
</tr>
<tr>
<td>T-tree indexes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Transactions</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Update statistics for data</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>dictionary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. Implemented in the server, rather than in the storage engine.

2. Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.

3. Implemented in the server via encryption functions.

4. Implemented in the server via encryption functions; In MySQL 5.7 and later, data-at-rest tablespace encryption is supported.
5. Support for foreign keys is available in MySQL Cluster NDB 7.3 and later.
6. InnoDB support for FULLTEXT indexes is available in MySQL 5.6 and later.
7. InnoDB support for geospatial indexing is available in MySQL 5.7 and later.
8. InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.
9. See the discussion later in this section.

15.1 Setting the Storage Engine

When you create a new table, you can specify which storage engine to use by adding an `ENGINE` table option to the `CREATE TABLE` statement:

```
-- ENGINE=INNODB not needed as of 5.5.5 unless you have set a
-- different default storage engine.
CREATE TABLE t1 (i INT) ENGINE = INNODB;
-- Simple table definitions can be switched from one to another.
CREATE TABLE t2 (i INT) ENGINE = CSV;
CREATE TABLE t3 (i INT) ENGINE = MEMORY;
```

If you omit the `ENGINE` option, the default storage engine is used. The default engine is InnoDB as of MySQL 5.5.5 (MyISAM before 5.5.5). You can specify the default engine by using the `--default-storage-engine` server startup option, or by setting the `default-storage-engine` option in the `my.cnf` configuration file.

At runtime, you can set the default storage engine to be used during the current session by setting the `default_storage_engine` system variable:

```
SET default_storage_engine=MYISAM;
```

When MySQL is installed on Windows using the MySQL Configuration Wizard, the InnoDB or MyISAM storage engine can be selected as the default. See Section 2.3.5.5, “The Database Usage Dialog”.

To convert a table from one storage engine to another, use an `ALTER TABLE` statement that indicates the new engine:

```
ALTER TABLE t ENGINE = MYISAM;
```


If you try to use a storage engine that is not compiled in or that is compiled in but deactivated, MySQL instead creates a table using the default storage engine. This behavior is convenient when you want to copy tables between MySQL servers that support different storage engines. (For example, in a replication setup, perhaps your master server supports transactional storage engines for increased safety, but the slave servers use only nontransactional storage engines for greater speed.)

This automatic substitution of the default storage engine for unavailable engines can be confusing for new MySQL users. A warning is generated whenever a storage engine is automatically changed. To prevent this from happening if the desired engine is unavailable, enable the `NO_ENGINE_SUBSTITUTION` SQL mode. In this case, an error occurs instead of a warning and the table is not created or altered if the desired engine is unavailable. See Section 5.1.10, “Server SQL Modes”.

For new tables, MySQL always creates an `.frm` file to hold the table and column definitions. The table’s index and data may be stored in one or more other files, depending on the storage engine. The server creates the `.frm` file above the storage engine level. Individual storage engines create any additional files required for the tables that they manage. If a table name contains special characters, the names for
the table files contain encoded versions of those characters as described in Section 9.2.4, “Mapping of Identifiers to File Names”.

A database may contain tables of different types. That is, tables need not all be created with the same storage engine.

15.2 Overview of MySQL Storage Engine Architecture

The MySQL pluggable storage engine architecture enables a database professional to select a specialized storage engine for a particular application need while being completely shielded from the need to manage any specific application coding requirements. The MySQL server architecture isolates the application programmer and DBA from all of the low-level implementation details at the storage level, providing a consistent and easy application model and API. Thus, although there are different capabilities across different storage engines, the application is shielded from these differences.

The pluggable storage engine architecture provides a standard set of management and support services that are common among all underlying storage engines. The storage engines themselves are the components of the database server that actually perform actions on the underlying data that is maintained at the physical server level.

This efficient and modular architecture provides huge benefits for those wishing to specifically target a particular application need—such as data warehousing, transaction processing, or high availability situations—while enjoying the advantage of utilizing a set of interfaces and services that are independent of any one storage engine.

The application programmer and DBA interact with the MySQL database through Connector APIs and service layers that are above the storage engines. If application changes bring about requirements that demand the underlying storage engine change, or that one or more storage engines be added to support new needs, no significant coding or process changes are required to make things work. The MySQL server architecture shields the application from the underlying complexity of the storage engine by presenting a consistent and easy-to-use API that applies across storage engines.

15.2.1 Pluggable Storage Engine Architecture

MySQL Server uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

Plugging in a Storage Engine

Before a storage engine can be used, the storage engine plugin shared library must be loaded into MySQL using the `INSTALL PLUGIN` statement. For example, if the EXAMPLE engine plugin is named `example` and the shared library is named `ha_example.so`, you load it with the following statement:

```
INSTALL PLUGIN example SONAME 'ha_example.so';
```

To install a pluggable storage engine, the plugin file must be located in the MySQL plugin directory, and the user issuing the `INSTALL PLUGIN` statement must have `INSERT` privilege for the `mysql.plugin` table.

The shared library must be located in the MySQL server plugin directory, the location of which is given by the `plugin_dir` system variable.

Unplugging a Storage Engine

To unplug a storage engine, use the `UNINSTALL PLUGIN` statement:
If you unplug a storage engine that is needed by existing tables, those tables become inaccessible, but will still be present on disk (where applicable). Ensure that there are no tables using a storage engine before you unplug the storage engine.

### 15.2.2 The Common Database Server Layer

A MySQL pluggable storage engine is the component in the MySQL database server that is responsible for performing the actual data I/O operations for a database as well as enabling and enforcing certain feature sets that target a specific application need. A major benefit of using specific storage engines is that you are only delivered the features needed for a particular application, and therefore you have less system overhead in the database, with the end result being more efficient and higher database performance. This is one of the reasons that MySQL has always been known to have such high performance, matching or beating proprietary monolithic databases in industry standard benchmarks.

From a technical perspective, what are some of the unique supporting infrastructure components that are in a storage engine? Some of the key feature differentiations include:

- **Concurrency**: Some applications have more granular lock requirements (such as row-level locks) than others. Choosing the right locking strategy can reduce overhead and therefore improve overall performance. This area also includes support for capabilities such as multi-version concurrency control or “snapshot” read.

- **Transaction Support**: Not every application needs transactions, but for those that do, there are very well defined requirements such as ACID compliance and more.

- **Referential Integrity**: The need to have the server enforce relational database referential integrity through DDL defined foreign keys.

- **Physical Storage**: This involves everything from the overall page size for tables and indexes as well as the format used for storing data to physical disk.

- **Index Support**: Different application scenarios tend to benefit from different index strategies. Each storage engine generally has its own indexing methods, although some (such as B-tree indexes) are common to nearly all engines.

- **Memory Caches**: Different applications respond better to some memory caching strategies than others, so although some memory caches are common to all storage engines (such as those used for user connections or MySQL’s high-speed Query Cache), others are uniquely defined only when a particular storage engine is put in play.

- **Performance Aids**: This includes multiple I/O threads for parallel operations, thread concurrency, database checkpointing, bulk insert handling, and more.

- **Miscellaneous Target Features**: This may include support for geospatial operations, security restrictions for certain data manipulation operations, and other similar features.

Each set of the pluggable storage engine infrastructure components are designed to offer a selective set of benefits for a particular application. Conversely, avoiding a set of component features helps reduce unnecessary overhead. It stands to reason that understanding a particular application’s set of requirements and selecting the proper MySQL storage engine can have a dramatic impact on overall system efficiency and performance.

### 15.3 The MyISAM Storage Engine
Before MySQL 5.5.5, MyISAM is the default storage engine. (The default was changed to InnoDB in MySQL 5.5.5.) MyISAM is based on the older (and no longer available) ISAM storage engine but has many useful extensions.

### Table 15.2 MyISAM Storage Engine Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-tree indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backup/point-in-time recovery</td>
<td>(Implemented in the server, rather than in the storage engine.) Yes</td>
</tr>
<tr>
<td>Cluster database support</td>
<td>No</td>
</tr>
<tr>
<td>Clustered indexes</td>
<td>No</td>
</tr>
<tr>
<td>Compressed data</td>
<td>Yes (Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.)</td>
</tr>
<tr>
<td>Data caches</td>
<td>No</td>
</tr>
<tr>
<td>Encrypted data</td>
<td>Yes (Implemented in the server via encryption functions.)</td>
</tr>
<tr>
<td>Foreign key support</td>
<td>No</td>
</tr>
<tr>
<td>Full-text search indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Geospatial data type support</td>
<td>Yes</td>
</tr>
<tr>
<td>Geospatial indexing support</td>
<td>Yes</td>
</tr>
<tr>
<td>Hash indexes</td>
<td>No</td>
</tr>
<tr>
<td>Index caches</td>
<td>Yes</td>
</tr>
<tr>
<td>Locking granularity</td>
<td>Table</td>
</tr>
<tr>
<td>MVCC</td>
<td>No</td>
</tr>
<tr>
<td>Replication support</td>
<td>(Implemented in the server, rather than in the storage engine.) Yes</td>
</tr>
<tr>
<td>Storage limits</td>
<td>256TB</td>
</tr>
<tr>
<td>T-tree indexes</td>
<td>No</td>
</tr>
<tr>
<td>Transactions</td>
<td>No</td>
</tr>
<tr>
<td>Update statistics for data dictionary</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Each MyISAM table is stored on disk in three files. The files have names that begin with the table name and have an extension to indicate the file type. An .frm file stores the table format. The data file has an .MYD (MYData) extension. The index file has an .MYI (MYIndex) extension.

To specify explicitly that you want a MyISAM table, indicate that with an ENGINE table option:

```
CREATE TABLE t (i INT) ENGINE = MYISAM;
```

As of MySQL 5.5.5, it is normally necessary to use ENGINE to specify the MyISAM storage engine because InnoDB is the default engine. Before 5.5.5, this is unnecessary because MyISAM is the default engine unless the default has been changed. To ensure that MyISAM is used in situations where the default might have been changed, include the ENGINE option explicitly.
You can check or repair MyISAM tables with the mysqlcheck client or myisamchk utility. You can also compress MyISAM tables with myisampack to take up much less space. See Section 4.5.3, "mysqlcheck — A Table Maintenance Program", Section 4.6.3, "myisamchk — MyISAM Table-Maintenance Utility", and Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables".

MyISAM tables have the following characteristics:

- All data values are stored with the low byte first. This makes the data machine and operating system independent. The only requirements for binary portability are that the machine uses two's-complement signed integers and IEEE floating-point format. These requirements are widely used among mainstream machines. Binary compatibility might not be applicable to embedded systems, which sometimes have peculiar processors.

  There is no significant speed penalty for storing data low byte first; the bytes in a table row normally are unaligned and it takes little more processing to read an unaligned byte in order than in reverse order. Also, the code in the server that fetches column values is not time critical compared to other code.

- All numeric key values are stored with the high byte first to permit better index compression.

- Large files (up to 63-bit file length) are supported on file systems and operating systems that support large files.

- There is a limit of \((2^{32})^2 \ (1.844E+19)\) rows in a MyISAM table.

- The maximum number of indexes per MyISAM table is 64.

  The maximum number of columns per index is 16.

- The maximum key length is 1000 bytes. This can also be changed by changing the source and recompiling. For the case of a key longer than 250 bytes, a larger key block size than the default of 1024 bytes is used.

- When rows are inserted in sorted order (as when you are using an AUTO_INCREMENT column), the index tree is split so that the high node only contains one key. This improves space utilization in the index tree.

- Internal handling of one AUTO_INCREMENT column per table is supported. MyISAM automatically updates this column for INSERT and UPDATE operations. This makes AUTO_INCREMENT columns faster (at least 10%). Values at the top of the sequence are not reused after being deleted. (When an AUTO_INCREMENT column is defined as the last column of a multiple-column index, reuse of values deleted from the top of a sequence does occur.) The AUTO_INCREMENT value can be reset with ALTER TABLE or myisamchk.

- Dynamic-sized rows are much less fragmented when mixing deletes with updates and inserts. This is done by automatically combining adjacent deleted blocks and by extending blocks if the next block is deleted.

- MyISAM supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can INSERT new rows into it at the same time that other threads are reading from the table. A free block can occur as a result of deleting rows or an update of a dynamic length row with more data than its current contents. When all free blocks are used up (filled in), future inserts become concurrent again. See Section 8.11.3, “Concurrent Inserts”.

- You can put the data file and index file in different directories on different physical devices to get more speed with the DATA DIRECTORY and INDEX DIRECTORY table options to CREATE TABLE. See Section 13.1.17, “CREATE TABLE Statement”.

- BLOB and TEXT columns can be indexed.
• **NULL** values are permitted in indexed columns. This takes 0 to 1 bytes per key.

• Each character column can have a different character set. See Chapter 10, *Character Sets, Collations, Unicode*.

• There is a flag in the **MyISAM** index file that indicates whether the table was closed correctly. If **mysql** is started with the **myisam_recover_options** system variable set, **MyISAM** tables are automatically checked when opened, and are repaired if the table wasn’t closed properly.

• **myisamchk** marks tables as checked if you run it with the **--update-state** option. **myisamchk --fast** checks only those tables that don’t have this mark.

• **myisamchk --analyze** stores statistics for portions of keys, as well as for entire keys.

• **myisampack** can pack **BLOB** and **VARCHAR** columns.

**MyISAM** also supports the following features:

• Support for a true **VARCHAR** type; a **VARCHAR** column starts with a length stored in one or two bytes.

• Tables with **VARCHAR** columns may have fixed or dynamic row length.

• The sum of the lengths of the **VARCHAR** and **CHAR** columns in a table may be up to 64KB.

• Arbitrary length **UNIQUE** constraints.

### Additional Resources


#### 15.3.1 MyISAM Startup Options

The following options to **mysql** can be used to change the behavior of **MyISAM** tables. For additional information, see Section 5.1.6, “Server Command Options”.

**Table 15.3 MyISAM Option and Variable Reference**

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>bulk_insert_buffer_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Both</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>concurrent_insert</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>delay_key_write</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>have_rtree_keys</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>key_buffer_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>log-isam</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>myisam-block-size</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>myisam_data_pointer_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>myisam_max_sort_file</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>myisam_mmap_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>myisam_recover_options</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>myisam_repair_threads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Both</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>myisam_sort_buffer_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Both</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>myisam_stats_method</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Both</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
The following system variables affect the behavior of MyISAM tables. For additional information, see Section 5.1.7, “Server System Variables”.

- **bulk_insert_buffer_size**
  
  The size of the tree cache used in bulk insert optimization.

  ![Note]
  
  This is a limit per thread!

- **delay_key_write=ALL**
  
  Don’t flush key buffers between writes for any MyISAM table.

  ![Note]
  
  If you do this, you should not access MyISAM tables from another program (such as from another MySQL server or with myisamchk) when the tables are in use. Doing so risks index corruption. Using --external-locking does not eliminate this risk.

- **myisam_max_sort_file_size**
  
  The maximum size of the temporary file that MySQL is permitted to use while re-creating a MyISAM index (during REPAIR TABLE, ALTER TABLE, or LOAD DATA). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

- **myisam_recover_options=mode**
  
  Set the mode for automatic recovery of crashed MyISAM tables.

- **myisam_sort_buffer_size**
  
  Set the size of the buffer used when recovering tables.

  Automatic recovery is activated if you start mysqld with the myisam_recover_options system variable set. In this case, when the server opens a MyISAM table, it checks whether the table is marked as crashed or whether the open count variable for the table is not 0 and you are running the server with external locking disabled. If either of these conditions is true, the following happens:

  - The server checks the table for errors.
  
  - If the server finds an error, it tries to do a fast table repair (with sorting and without re-creating the data file).
  
  - If the repair fails because of an error in the data file (for example, a duplicate-key error), the server tries again, this time re-creating the data file.
  
  - If the repair still fails, the server tries once more with the old repair option method (write row by row without sorting). This method should be able to repair any type of error and has low disk space requirements.
If the recovery wouldn’t be able to recover all rows from previously completed statements and you didn’t specify `FORCE` in the value of the `myisam_recover_options` system variable, automatic repair aborts with an error message in the error log:

`Error: Couldn't repair table: test.g00pages`

If you specify `FORCE`, a warning like this is written instead:

`Warning: Found 344 of 354 rows when repairing ./test/g00pages`

If the automatic recovery value includes `BACKUP`, the recovery process creates files with names of the form `tbl_name-datetime.BAK`. You should have a `cron` script that automatically moves these files from the database directories to backup media.

### 15.3.2 Space Needed for Keys

**MyISAM** tables use B-tree indexes. You can roughly calculate the size for the index file as \((\text{key_length} + 4)/0.67\), summed over all keys. This is for the worst case when all keys are inserted in sorted order and the table doesn’t have any compressed keys.

String indexes are space compressed. If the first index part is a string, it is also prefix compressed. Space compression makes the index file smaller than the worst-case figure if a string column has a lot of trailing space or is a `VARCHAR` column that is not always used to the full length. Prefix compression is used on keys that start with a string. Prefix compression helps if there are many strings with an identical prefix.

In **MyISAM** tables, you can also prefix compress numbers by specifying the `PACK_KEYS=1` table option when you create the table. Numbers are stored with the high byte first, so this helps when you have many integer keys that have an identical prefix.

### 15.3.3 MyISAM Table Storage Formats

**MyISAM** supports three different storage formats. Two of them, fixed and dynamic format, are chosen automatically depending on the type of columns you are using. The third, compressed format, can be created only with the `myisampack` utility (see Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables").

When you use `CREATE TABLE` or `ALTER TABLE` for a table that has no `BLOB` or `TEXT` columns, you can force the table format to `FIXED` or `DYNAMIC` with the `ROW_FORMAT` table option.


You can decompress (unpack) compressed **MyISAM** tables using `myisamchk --unpack`; see Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility", for more information.

#### 15.3.3.1 Static (Fixed-Length) Table Characteristics

Static format is the default for **MyISAM** tables. It is used when the table contains no variable-length columns (`VARCHAR`, `VARBINARY`, `BLOB`, or `TEXT`). Each row is stored using a fixed number of bytes.

Of the three **MyISAM** storage formats, static format is the simplest and most secure (least subject to corruption). It is also the fastest of the on-disk formats due to the ease with which rows in the data file can be found on disk: To look up a row based on a row number in the index, multiply the row number by the row length to calculate the row position. Also, when scanning a table, it is very easy to read a constant number of rows with each disk read operation.

The security is evidenced if your computer crashes while the MySQL server is writing to a fixed-format **MyISAM** file. In this case, `myisamchk` can easily determine where each row starts and ends, so it can
usually reclaim all rows except the partially written one. MyISAM table indexes can always be reconstructed based on the data rows.

Note

Fixed-length row format is only available for tables without BLOB or TEXT columns. Creating a table with these columns with an explicit ROW_FORMAT clause will not raise an error or warning; the format specification will be ignored.

Static-format tables have these characteristics:

- **CHAR** and **VARCHAR** columns are space-padded to the specified column width, although the column type is not altered. **BINARY** and **VARBINARY** columns are padded with 0x00 bytes to the column width.
- **NULL** columns require additional space in the row to record whether their values are **NULL**. Each **NULL** column takes one bit extra, rounded up to the nearest byte.
- Very quick.
- Easy to cache.
- Easy to reconstruct after a crash, because rows are located in fixed positions.
- Reorganization is unnecessary unless you delete a huge number of rows and want to return free disk space to the operating system. To do this, use OPTIMIZE TABLE or myisamchk -r.
- Usually require more disk space than dynamic-format tables.
- The expected row length in bytes for static-sized rows is calculated using the following expression:

\[
\text{row length} = 1 + (\text{sum of column lengths}) + (\text{number of NULL columns} + \text{delete_flag} + ?)/8 + (\text{number of variable-length columns})
\]

\text{delete_flag} is 1 for tables with static row format. Static tables use a bit in the row record for a flag that indicates whether the row has been deleted. \text{delete_flag} is 0 for dynamic tables because the flag is stored in the dynamic row header.

15.3.3.2 Dynamic Table Characteristics

Dynamic storage format is used if a MyISAM table contains any variable-length columns (VARCHAR, VARBINARY, BLOB, or TEXT), or if the table was created with the ROW_FORMAT=DYNAMIC table option.

Dynamic format is a little more complex than static format because each row has a header that indicates how long it is. A row can become fragmented (stored in noncontiguous pieces) when it is made longer as a result of an update.

You can use OPTIMIZE TABLE or myisamchk -r to defragment a table. If you have fixed-length columns that you access or change frequently in a table that also contains some variable-length columns, it might be a good idea to move the variable-length columns to other tables just to avoid fragmentation.

Dynamic-format tables have these characteristics:

- All string columns are dynamic except those with a length less than four.
- Each row is preceded by a bitmap that indicates which columns contain the empty string (for string columns) or zero (for numeric columns). This does not include columns that contain NULL values. If a string column has a length of zero after trailing space removal, or a numeric column has a value of zero,
it is marked in the bitmap and not saved to disk. Nonempty strings are saved as a length byte plus the string contents.

- **NULL** columns require additional space in the row to record whether their values are **NULL**. Each **NULL** column takes one bit extra, rounded up to the nearest byte.

- Much less disk space usually is required than for fixed-length tables.

- Each row uses only as much space as is required. However, if a row becomes larger, it is split into as many pieces as are required, resulting in row fragmentation. For example, if you update a row with information that extends the row length, the row becomes fragmented. In this case, you may have to run `OPTIMIZE TABLE` or `myisamchk -r` from time to time to improve performance. Use `myisamchk -ei` to obtain table statistics.

- More difficult than static-format tables to reconstruct after a crash, because rows may be fragmented into many pieces and links (fragments) may be missing.

- The expected row length for dynamic-sized rows is calculated using the following expression:

  \[
  \text{Expected Row Length} = 3 + \left( \frac{\text{number of columns} + 7}{8} \right) + \left( \frac{\text{number of char columns}}{8} \right) + \text{packed size of numeric columns} + \left( \frac{\text{length of strings}}{8} \right) + \left( \frac{\text{number of NULL columns} + 7}{8} \right)
  \]

  There is a penalty of 6 bytes for each link. A dynamic row is linked whenever an update causes an enlargement of the row. Each new link is at least 20 bytes, so the next enlargement probably goes in the same link. If not, another link is created. You can find the number of links using `myisamchk -ed`. All links may be removed with `OPTIMIZE TABLE` or `myisamchk -r`.

### 15.3.3.3 Compressed Table Characteristics

Compressed storage format is a read-only format that is generated with the `myisampack` tool. Compressed tables can be uncompressed with `myisamchk`.

Compressed tables have the following characteristics:

- Compressed tables take very little disk space. This minimizes disk usage, which is helpful when using slow disks (such as CD-ROMs).

- Each row is compressed separately, so there is very little access overhead. The header for a row takes up one to three bytes depending on the biggest row in the table. Each column is compressed differently. There is usually a different Huffman tree for each column. Some of the compression types are:

  - Suffix space compression.
  - Prefix space compression.
  - Numbers with a value of zero are stored using one bit.
  - If values in an integer column have a small range, the column is stored using the smallest possible type. For example, a **BIGINT** column (eight bytes) can be stored as a **TINYINT** column (one byte) if all its values are in the range from \(-128\) to \(127\).
  - If a column has only a small set of possible values, the data type is converted to **ENUM**.
  - A column may use any combination of the preceding compression types.
MyISAM Table Problems

- Can be used for fixed-length or dynamic-length rows.

**Note**
While a compressed table is read only, and you cannot therefore update or add rows in the table, DDL (Data Definition Language) operations are still valid. For example, you may still use `DROP` to drop the table, and `TRUNCATE TABLE` to empty the table.

### 15.3.4 MyISAM Table Problems

The file format that MySQL uses to store data has been extensively tested, but there are always circumstances that may cause database tables to become corrupted. The following discussion describes how this can happen and how to handle it.

#### 15.3.4.1 Corrupted MyISAM Tables

Even though the MyISAM table format is very reliable (all changes to a table made by an SQL statement are written before the statement returns), you can still get corrupted tables if any of the following events occur:

- The `mysqld` process is killed in the middle of a write.
- An unexpected computer shutdown occurs (for example, the computer is turned off).
- Hardware failures.
- You are using an external program (such as `myisamchk`) to modify a table that is being modified by the server at the same time.
- A software bug in the MySQL or MyISAM code.

Typical symptoms of a corrupt table are:

- You get the following error while selecting data from the table:

  **Incorrect key file for table: '...'. Try to repair it**

- Queries don't find rows in the table or return incomplete results.

You can check the health of a MyISAM table using the `CHECK TABLE` statement, and repair a corrupted MyISAM table with `REPAIR TABLE`. When `mysqld` is not running, you can also check or repair a table with the `myisamchk` command. See Section 13.7.2.2, “CHECK TABLE Statement”, Section 13.7.2.5, “REPAIR TABLE Statement”, and Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

If your tables become corrupted frequently, you should try to determine why this is happening. The most important thing to know is whether the table became corrupted as a result of a server crash. You can verify this easily by looking for a recent restarted `mysqld` message in the error log. If there is such a message, it is likely that table corruption is a result of the server dying. Otherwise, corruption may have occurred during normal operation. This is a bug. You should try to create a reproducible test case that demonstrates the problem. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”, and Section 24.5, “Debugging and Porting MySQL”.

#### 15.3.4.2 Problems from Tables Not Being Closed Properly

Each MyISAM index file (.MYI file) has a counter in the header that can be used to check whether a table has been closed properly. If you get the following warning from `CHECK TABLE` or `myisamchk`, it means that this counter has gone out of sync:
This warning doesn't necessarily mean that the table is corrupted, but you should at least check the table.

The counter works as follows:

- The first time a table is updated in MySQL, a counter in the header of the index files is incremented.
- The counter is not changed during further updates.
- When the last instance of a table is closed (because a `FLUSH TABLES` operation was performed or because there is no room in the table cache), the counter is decremented if the table has been updated at any point.
- When you repair the table or check the table and it is found to be okay, the counter is reset to zero.
- To avoid problems with interaction with other processes that might check the table, the counter is not decremented on close if it was zero.

In other words, the counter can become incorrect only under these conditions:

- A `MyISAM` table is copied without first issuing `LOCK TABLES` and `FLUSH TABLES`.
- MySQL has crashed between an update and the final close. (The table may still be okay because MySQL always issues writes for everything between each statement.)
- A table was modified by `myisamchk --recover` or `myisamchk --update-state` at the same time that it was in use by `mysqld`.
- Multiple `mysqld` servers are using the table and one server performed a `REPAIR TABLE` or `CHECK TABLE` on the table while it was in use by another server. In this setup, it is safe to use `CHECK TABLE`, although you might get the warning from other servers. However, `REPAIR TABLE` should be avoided because when one server replaces the data file with a new one, this is not known to the other servers.

In general, it is a bad idea to share a data directory among multiple servers. See Section 5.7, “Running Multiple MySQL Instances on One Machine”, for additional discussion.

### 15.4 The MEMORY Storage Engine

The `MEMORY` storage engine (formerly known as `HEAP`) creates special-purpose tables with contents that are stored in memory. Because the data is vulnerable to crashes, hardware issues, or power outages, only use these tables as temporary work areas or read-only caches for data pulled from other tables.

**Table 15.4 MEMORY Storage Engine Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-tree indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Backup/point-in-time recovery</td>
<td>Yes</td>
</tr>
<tr>
<td>Cluster database support</td>
<td>No</td>
</tr>
<tr>
<td>Clustered indexes</td>
<td>No</td>
</tr>
<tr>
<td>Compressed data</td>
<td>No</td>
</tr>
<tr>
<td>Data caches</td>
<td>N/A</td>
</tr>
<tr>
<td>Encrypted data</td>
<td>Yes (Implemented in the server via encryption functions.)</td>
</tr>
</tbody>
</table>
When to Use MEMORY or NDB Cluster

Developers looking to deploy applications that use the MEMORY storage engine for important, highly available, or frequently updated data should consider whether NDB Cluster is a better choice. A typical use case for the MEMORY engine involves these characteristics:

- Operations involving transient, non-critical data such as session management or caching. When the MySQL server halts or restarts, the data in MEMORY tables is lost.
- In-memory storage for fast access and low latency. Data volume can fit entirely in memory without causing the operating system to swap out virtual memory pages.
- A read-only or read-mostly data access pattern (limited updates).

NDB Cluster offers the same features as the MEMORY engine with higher performance levels, and provides additional features not available with MEMORY:
• Row-level locking and multiple-thread operation for low contention between clients.
• Scalability even with statement mixes that include writes.
• Optional disk-backed operation for data durability.
• Shared-nothing architecture and multiple-host operation with no single point of failure, enabling 99.999% availability.
• Automatic data distribution across nodes; application developers need not craft custom sharding or partitioning solutions.
• Support for variable-length data types (including BLOB and TEXT) not supported by MEMORY.

Performance Characteristics

MEMORY performance is constrained by contention resulting from single-thread execution and table lock overhead when processing updates. This limits scalability when load increases, particularly for statement mixes that include writes.

Despite the in-memory processing for MEMORY tables, they are not necessarily faster than InnoDB tables on a busy server, for general-purpose queries, or under a read/write workload. In particular, the table locking involved with performing updates can slow down concurrent usage of MEMORY tables from multiple sessions.

Depending on the kinds of queries performed on a MEMORY table, you might create indexes as either the default hash data structure (for looking up single values based on a unique key), or a general-purpose B-tree data structure (for all kinds of queries involving equality, inequality, or range operators such as less than or greater than). The following sections illustrate the syntax for creating both kinds of indexes. A common performance issue is using the default hash indexes in workloads where B-tree indexes are more efficient.

Characteristics of MEMORY Tables

The MEMORY storage engine associates each table with one disk file, which stores the table definition (not the data). The file name begins with the table name and has an extension of .frm.

MEMORY tables have the following characteristics:

• Space for MEMORY tables is allocated in small blocks. Tables use 100% dynamic hashing for inserts. No overflow area or extra key space is needed. No extra space is needed for free lists. Deleted rows are put in a linked list and are reused when you insert new data into the table. MEMORY tables also have none of the problems commonly associated with deletes plus inserts in hashed tables.

• MEMORY tables use a fixed-length row-storage format. Variable-length types such as VARCHAR are stored using a fixed length.

• MEMORY tables cannot contain BLOB or TEXT columns.

• MEMORY includes support for AUTO_INCREMENT columns.

• Non-TEMPORARY MEMORY tables are shared among all clients, just like any other non-TEMPORARY table.

DDL Operations for MEMORY Tables

To create a MEMORY table, specify the clause ENGINE=MEMORY on the CREATE TABLE statement.
**Indexes**

```
CREATE TABLE t (i INT) ENGINE = MEMORY;
```

As indicated by the engine name, **MEMORY** tables are stored in memory. They use hash indexes by default, which makes them very fast for single-value lookups, and very useful for creating temporary tables. However, when the server shuts down, all rows stored in **MEMORY** tables are lost. The tables themselves continue to exist because their definitions are stored in .frm files on disk, but they are empty when the server restarts.

This example shows how you might create, use, and remove a **MEMORY** table:

```
mysql> CREATE TABLE test ENGINE=MEMORY
    -> SELECT ip,SUM(downloads) AS down
    -> FROM log_table GROUP BY ip;

mysql> SELECT COUNT(ip),AVG(down) FROM test;

mysql> DROP TABLE test;
```

The maximum size of **MEMORY** tables is limited by the `max_heap_table_size` system variable, which has a default value of 16MB. To enforce different size limits for **MEMORY** tables, change the value of this variable. The value in effect for `CREATE TABLE`, or a subsequent `ALTER TABLE` or `TRUNCATE TABLE`, is the value used for the life of the table. A server restart also sets the maximum size of existing **MEMORY** tables to the global `max_heap_table_size` value. You can set the size for individual tables as described later in this section.

**Indexes**

The **MEMORY** storage engine supports both **HASH** and **BTREE** indexes. You can specify one or the other for a given index by adding a `USING` clause as shown here:

```
CREATE TABLE lookup
    (id INT, INDEX USING HASH (id))
ENGINE = MEMORY;
```

```
CREATE TABLE lookup
    (id INT, INDEX USING BTREE (id))
ENGINE = MEMORY;
```

For general characteristics of B-tree and hash indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

**MEMORY** tables can have up to 64 indexes per table, 16 columns per index and a maximum key length of 3072 bytes.

If a **MEMORY** table hash index has a high degree of key duplication (many index entries containing the same value), updates to the table that affect key values and all deletes are significantly slower. The degree of this slowdown is proportional to the degree of duplication (or, inversely proportional to the index cardinality). You can use a **BTREE** index to avoid this problem.

**MEMORY** tables can have nonunique keys. (This is an uncommon feature for implementations of hash indexes.)

Columns that are indexed can contain **NULL** values.

**User-Created and Temporary Tables**

**MEMORY** table contents are stored in memory, which is a property that **MEMORY** tables share with internal temporary tables that the server creates on the fly while processing queries. However, the two types of tables differ in that **MEMORY** tables are not subject to storage conversion, whereas internal temporary tables are:

- If an internal temporary table becomes too large, the server automatically converts it to on-disk storage, as described in Section 8.4.4, “Internal Temporary Table Use in MySQL”.

1905
• User-created MEMORY tables are never converted to disk tables.

Loading Data

To populate a MEMORY table when the MySQL server starts, you can use the init_file system variable. For example, you can put statements such as INSERT INTO ... SELECT or LOAD DATA into a file to load the table from a persistent data source, and use init_file to name the file. See Section 5.1.7, “Server System Variables”, and Section 13.2.6, “LOAD DATA Statement”.

For loading data into MEMORY tables accessed by other sessions concurrently, MEMORY supports INSERT DELAYED. See Section 13.2.5.3, “INSERT DELAYED Statement”.

MEMORY Tables and Replication

A server’s MEMORY tables become empty when it is shut down and restarted. If the server is a replication master, its slaves are not aware that these tables have become empty, so you see out-of-date content if you select data from the tables on the slaves. To synchronize master and slave MEMORY tables, when a MEMORY table is used on a master for the first time since it was started, a DELETE statement is written to the master’s binary log, to empty the table on the slaves also. The slave still has outdated data in the table during the interval between the master’s restart and its first use of the table. To avoid this interval when a direct query to the slave could return stale data, use the init_file system variable set to name a file containing statements that populate the MEMORY table on the master at startup.

Managing Memory Use

The server needs sufficient memory to maintain all MEMORY tables that are in use at the same time.

Memory is not reclaimed if you delete individual rows from a MEMORY table. Memory is reclaimed only when the entire table is deleted. Memory that was previously used for deleted rows is re-used for new rows within the same table. To free all the memory used by a MEMORY table when you no longer require its contents, execute DELETE or TRUNCATE TABLE to remove all rows, or remove the table altogether using DROP TABLE. To free up the memory used by deleted rows, use ALTER TABLE ENGINE=MEMORY to force a table rebuild.

The memory needed for one row in a MEMORY table is calculated using the following expression:

\[
\text{SUM} \over \text{ALL_BTREE\_KEYS}(\text{max\_length\_of\_key} \times \text{sizeof(char*)} \times 4) + \text{SUM} \over \text{ALL\_HASH\_KEYS}(\text{sizeof(char*)} \times 2) + \text{ALIGN}(\text{length\_of\_row}, \text{sizeof(char*)})
\]

ALIGN() represents a round-up factor to cause the row length to be an exact multiple of the char pointer size. sizeof(char*) is 4 on 32-bit machines and 8 on 64-bit machines.

As mentioned earlier, the max_heap_table_size system variable sets the limit on the maximum size of MEMORY tables. To control the maximum size for individual tables, set the session value of this variable before creating each table. (Do not change the global max_heap_table_size value unless you intend the value to be used for MEMORY tables created by all clients.) The following example creates two MEMORY tables, with a maximum size of 1MB and 2MB, respectively:

```
mysql> SET max_heap_table_size = 1024*1024;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t1 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE t1 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.01 sec)
```

```
mysql> SET max_heap_table_size = 1024*1024*2;
Query OK, 0 rows affected (0.00 sec)
```
Additional Resources

mysql> CREATE TABLE t2 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.00 sec)

Both tables revert to the server's global `max_heap_table_size` value if the server restarts.

You can also specify a `MAX_ROWS` table option in `CREATE TABLE` statements for `MEMORY` tables to provide a hint about the number of rows you plan to store in them. This does not enable the table to grow beyond the `max_heap_table_size` value, which still acts as a constraint on maximum table size. For maximum flexibility in being able to use `MAX_ROWS`, set `max_heap_table_size` at least as high as the value to which you want each `MEMORY` table to be able to grow.

Additional Resources

A forum dedicated to the `MEMORY` storage engine is available at https://forums.mysql.com/list.php?92.

15.5 The CSV Storage Engine

The CSV storage engine stores data in text files using comma-separated values format.

The CSV storage engine is always compiled into the MySQL server.

To examine the source for the CSV engine, look in the `storage/csv` directory of a MySQL source distribution.

When you create a CSV table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. The storage engine also creates plain text data file having a name that begins with the table name and has a `.CSV` extension. When you store data into the table, the storage engine saves it into the data file in comma-separated values format.

```
mysql> CREATE TABLE test (i INT NOT NULL, c CHAR(10) NOT NULL) ENGINE = CSV;
Query OK, 0 rows affected (0.06 sec)
mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.05 sec)
Records: 2  Duplicates: 0  Warnings: 0
mysql> SELECT * FROM test;
+---+------------+
<table>
<thead>
<tr>
<th>i</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>record one</td>
</tr>
<tr>
<td>2</td>
<td>record two</td>
</tr>
</tbody>
</table>
+---+------------+
2 rows in set (0.00 sec)
```

Creating a CSV table also creates a corresponding metafile that stores the state of the table and the number of rows that exist in the table. The name of this file is the same as the name of the table with the extension `CSM`.

If you examine the `test.CSV` file in the database directory created by executing the preceding statements, its contents should look like this:

```
"1","record one"
"2","record two"
```

This format can be read, and even written, by spreadsheet applications such as Microsoft Excel or StarOffice Calc.
15.5.1 Repairing and Checking CSV Tables

The CSV storage engine supports the CHECK TABLE and REPAIR TABLE statements to verify and, if possible, repair a damaged CSV table.

When running the CHECK TABLE statement, the CSV file will be checked for validity by looking for the correct field separators, escaped fields (matching or missing quotation marks), the correct number of fields compared to the table definition and the existence of a corresponding CSV metafile. The first invalid row discovered will report an error. Checking a valid table produces output like that shown below:

```
mysql> CHECK TABLE csvtest;
+--------------+-------+----------+----------+
| Table        | Op    | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | status   | OK       |
+--------------+-------+----------+----------+
```

A check on a corrupted table returns a fault:

```
mysql> CHECK TABLE csvtest;
+--------------+-------+----------+----------+
| Table        | Op    | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | error    | Corrupt  |
+--------------+-------+----------+----------+
```

If the check fails, the table is marked as crashed (corrupt). Once a table has been marked as corrupt, it is automatically repaired when you next run CHECK TABLE or execute a SELECT statement. The corresponding corrupt status and new status will be displayed when running CHECK TABLE:

```
mysql> CHECK TABLE csvtest;
+--------------+-------+----------+----------------------------+
| Table        | Op    | Msg_type | Msg_text                   |
+--------------+-------+----------+----------------------------+
| test.csvtest | check | warning  | Table is marked as crashed |
| test.csvtest | check | status   | OK                         |
+--------------+-------+----------+----------------------------+
```

To repair a table, use REPAIR TABLE, which copies as many valid rows from the existing CSV data as possible, and then replaces the existing CSV file with the recovered rows. Any rows beyond the corrupted data are lost.

```
mysql> REPAIR TABLE csvtest;
+--------------+--------+----------+----------+
| Table        | Op     | Msg_type | Msg_text |
+--------------+--------+----------+----------+
| test.csvtest | repair | status   | OK       |
+--------------+--------+----------+----------+
```

**Warning**

During repair, only the rows from the CSV file up to the first damaged row are copied to the new table. All other rows from the first damaged row to the end of the table are removed, even valid rows.

15.5.2 CSV Limitations

The CSV storage engine does not support indexing.

Partitioning is not supported for tables using the CSV storage engine.
The ARCHIVE Storage Engine

All tables that you create using the CSV storage engine must have the NOT NULL attribute on all columns.

### 15.6 The ARCHIVE Storage Engine

The ARCHIVE storage engine is used for storing large amounts of data without indexes in a very small footprint.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-tree indexes</td>
<td>No</td>
</tr>
<tr>
<td>Backup/point-in-time recovery</td>
<td>Yes (Implemented in the server, rather than in the storage engine.)</td>
</tr>
<tr>
<td>Cluster database support</td>
<td>No</td>
</tr>
<tr>
<td>Clustered indexes</td>
<td>No</td>
</tr>
<tr>
<td>Compressed data</td>
<td>Yes</td>
</tr>
<tr>
<td>Data caches</td>
<td>No</td>
</tr>
<tr>
<td>Encrypted data</td>
<td>Yes (Implemented in the server via encryption functions.)</td>
</tr>
<tr>
<td>Foreign key support</td>
<td>No</td>
</tr>
<tr>
<td>Full-text search indexes</td>
<td>No</td>
</tr>
<tr>
<td>Geospatial data type support</td>
<td>Yes</td>
</tr>
<tr>
<td>Geospatial indexing support</td>
<td>No</td>
</tr>
<tr>
<td>Hash indexes</td>
<td>No</td>
</tr>
<tr>
<td>Index caches</td>
<td>No</td>
</tr>
<tr>
<td>Locking granularity</td>
<td>Row</td>
</tr>
<tr>
<td>MVCC</td>
<td>No</td>
</tr>
<tr>
<td>Replication support</td>
<td>Yes (Implemented in the server, rather than in the storage engine.)</td>
</tr>
<tr>
<td>Storage limits</td>
<td>None</td>
</tr>
<tr>
<td>T-tree indexes</td>
<td>No</td>
</tr>
<tr>
<td>Transactions</td>
<td>No</td>
</tr>
<tr>
<td>Update statistics for data dictionary</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The ARCHIVE storage engine is included in MySQL binary distributions. To enable this storage engine if you build MySQL from source, invoke CMake with the -DWITH_ARCHIVE_STORAGE_ENGINE option.

To examine the source for the ARCHIVE engine, look in the storage/archive directory of a MySQL source distribution.

You can check whether the ARCHIVE storage engine is available with the SHOW ENGINES statement.

When you create an ARCHIVE table, the server creates a table format file in the database directory. The file begins with the table name and has an .frm extension. The storage engine creates other files, all having names beginning with the table name. The data file has an extension of .ARZ. An .ARN file may appear during optimization operations.
The ARCHIVE engine supports INSERT, REPLACE, and SELECT, but not DELETE or UPDATE. It does support ORDER BY operations, BLOB columns, and basically all data types including spatial data types (see Section 11.4.1, “Spatial Data Types”). Geographic spatial reference systems are not supported. The ARCHIVE engine uses row-level locking.

The ARCHIVE engine supports the AUTO_INCREMENT column attribute. The AUTO_INCREMENT column can have either a unique or nonunique index. Attempting to create an index on any other column results in an error. The ARCHIVE engine also supports the AUTO_INCREMENT table option in CREATE TABLE statements to specify the initial sequence value for a new table or reset the sequence value for an existing table, respectively.

ARCHIVE does not support inserting a value into an AUTO_INCREMENT column less than the current maximum column value. Attempts to do so result in an ER_DUP_KEY error.

The ARCHIVE engine ignores BLOB columns if they are not requested and scans past them while reading.

Storage: Rows are compressed as they are inserted. The ARCHIVE engine uses zlib lossless data compression (see http://www.zlib.net/). You can use OPTIMIZE TABLE to analyze the table and pack it into a smaller format (for a reason to use OPTIMIZE TABLE, see later in this section). The engine also supports CHECK TABLE. There are several types of insertions that are used:

- An INSERT statement just pushes rows into a compression buffer, and that buffer flushes as necessary. The insertion into the buffer is protected by a lock. A SELECT forces a flush to occur, unless the only insertions that have come in were INSERT DELAYED (those flush as necessary). See Section 13.2.5.3, “INSERT DELAYED Statement”.

- A bulk insert is visible only after it completes, unless other inserts occur at the same time, in which case it can be seen partially. A SELECT never causes a flush of a bulk insert unless a normal insert occurs while it is loading.

Retrieval: On retrieval, rows are uncompressed on demand; there is no row cache. A SELECT operation performs a complete table scan: When a SELECT occurs, it finds out how many rows are currently available and reads that number of rows. SELECT is performed as a consistent read. Note that lots of SELECT statements during insertion can deteriorate the compression, unless only bulk or delayed inserts are used. To achieve better compression, you can use OPTIMIZE TABLE or REPAIR TABLE. The number of rows in ARCHIVE tables reported by SHOW TABLE STATUS is always accurate. See Section 13.7.2.4, “OPTIMIZE TABLE Statement”, Section 13.7.2.5, “REPAIR TABLE Statement”, and Section 13.7.5.37, “SHOW TABLE STATUS Statement”.

Additional Resources

- A forum dedicated to the ARCHIVE storage engine is available at https://forums.mysql.com/list.php?112.

15.7 The BLACKHOLE Storage Engine

The BLACKHOLE storage engine acts as a “black hole” that accepts data but throws it away and does not store it. Retrievals always return an empty result:

```
mysql> CREATE TABLE test(i INT, c CHAR(10)) ENGINE = BLACKHOLE;
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM test;
```
To enable the BLACKHOLE storage engine if you build MySQL from source, invoke CMake with the `-DWITH_BLACKHOLE_STORAGE_ENGINE` option.

To examine the source for the BLACKHOLE engine, look in the `sql` directory of a MySQL source distribution.

When you create a BLACKHOLE table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. There are no other files associated with the table.

The BLACKHOLE storage engine supports all kinds of indexes. That is, you can include index declarations in the table definition.

You can check whether the BLACKHOLE storage engine is available with the `SHOW ENGINES` statement.

Inserts into a BLACKHOLE table do not store any data, but if statement based binary logging is enabled, the SQL statements are logged and replicated to slave servers. This can be useful as a repeater or filter mechanism.

Suppose that your application requires slave-side filtering rules, but transferring all binary log data to the slave first results in too much traffic. In such a case, it is possible to set up on the master host a “dummy” slave process whose default storage engine is BLACKHOLE, depicted as follows:

**Figure 15.1 Replication using BLACKHOLE for Filtering**

The master writes to its binary log. The “dummy” `mysqld` process acts as a slave, applying the desired combination of `replicate-do-` and `replicate-ignore-` rules, and writes a new, filtered binary log of its own. (See Section 17.1.3, “Replication and Binary Logging Options and Variables”.) This filtered log is provided to the slave.

The dummy process does not actually store any data, so there is little processing overhead incurred by running the additional `mysqld` process on the replication master host. This type of setup can be repeated with additional replication slaves.
The BLACKHOLE Storage Engine

**INSERT** triggers for **BLACKHOLE** tables work as expected. However, because the **BLACKHOLE** table does not actually store any data, **UPDATE** and **DELETE** triggers are not activated: The **FOR EACH ROW** clause in the trigger definition does not apply because there are no rows.

Other possible uses for the **BLACKHOLE** storage engine include:

- Verification of dump file syntax.
- Measurement of the overhead from binary logging, by comparing performance using **BLACKHOLE** with and without binary logging enabled.
- **BLACKHOLE** is essentially a “no-op” storage engine, so it could be used for finding performance bottlenecks not related to the storage engine itself.

The **BLACKHOLE** engine is transaction-aware, in the sense that committed transactions are written to the binary log and rolled-back transactions are not.

### Blackhole Engine and Auto Increment Columns

The Blackhole engine is a no-op engine. Any operations performed on a table using Blackhole will have no effect. This should be born in mind when considering the behavior of primary key columns that auto increment. The engine will not automatically increment field values, and does not retain auto increment field state. This has important implications in replication.

Consider the following replication scenario where all three of the following conditions apply:

1. On a master server there is a blackhole table with an auto increment field that is a primary key.
2. On a slave the same table exists but using the MyISAM engine.
3. Inserts are performed into the master's table without explicitly setting the auto increment value in the **INSERT** statement itself or through using a **SET INSERT_ID** statement.

In this scenario replication will fail with a duplicate entry error on the primary key column.

In statement based replication, the value of **INSERT_ID** in the context event will always be the same. Replication will therefore fail due to trying insert a row with a duplicate value for a primary key column.

In row based replication, the value that the engine returns for the row always be the same for each insert. This will result in the slave attempting to replay two insert log entries using the same value for the primary key column, and so replication will fail.

### Column Filtering

When using row-based replication, (**binlog_format=ROW**), a slave where the last columns are missing from a table is supported, as described in the section **Section 17.4.1.9, “Replication with Differing Table Definitions on Master and Slave”**.

This filtering works on the slave side, that is, the columns are copied to the slave before they are filtered out. There are at least two cases where it is not desirable to copy the columns to the slave:

1. If the data is confidential, so the slave server should not have access to it.
2. If the master has many slaves, filtering before sending to the slaves may reduce network traffic.

Master column filtering can be achieved using the **BLACKHOLE** engine. This is carried out in a way similar to how master table filtering is achieved - by using the **BLACKHOLE** engine and the **--replicate-do-table** or **--replicate-ignore-table** option.
The setup for the master is:

```sql
CREATE TABLE t1 (public_col_1, ..., public_col_N,
    secret_col_1, ..., secret_col_M) ENGINE=MyISAM;
```

The setup for the trusted slave is:

```sql
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=BLACKHOLE;
```

The setup for the untrusted slave is:

```sql
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=MyISAM;
```

### 15.8 The MERGE Storage Engine

The **MERGE** storage engine, also known as the **MRG_MyISAM** engine, is a collection of identical **MyISAM** tables that can be used as one. “Identical” means that all tables have identical column data types and index information. You cannot merge **MyISAM** tables in which the columns are listed in a different order, do not have exactly the same data types in corresponding columns, or have the indexes in different order. However, any or all of the **MyISAM** tables can be compressed with **myisampack**. See Section 4.6.5, "**myisampack** — Generate Compressed, Read-Only MyISAM Tables". Differences between tables such as these do not matter:

- Names of corresponding columns and indexes can differ.
- Comments for tables, columns, and indexes can differ.
- Table options such as **AVG_ROW_LENGTH**, **MAX_ROWS**, or **PACK_KEYS** can differ.

An alternative to a **MERGE** table is a partitioned table, which stores partitions of a single table in separate files. Partitioning enables some operations to be performed more efficiently and is not limited to the **MyISAM** storage engine. For more information, see Chapter 19, **Partitioning**.

When you create a **MERGE** table, MySQL creates two files on disk. The files have names that begin with the table name and have an extension to indicate the file type. An **.frm** file stores the table format, and an **.MRG** file contains the names of the underlying **MyISAM** tables that should be used as one. The tables do not have to be in the same database as the **MERGE** table.

You can use **SELECT**, **DELETE**, **UPDATE**, and **INSERT** on **MERGE** tables. You must have **SELECT**, **DELETE**, and **UPDATE** privileges on the **MyISAM** tables that you map to a **MERGE** table.

---

**Note**

The use of **MERGE** tables entails the following security issue: If a user has access to a **MyISAM** table `t`, that user can create a **MERGE** table `m` that accesses `t`. However, if the user's privileges on `t` are subsequently revoked, the user can continue to access `t` by doing so through `m`.

Use of **DROP TABLE** with a **MERGE** table drops only the **MERGE** specification. The underlying tables are not affected.

To create a **MERGE** table, you must specify a **UNION=(list-of-tables)** option that indicates which **MyISAM** tables to use. You can optionally specify an **INSERT_METHOD** option to control how inserts into the **MERGE** table take place. Use a value of **FIRST** or **LAST** to cause inserts to be made in the first or last underlying table, respectively. If you specify no **INSERT_METHOD** option or if you specify it with a value of **NO**, inserts into the **MERGE** table are not permitted and attempts to do so result in an error.

The following example shows how to create a **MERGE** table:
The MERGE Storage Engine

```sql
mysql> CREATE TABLE t1 (  
    -> a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,  
    -> message CHAR(20)) ENGINE=MyISAM;

mysql> CREATE TABLE t2 (  
    -> a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,  
    -> message CHAR(20)) ENGINE=MyISAM;

mysql> INSERT INTO t1 (message) VALUES ('Testing'), ('table'), ('t1');

mysql> INSERT INTO t2 (message) VALUES ('Testing'), ('table'), ('t2');

mysql> CREATE TABLE total (  
    -> a INT NOT NULL AUTO_INCREMENT,  
    -> message CHAR(20), INDEX(a))  
    -> ENGINE=MERGE UNION=(t1,t2) INSERT_METHOD=LAST;
```

Column `a` is indexed as a `PRIMARY KEY` in the underlying `MyISAM` tables, but not in the `MERGE` table. There it is indexed but not as a `PRIMARY KEY` because a `MERGE` table cannot enforce uniqueness over the set of underlying tables. (Similarly, a column with a `UNIQUE` index in the underlying tables should be indexed in the `MERGE` table but not as a `UNIQUE` index.)

After creating the `MERGE` table, you can use it to issue queries that operate on the group of tables as a whole:

```sql
mysql> SELECT * FROM total;
+---+---------+
| a | message |
+---+---------+
| 1 | Testing |
| 2 | table   |
| 3 | t1      |
| 1 | Testing |
| 2 | table   |
| 3 | t2      |
+---+---------+
```

To remap a `MERGE` table to a different collection of `MyISAM` tables, you can use one of the following methods:

- **DROP** the `MERGE` table and re-create it.

- **Use** `ALTER TABLE tbl_name UNION=(...)` to change the list of underlying tables.

  It is also possible to use `ALTER TABLE ... UNION=(...)` (that is, with an empty `UNION` clause) to remove all of the underlying tables. However, in this case, the table is effectively empty and inserts fail because there is no underlying table to take new rows. Such a table might be useful as a template for creating new `MERGE` tables with `CREATE TABLE ... LIKE`.

The underlying table definitions and indexes must conform closely to the definition of the `MERGE` table. Conformance is checked when a table that is part of a `MERGE` table is opened, not when the `MERGE` table is created. If any table fails the conformance checks, the operation that triggered the opening of the table fails. This means that changes to the definitions of tables within a `MERGE` may cause a failure when the `MERGE` table is accessed. The conformance checks applied to each table are:

- The underlying table and the `MERGE` table must have the same number of columns.

- The column order in the underlying table and the `MERGE` table must match.

- Additionally, the specification for each corresponding column in the parent `MERGE` table and the underlying tables are compared and must satisfy these checks:
  - The column type in the underlying table and the `MERGE` table must be equal.
  - The column length in the underlying table and the `MERGE` table must be equal.
• The column of the underlying table and the **MERGE** table can be **NULL**.

• The underlying table must have at least as many indexes as the **MERGE** table. The underlying table may have more indexes than the **MERGE** table, but cannot have fewer.

**Note**

A known issue exists where indexes on the same columns must be in identical order, in both the **MERGE** table and the underlying **MyISAM** table. See Bug #33653.

Each index must satisfy these checks:

• The index type of the underlying table and the **MERGE** table must be the same.

• The number of index parts (that is, multiple columns within a compound index) in the index definition for the underlying table and the **MERGE** table must be the same.

• For each index part:
  • Index part lengths must be equal.
  • Index part types must be equal.
  • Index part languages must be equal.
  • Check whether index parts can be **NULL**.

If a **MERGE** table cannot be opened or used because of a problem with an underlying table, **CHECK TABLE** displays information about which table caused the problem.

**Additional Resources**


**15.8.1 MERGE Table Advantages and Disadvantages**

**MERGE** tables can help you solve the following problems:

• Easily manage a set of log tables. For example, you can put data from different months into separate tables, compress some of them with **myisampack**, and then create a **MERGE** table to use them as one.

• Obtain more speed. You can split a large read-only table based on some criteria, and then put individual tables on different disks. A **MERGE** table structured this way could be much faster than using a single large table.

• Perform more efficient searches. If you know exactly what you are looking for, you can search in just one of the underlying tables for some queries and use a **MERGE** table for others. You can even have many different **MERGE** tables that use overlapping sets of tables.

• Perform more efficient repairs. It is easier to repair individual smaller tables that are mapped to a **MERGE** table than to repair a single large table.

• Instantly map many tables as one. A **MERGE** table need not maintain an index of its own because it uses the indexes of the individual tables. As a result, **MERGE** table collections are very fast to create or remap. (You must still specify the index definitions when you create a **MERGE** table, even though no indexes are created.)
• If you have a set of tables from which you create a large table on demand, you can instead create a
`MERGE` table from them on demand. This is much faster and saves a lot of disk space.

• Exceed the file size limit for the operating system. Each `MyISAM` table is bound by this limit, but a
collection of `MyISAM` tables is not.

• You can create an alias or synonym for a `MyISAM` table by defining a `MERGE` table that maps to that
single table. There should be no really notable performance impact from doing this (only a couple of
indirect calls and `memcpy()` calls for each read).

The disadvantages of `MERGE` tables are:

• You can use only identical `MyISAM` tables for a `MERGE` table.

• Some `MyISAM` features are unavailable in `MERGE` tables. For example, you cannot create `FULLTEXT`
indexes on `MERGE` tables. (You can create `FULLTEXT` indexes on the underlying `MyISAM` tables, but you
cannot search the `MERGE` table with a full-text search.)

• If the `MERGE` table is nontemporary, all underlying `MyISAM` tables must be nontemporary. If the `MERGE`
table is temporary, the `MyISAM` tables can be any mix of temporary and nontemporary.

• `MERGE` tables use more file descriptors than `MyISAM` tables. If 10 clients are using a `MERGE` table that
maps to 10 tables, the server uses `(10 × 10) + 10` file descriptors. (10 data file descriptors for each of the
10 clients, and 10 index file descriptors shared among the clients.)

• Index reads are slower. When you read an index, the `MERGE` storage engine needs to issue a read on all
underlying tables to check which one most closely matches a given index value. To read the next index
value, the `MERGE` storage engine needs to search the read buffers to find the next value. Only when one
index buffer is used up does the storage engine need to read the next index block. This makes `MERGE`
indexes much slower on `eq_ref` searches, but not much slower on `ref` searches. For more information
about `eq_ref` and `ref`, see Section 13.8.2, "EXPLAIN Statement".

15.8.2 MERGE Table Problems

The following are known problems with `MERGE` tables:

• In versions of MySQL Server prior to 5.1.23, it was possible to create temporary merge tables with
nontemporary child `MyISAM` tables.

From versions 5.1.23, `MERGE` children were locked through the parent table. If the parent was
temporary, it was not locked and so the children were not locked either. Parallel use of the `MyISAM`
tables corrupted them.

• If you use `ALTER TABLE` to change a `MERGE` table to another storage engine, the mapping to the
underlying tables is lost. Instead, the rows from the underlying `MyISAM` tables are copied into the altered
table, which then uses the specified storage engine.

• The `INSERT_METHOD` table option for a `MERGE` table indicates which underlying `MyISAM` table to use for
inserts into the `MERGE` table. However, use of the `AUTO_INCREMENT` table option for that `MyISAM` table
has no effect for inserts into the `MERGE` table until at least one row has been inserted directly into the
`MyISAM` table.

• A `MERGE` table cannot maintain uniqueness constraints over the entire table. When you perform an
`INSERT`, the data goes into the first or last `MyISAM` table (as determined by the `INSERT_METHOD`
option). MySQL ensures that unique key values remain unique within that `MyISAM` table, but not over all
the underlying tables in the collection.
• Because the **MERGE** engine cannot enforce uniqueness over the set of underlying tables, **REPLACE** does not work as expected. The two key facts are:

  • **REPLACE** can detect unique key violations only in the underlying table to which it is going to write (which is determined by the **INSERT_METHOD** option). This differs from violations in the **MERGE** table itself.

  • If **REPLACE** detects a unique key violation, it will change only the corresponding row in the underlying table it is writing to; that is, the first or last table, as determined by the **INSERT_METHOD** option.

Similar considerations apply for **INSERT ... ON DUPLICATE KEY UPDATE**.

• **MERGE** tables do not support partitioning. That is, you cannot partition a **MERGE** table, nor can any of a **MERGE** table's underlying **MyISAM** tables be partitioned.

• You should not use **ANALYZE TABLE**, **REPAIR TABLE**, **OPTIMIZE TABLE**, **ALTER TABLE**, **DROP TABLE**, **DELETE** without a **WHERE** clause, or **TRUNCATE TABLE** on any of the tables that are mapped into an open **MERGE** table. If you do so, the **MERGE** table may still refer to the original table and yield unexpected results. To work around this problem, ensure that no **MERGE** tables remain open by issuing a **FLUSH TABLES** statement prior to performing any of the named operations.

The unexpected results include the possibility that the operation on the **MERGE** table will report table corruption. If this occurs after one of the named operations on the underlying **MyISAM** tables, the corruption message is spurious. To deal with this, issue a **FLUSH TABLES** statement after modifying the **MyISAM** tables.

• **DROP TABLE** on a table that is in use by a **MERGE** table does not work on Windows because the **MERGE** storage engine's table mapping is hidden from the upper layer of MySQL. Windows does not permit open files to be deleted, so you first must flush all **MERGE** tables (with **FLUSH TABLES**) or drop the **MERGE** table before dropping the table.

• The definition of the **MyISAM** tables and the **MERGE** table are checked when the tables are accessed (for example, as part of a **SELECT** or **INSERT** statement). The checks ensure that the definitions of the tables and the parent **MERGE** table definition match by comparing column order, types, sizes and associated indexes. If there is a difference between the tables, an error is returned and the statement fails. Because these checks take place when the tables are opened, any changes to the definition of a single table, including column changes, column ordering, and engine alterations will cause the statement to fail.

• The order of indexes in the **MERGE** table and its underlying tables should be the same. If you use **ALTER TABLE** to add a **UNIQUE** index to a table used in a **MERGE** table, and then use **ALTER TABLE** to add a nonunique index on the **MERGE** table, the index ordering is different for the tables if there was already a nonunique index in the underlying table. (This happens because **ALTER TABLE** puts **UNIQUE** indexes before nonunique indexes to facilitate rapid detection of duplicate keys.) Consequently, queries on tables with such indexes may return unexpected results.

• If you encounter an error message similar to **ERROR 1017 (HY000): Can't find file: 'tbl_name.MRG' (errno: 2)**, it generally indicates that some of the underlying tables do not use the **MyISAM** storage engine. Confirm that all of these tables are **MyISAM**.

• The maximum number of rows in a **MERGE** table is $2^{64}$ (~1.844E+19; the same as for a **MyISAM** table). It is not possible to merge multiple **MyISAM** tables into a single **MERGE** table that would have more than this number of rows.

• The **MERGE** storage engine does not support **INSERT DELAYED** statements.

• Use of underlying **MyISAM** tables of differing row formats with a parent **MERGE** table is currently known to fail. See Bug #32364.
The FEDERATED Storage Engine

- You cannot change the union list of a nontemporary MERGE table when *LOCK TABLES* is in effect. The following does not work:

```sql
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ...;
LOCK TABLES t1 WRITE, t2 WRITE, m1 WRITE;
ALTER TABLE m1 ... UNION=(t1,t2) ...;
```

However, you can do this with a temporary MERGE table.

- You cannot create a MERGE table with CREATE ... SELECT, neither as a temporary MERGE table, nor as a nontemporary MERGE table. For example:

```sql
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ... SELECT ...;
```

Attempts to do this result in an error: *tbl_name* is not BASE TABLE.

- In some cases, differing PACK_KEYS table option values among the MERGE and underlying tables cause unexpected results if the underlying tables contain CHAR or BINARY columns. As a workaround, use ALTER TABLE to ensure that all involved tables have the same PACK_KEYS value. (Bug #50646)

## 15.9 The FEDERATED Storage Engine

The FEDERATED storage engine lets you access data from a remote MySQL database without using replication or cluster technology. Querying a local FEDERATED table automatically pulls the data from the remote (federated) tables. No data is stored on the local tables.

To include the FEDERATED storage engine if you build MySQL from source, invoke CMake with the `-DWITH_FEDERATED_STORAGE_ENGINE` option.

The FEDERATED storage engine is not enabled by default in the running server; to enable FEDERATED, you must start the MySQL server binary using the `--federated` option.

To examine the source for the FEDERATED engine, look in the `storage/federated` directory of a MySQL source distribution.

### 15.9.1 FEDERATED Storage Engine Overview

When you create a table using one of the standard storage engines (such as MyISAM, CSV or InnoDB), the table consists of the table definition and the associated data. When you create a FEDERATED table, the table definition is the same, but the physical storage of the data is handled on a remote server.

A FEDERATED table consists of two elements:

- A remote server with a database table, which in turn consists of the table definition (stored in the `.frm` file) and the associated table. The table type of the remote table may be any type supported by the remote mysqld server, including MyISAM or InnoDB.

- A local server with a database table, where the table definition matches that of the corresponding table on the remote server. The table definition is stored within the `.frm` file. However, there is no data file on the local server. Instead, the table definition includes a connection string that points to the remote table.

When executing queries and statements on a FEDERATED table on the local server, the operations that would normally insert, update or delete information from a local data file are instead sent to the remote server for execution, where they update the data file on the remote server or return matching rows from the remote server.

The basic structure of a FEDERATED table setup is shown in Figure 15.2, “FEDERATED Table Structure”.
How to Create FEDERATED Tables

When a client issues an SQL statement that refers to a FEDERATED table, the flow of information between the local server (where the SQL statement is executed) and the remote server (where the data is physically stored) is as follows:

1. The storage engine looks through each column that the FEDERATED table has and constructs an appropriate SQL statement that refers to the remote table.
2. The statement is sent to the remote server using the MySQL client API.
3. The remote server processes the statement and the local server retrieves any result that the statement produces (an affected-rows count or a result set).
4. If the statement produces a result set, each column is converted to internal storage engine format that the FEDERATED engine expects and can use to display the result to the client that issued the original statement.

The local server communicates with the remote server using MySQL client C API functions. It invokes `mysql_real_query()` to send the statement. To read a result set, it uses `mysql_store_result()` and fetches rows one at a time using `mysql_fetch_row()`.

### 15.9.2 How to Create FEDERATED Tables

To create a FEDERATED table you should follow these steps:

1. Create the table on the remote server. Alternatively, make a note of the table definition of an existing table, perhaps using the `SHOW CREATE TABLE` statement.
2. Create the table on the local server with an identical table definition, but adding the connection information that links the local table to the remote table.

For example, you could create the following table on the remote server:

```sql
CREATE TABLE test_table (  
id INT(20) NOT NULL AUTO_INCREMENT,
name VARCHAR(32) NOT NULL DEFAULT '','
other INT(20) NOT NULL DEFAULT '0',
PRIMARY KEY (id),
INDEX name (name),
INDEX other_key (other)
) 
ENGINE=MyISAM
```
To create the local table that will be federated to the remote table, there are two options available. You can either create the local table and specify the connection string (containing the server name, login, password) to be used to connect to the remote table using the `CONNECTION`, or you can use an existing connection that you have previously created using the `CREATE SERVER` statement.

**Important**

When you create the local table it *must* have an identical field definition to the remote table.

**Note**

You can improve the performance of a FEDERATED table by adding indexes to the table on the host. The optimization will occur because the query sent to the remote server will include the contents of the `WHERE` clause and will be sent to the remote server and subsequently executed locally. This reduces the network traffic that would otherwise request the entire table from the server for local processing.

### 15.9.2.1 Creating a FEDERATED Table Using CONNECTION

To use the first method, you must specify the `CONNECTION` string after the engine type in a `CREATE TABLE` statement. For example:

```sql
CREATE TABLE federated_table {
    id     INT(20) NOT NULL AUTO_INCREMENT,
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
}
ENGINE=FEDERATED
DEFAULT CHARSET=latin1
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

**Note**

`CONNECTION` replaces the `COMMENT` used in some previous versions of MySQL.

The `CONNECTION` string contains the information required to connect to the remote server containing the table that will be used to physically store the data. The connection string specifies the server name, login credentials, port number and database/table information. In the example, the remote table is on the server `remote_host`, using port 9306. The name and port number should match the host name (or IP address) and port number of the remote MySQL server instance you want to use as your remote table.

The format of the connection string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

Where:

- **scheme**: A recognized connection protocol. Only `mysql` is supported as the `scheme` value at this point.

- **user_name**: The user name for the connection. This user must have been created on the remote server, and must have suitable privileges to perform the required actions (SELECT, INSERT, UPDATE, and so forth) on the remote table.
How to Create FEDERATED Tables

- **password**: (Optional) The corresponding password for user_name.
- **host_name**: The host name or IP address of the remote server.
- **port_num**: (Optional) The port number for the remote server. The default is 3306.
- **db_name**: The name of the database holding the remote table.
- **tbl_name**: The name of the remote table. The name of the local and the remote table do not have to match.

Sample connection strings:

```
CONNECTION='mysql://username:password@hostname:port/database/tablename'
CONNECTION='mysql://username@hostname/database/tablename'
CONNECTION='mysql://username:password@hostname/database/tablename'
```

### 15.9.2.2 Creating a FEDERATED Table Using CREATE SERVER

If you are creating a number of FEDERATED tables on the same server, or if you want to simplify the process of creating FEDERATED tables, you can use the CREATE SERVER statement to define the server connection parameters, just as you would with the CONNECTION string.

The format of the CREATE SERVER statement is:

```
CREATE SERVER server_name
FOREIGN DATA WRAPPER wrapper_name
OPTIONS (option [, option] ...)
```

The server_name is used in the connection string when creating a new FEDERATED table.

For example, to create a server connection identical to the CONNECTION string:

```
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

You would use the following statement:

```
CREATE SERVER fedlink
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'fed_user', HOST 'remote_host', PORT 9306, DATABASE 'federated');
```

To create a FEDERATED table that uses this connection, you still use the CONNECTION keyword, but specify the name you used in the CREATE SERVER statement.

```
CREATE TABLE test_table (  
id     INT(20) NOT NULL AUTO_INCREMENT,  
name   VARCHAR(32) NOT NULL DEFAULT '',  
other  INT(20) NOT NULL DEFAULT '0',  
)  
PRIMARY KEY (id),  
INDEX name (name),  
INDEX other_key (other)  
)  
ENGINE=FEDERATED  
DEFAULT CHARSET=latin1  
CONNECTION='fedlink/test_table';
```

The connection name in this example contains the name of the connection (fedlink) and the name of the table (test_table) to link to, separated by a slash. If you specify only the connection name without a table name, the table name of the local table is used instead.

For more information on CREATE SERVER, see Section 13.1.16, “CREATE SERVER Statement”.
The `CREATE SERVER` statement accepts the same arguments as the `CONNECTION` string. The `CREATE SERVER` statement updates the rows in the `mysql.servers` table. See the following table for information on the correspondence between parameters in a connection string, options in the `CREATE SERVER` statement, and the columns in the `mysql.servers` table. For reference, the format of the `CONNECTION` string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

<table>
<thead>
<tr>
<th>Description</th>
<th><code>CONNECTION</code> string</th>
<th><code>CREATE SERVER</code> option</th>
<th><code>mysql.servers</code> column</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection scheme</td>
<td><code>scheme</code></td>
<td><code>wrapper_name</code></td>
<td><code>Wrapper</code></td>
</tr>
<tr>
<td>Remote user</td>
<td><code>user_name</code></td>
<td><code>USER</code></td>
<td><code>Username</code></td>
</tr>
<tr>
<td>Remote password</td>
<td><code>password</code></td>
<td><code>PASSWORD</code></td>
<td><code>Password</code></td>
</tr>
<tr>
<td>Remote host</td>
<td><code>host_name</code></td>
<td><code>HOST</code></td>
<td><code>Host</code></td>
</tr>
<tr>
<td>Remote port</td>
<td><code>port_num</code></td>
<td><code>PORT</code></td>
<td><code>Port</code></td>
</tr>
<tr>
<td>Remote database</td>
<td><code>db_name</code></td>
<td><code>DATABASE</code></td>
<td><code>Db</code></td>
</tr>
</tbody>
</table>

### 15.9.3 FEDERATED Storage Engine Notes and Tips

You should be aware of the following points when using the FEDERATED storage engine:

- **FEDERATED** tables may be replicated to other slaves, but you must ensure that the slave servers are able to use the user/password combination that is defined in the `CONNECTION` string (or the row in the `mysql.servers` table) to connect to the remote server.

The following items indicate features that the FEDERATED storage engine does and does not support:

- The remote server must be a MySQL server.

- The remote table that a FEDERATED table points to **must** exist before you try to access the table through the FEDERATED table.

- It is possible for one FEDERATED table to point to another, but you must be careful not to create a loop.

- A FEDERATED table does not support indexes in the usual sense; because access to the table data is handled remotely, it is actually the remote table that makes use of indexes. This means that, for a query that cannot use any indexes and so requires a full table scan, the server fetches all rows from the remote table and filters them locally. This occurs regardless of any `WHERE` or `LIMIT` used with this `SELECT` statement; these clauses are applied locally to the returned rows.

Queries that fail to use indexes can thus cause poor performance and network overload. In addition, since returned rows must be stored in memory, such a query can also lead to the local server swapping, or even hanging.

- Care should be taken when creating a FEDERATED table since the index definition from an equivalent MyISAM or other table may not be supported. For example, creating a FEDERATED table with an index prefix on `VARCHAR`, `TEXT` or `BLOB` columns will fail. The following definition in MyISAM is valid:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=MYISAM;
  ```

  The key prefix in this example is incompatible with the FEDERATED engine, and the equivalent statement will fail:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=FEDERATED
  ```
If possible, you should try to separate the column and index definition when creating tables on both the remote server and the local server to avoid these index issues.

- Internally, the implementation uses `SELECT`, `INSERT`, `UPDATE`, and `DELETE`, but not `HANDLER`.

- The `FEDERATED` storage engine supports `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, and indexes. It does not support `ALTER TABLE`, or any Data Definition Language statements that directly affect the structure of the table, other than `DROP TABLE`. The current implementation does not use prepared statements.

- `FEDERATED` accepts `INSERT ... ON DUPLICATE KEY UPDATE` statements, but if a duplicate-key violation occurs, the statement fails with an error.

- Transactions are not supported.

- `FEDERATED` performs bulk-insert handling such that multiple rows are sent to the remote table in a batch, which improves performance. Also, if the remote table is transactional, it enables the remote storage engine to perform statement rollback properly should an error occur. This capability has the following limitations:
  - The size of the insert cannot exceed the maximum packet size between servers. If the insert exceeds this size, it is broken into multiple packets and the rollback problem can occur.
  - Bulk-insert handling does not occur for `INSERT ... ON DUPLICATE KEY UPDATE`.

- There is no way for the `FEDERATED` engine to know if the remote table has changed. The reason for this is that this table must work like a data file that would never be written to by anything other than the database system. The integrity of the data in the local table could be breached if there was any change to the remote database.

- When using a `CONNECTION` string, you cannot use an '@' character in the password. You can get round this limitation by using the `CREATE SERVER` statement to create a server connection.

- The `insert_id` and `timestamp` options are not propagated to the data provider.

- Any `DROP TABLE` statement issued against a `FEDERATED` table drops only the local table, not the remote table.

- `FEDERATED` tables do not work with the query cache.

- User-defined partitioning is not supported for `FEDERATED` tables.

### 15.9.4 FEDERATED Storage Engine Resources

The following additional resources are available for the `FEDERATED` storage engine:


### 15.10 The EXAMPLE Storage Engine

The `EXAMPLE` storage engine is a stub engine that does nothing. Its purpose is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.
To enable the `EXAMPLE` storage engine if you build MySQL from source, invoke `CMake` with the `-DWITH_EXAMPLE_STORAGE_ENGINE` option.

To examine the source for the `EXAMPLE` engine, look in the `storage/example` directory of a MySQL source distribution.

When you create an `EXAMPLE` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. No other files are created. No data can be stored into the table. Retrievals return an empty result.

```sql
mysql> CREATE TABLE test (i INT) ENGINE = EXAMPLE;
Query OK, 0 rows affected (0.78 sec)

mysql> INSERT INTO test VALUES(1),(2),(3);
ERROR 1031 (HY000): Table storage engine for 'test' doesn't have this option

mysql> SELECT * FROM test;
Empty set (0.31 sec)
```

The `EXAMPLE` storage engine does not support indexing.

### 15.11 Other Storage Engines

Other storage engines may be available from third parties and community members that have used the Custom Storage Engine interface.

Third party engines are not supported by MySQL. For further information, documentation, installation guides, bug reporting or for any help or assistance with these engines, please contact the developer of the engine directly.

For more information on developing a customer storage engine that can be used with the Pluggable Storage Engine Architecture, see [MySQL Internals: Writing a Custom Storage Engine](https://dev.mysql.com/doc/refman/8.0/en/custom-storage-engines.html).
Chapter 16 High Availability and Scalability

Table of Contents

16.1 Using ZFS Replication .......................................................... 1927
  16.1.1 Using ZFS for File System Replication ................................ 1928
  16.1.2 Configuring MySQL for ZFS Replication ............................... 1929
  16.1.3 Handling MySQL Recovery with ZFS ..................................... 1930
16.2 Using MySQL with memcached .............................................. 1930
  16.2.1 Installing memcached .................................................... 1931
  16.2.2 Using memcached ......................................................... 1933
  16.2.3 Developing a memcached Application .................................. 1952
  16.2.4 Getting memcached Statistics .......................................... 1977
  16.2.5 memcached FAQ .......................................................... 1986

Data is the currency of today’s web, mobile, social, enterprise and cloud applications. Ensuring data is always available is a top priority for any organization. Minutes of downtime can result in significant loss of revenue and reputation.

There is no “one size fits all” approach to delivering High Availability (HA). Unique application attributes, business requirements, operational capabilities and legacy infrastructure can all influence HA technology selection. And technology is only one element in delivering HA: people and processes are just as critical as the technology itself.

MySQL is deployed into many applications demanding availability and scalability. Availability refers to the ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware and maintenance activity that may otherwise cause downtime. Scalability refers to the ability to spread both the database and the load of your application queries across multiple MySQL servers.

Because each application has different operational and availability requirements, MySQL offers a range of certified and supported solutions, delivering the appropriate levels of High Availability (HA) and scalability to meet service level requirements. Such solutions extend from replication, through virtualization and geographically redundant, multi-data center solutions delivering 99.999% uptime.

Selecting the right high availability solution for an application largely depends on:

• The level of availability required.
• The type of application being deployed.
• Accepted best practices within your own environment.

The primary solutions supported by MySQL include:

• MySQL Replication. Learn more: Chapter 17, Replication.
• MySQL Cluster. Learn more: Chapter 18, MySQL NDB Cluster 7.2.
• Oracle MySQL Cloud Service. Learn more about MySQL Cloud Service.
• Oracle Clusterware Agent for MySQL. Learn more about Oracle Clusterware.
• MySQL with Solaris Cluster. Learn more about Solaris Cluster.

Further options are available using third-party solutions.
Each architecture used to achieve highly available database services is differentiated by the levels of uptime it offers. These architectures can be grouped into three main categories:

- Data Replication.
- Clustered & Virtualized Systems.
- Shared-Nothing, Geographically-Replicated Clusters.

As illustrated in the following figure, each of these architectures offers progressively higher levels of uptime, which must be balanced against potentially greater levels of cost and complexity that each can incur. Simply deploying a high availability architecture is not a guarantee of actually delivering HA. In fact, a poorly implemented and maintained shared-nothing cluster could easily deliver lower levels of availability than a simple data replication solution.

Figure 16.1 Tradeoffs: Cost and Complexity versus Availability

The following table compares the HA and Scalability capabilities of the various MySQL solutions:

Table 16.1 Feature Comparison of MySQL HA Solutions

<table>
<thead>
<tr>
<th>Requirement</th>
<th>MySQL Replication</th>
<th>MySQL Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platform Support</td>
<td>All Supported by MySQL Server [<a href="https://www.mysql.com/support/supportedplatforms/databas.html">https://www.mysql.com/support/supportedplatforms/databas.html</a>]</td>
<td>All Supported by MySQL Cluster [<a href="https://www.mysql.com/support/supportedplatforms/cluster.html">https://www.mysql.com/support/supportedplatforms/cluster.html</a>]</td>
</tr>
<tr>
<td>Automated IP Failover</td>
<td>No</td>
<td>Depends on Connector and Configuration</td>
</tr>
<tr>
<td>Automated Database Failover</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Automatic Data Resynchronization</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Using ZFS Replication

### Requirement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>MySQL Replication</th>
<th>MySQL Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Failover Time</td>
<td>User / Script Dependent</td>
<td>1 Second and Less</td>
</tr>
<tr>
<td>Synchronous Replication</td>
<td>No, Asynchronous and Semisynchronous</td>
<td>Yes</td>
</tr>
<tr>
<td>Shared Storage</td>
<td>No, Distributed</td>
<td>No, Distributed</td>
</tr>
<tr>
<td>Geographic redundancy support</td>
<td>Yes</td>
<td>Yes, via MySQL Replication</td>
</tr>
<tr>
<td>Update Schema On-Line</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Scallability

<table>
<thead>
<tr>
<th>Scallability</th>
<th>One Master, Multiple Slaves</th>
<th>255</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Built-in Load Balancing</td>
<td>Reads, via MySQL Replication</td>
<td>Yes, Reads and Writes</td>
</tr>
<tr>
<td>Supports Read-Intensive Workloads</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports Write-Intensive Workloads</td>
<td>Yes, via Application-Level Sharding</td>
<td>Yes, via Auto-Sharding</td>
</tr>
<tr>
<td>Scale On-Line (add nodes, repartition, etc.)</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 16.1 Using ZFS Replication

To support high availability environments, providing an instant copy of the information on both the currently active machine and the hot backup is a critical part of the HA solution. There are many solutions to this problem, such as Chapter 17, Replication.

The ZFS file system provides functionality to create a snapshot of the file system contents, transfer the snapshot to another machine, and extract the snapshot to recreate the file system. You can create a snapshot at any time, and you can create as many snapshots as you like. By continually creating, transferring, and restoring snapshots, you can provide synchronization between one or more machines in a fashion similar to DRBD.

The following example shows a simple Solaris system running with a single ZFS pool, mounted at `/scratchpool`:

```
Filesystem size used avail capacity Mounted on
/dev/dsk/c0d0s0 4.6G 3.7G 886M 82% /dev/dsk/c0d0s7 26G 913M 25G 4% /export/home
scratchpool 16G 24K 16G 1% /scratchpool
```

The MySQL data is stored in a directory on `/scratchpool`. To help demonstrate some of the basic replication functionality, there are also other items stored in `/scratchpool` as well:

```
total 17
drwxr-x-x  31 root bin 50 Jul 21 07:32 DTT/
drwxr-x-x  4 root bin  5 Jul 21 07:32 SUNWmlib/
drwxr-x-x  4 root sys 16 Nov  5 09:56 SUNWspro/
```
Using ZFS for File System Replication

To create a snapshot of the file system, you use `zfs snapshot`, specifying the pool and the snapshot name:

```
root-shell> zfs snapshot scratchpool@snap1
```

To list the snapshots already taken:

```
root-shell> zfs list -t snapshot
NAME                USED  AVAIL  REFER  MOUNTPOINT
scratchpool@snap1      0      -  24.5K  -
scratchpool@snap2      0      -  24.5K  -
```

The snapshots themselves are stored within the file system metadata, and the space required to keep them varies as time goes on because of the way the snapshots are created. The initial creation of a snapshot is very quick, because instead of taking an entire copy of the data and metadata required to hold the entire snapshot, ZFS records only the point in time and metadata of when the snapshot was created.

As more changes to the original file system are made, the size of the snapshot increases because more space is required to keep the record of the old blocks. If you create lots of snapshots, say one per day, and then delete the snapshots from earlier in the week, the size of the newer snapshots might also increase, as the changes that make up the newer state have to be included in the more recent snapshots, rather than being spread over the seven snapshots that make up the week.

You cannot directly back up the snapshots because they exist within the file system metadata rather than as regular files. To get the snapshot into a format that you can copy to another file system, tape, and so on, you use the `zfs send` command to create a stream version of the snapshot.

For example, to write the snapshot out to a file:

```
root-shell> zfs send scratchpool@snap1 >/backup/scratchpool-snap1
```

Or tape:

```
root-shell> zfs send scratchpool@snap1 >/dev/rmt/0
```

You can also write out the incremental changes between two snapshots using `zfs send`:

```
root-shell> zfs send scratchpool@snap1 scratchpool@snap2 >/backup/scratchpool-changes
```

To recover a snapshot, you use `zfs recv`, which applies the snapshot information either to a new file system, or to an existing one.

### 16.1.1 Using ZFS for File System Replication

Because `zfs send` and `zfs recv` use streams to exchange data, you can use them to replicate information from one system to another by combining `zfs send`, `ssh`, and `zfs recv`.

For example, to copy a snapshot of the `scratchpool` file system to a new file system called `slavepool` on a new server, you would use the following command. This sequence combines the snapshot of `scratchpool`, the transmission to the slave machine (using `ssh` with login credentials), and the recovery of the snapshot on the slave using `zfs recv`:

```
root-shell> zfs send scratchpool@snap1 | ssh id@host pfexec zfs recv -F slavepool
```

The first part of the pipeline, `zfs send scratchpool@snap1`, streams the snapshot. The `ssh` command, and the command that it executes on the other server, `pfexec zfs recv -F slavepool`, receives the streamed snapshot data and writes it to slavepool. In this instance, I've specified the `-F` option which forces the snapshot data to be applied, and is therefore destructive. This is fine, as I'm creating the first version of my replicated file system.
On the slave machine, the replicated file system contains the exact same content:

```
root-shell> ls -al /slavepool/
total 23
drwxr-xr-x 6 root  root  7 Nov  8 09:13 ./
```

Once a snapshot has been created, to synchronize the file system again, you create a new snapshot and then use the incremental snapshot feature of `zfs send` to send the changes between the two snapshots to the slave machine again:

```
root-shell> zfs send -i scratchpool@snapshot1 scratchpool@snapshot2 |ssh id@host pfexec zfs recv slavepool
```

This operation only succeeds if the file system on the slave machine has not been modified at all. You cannot apply the incremental changes to a destination file system that has changed. In the example above, the `ls` command would cause problems by changing the metadata, such as the last access time for files or directories.

To prevent changes on the slave file system, set the file system on the slave to be read-only:

```
root-shell> zfs set readonly=on slavepool
```

Setting `readonly` means that you cannot change the file system on the slave by normal means, including the file system metadata. Operations that would normally update metadata (like our `ls`) silently perform their function without attempting to update the file system state.

In essence, the slave file system is nothing but a static copy of the original file system. However, even when configured to be read-only, a file system can have snapshots applied to it. With the file system set to read only, re-run the initial copy:

```
root-shell> zfs send scratchpool@snap1 |ssh id@host pfexec zfs recv -F slavepool
```

Now you can make changes to the original file system and replicate them to the slave.

### 16.1.2 Configuring MySQL for ZFS Replication

Configuring MySQL on the source file system is a case of creating the data on the file system that you intend to replicate. The configuration file in the example below has been updated to use `/scratchpool/mysql-data` as the data directory, and now you can initialize the tables:

```
root-shell> mysql_install_db --defaults-file=/etc/mysql/5.5/my.cnf --user=mysql
```

To synchronize the initial information, perform a new snapshot and then send an incremental snapshot to the slave using `zfs send`:

```
root-shell> zfs snapshot scratchpool@snap2
```

```
root-shell> zfs send -i scratchpool@snap1 scratchpool@snap2 |ssh id@host pfexec zfs recv slavepool
```

Doublecheck that the slave has the data by looking at the MySQL data directory on the `slavepool`:

```
root-shell> ls -al /slavepool/mysql-data/
```

Now you can start up MySQL, create some data, and then replicate the changes using `zfs send` `zfs recv` to the slave to synchronize the changes.

The rate at which you perform the synchronization depends on your application and environment. The limitation is the speed required to perform the snapshot and then to send the changes over the network.
To automate the process, create a script that performs the snapshot, send, and receive operation, and use `cron` to synchronize the changes at set times or intervals.

### 16.1.3 Handling MySQL Recovery with ZFS

When using ZFS replication to provide a constant copy of your data, ensure that you can recover your tables, either manually or automatically, in the event of a failure of the original system.

In the event of a failure, follow this sequence:

1. Stop the script on the master, if it is still up and running.
2. Set the slave file system to be read/write:
   ```shell
   root-shell> zfs set readonly=off slavepool
   ```
3. Start up `mysqld` on the slave. If you are using InnoDB, you get auto-recovery, if it is needed, to make sure the table data is correct, as shown here when I started up from our mid-INSERT snapshot:
   ```
   InnoDB: The log sequence number in ibdata files does not match
   InnoDB: the log sequence number in the ib_logfiles!
   081109 15:59:59  InnoDB: Database was not shut down normally!
   InnoDB: Starting crash recovery.
   InnoDB: Reading tablespace information from the .ibd files...
   InnoDB: Restoring possible half-written data pages from the doublewrite
   InnoDB: buffer...
   081109 16:00:03  InnoDB: Started; log sequence number 0 1142807951
   081109 16:00:03 [Note] /slavepool/mysql-5.0.67-solaris10-i386/bin/mysqld: ready for connections.
   Version: '5.0.67'  socket: '/tmp/mysql.sock'  port: 3306  MySQL Community Server (GPL)
   ```
   Use InnoDB tables and a regular synchronization schedule to reduce the risk for significant data loss. On MyISAM tables, you might need to run `REPAIR TABLE`, and you might even have lost some information.

### 16.2 Using MySQL with memcached

`memcached` is a simple, highly scalable key-based cache that stores data and objects wherever dedicated or spare RAM is available for quick access by applications, without going through layers of parsing or disk I/O. To use, you run the `memcached` command on one or more hosts and then use the shared cache to store objects. For more usage instructions, see Section 16.2.2, “Using memcached”

Benefits of using memcached include:

- Because all information is stored in RAM, the access speed is faster than loading the information each time from disk.
- Because the “value” portion of the key-value pair does not have any data type restrictions, you can cache data such as complex structures, documents, images, or a mixture of such things.
- If you use the in-memory cache to hold transient information, or as a read-only cache for information also stored in a database, the failure of any memcached server is not critical. For persistent data, you can fall back to an alternative lookup method using database queries, and reload the data into RAM on a different server.

The typical usage environment is to modify your application so that information is read from the cache provided by memcached. If the information is not in memcached, then the data is loaded from the MySQL database and written into the cache so that future requests for the same object benefit from the cached data.

For a typical deployment layout, see Figure 16.2, “memcached Architecture Overview”.

1930
Installing **memcached**

**Figure 16.2 memcached Architecture Overview**

In the example structure, any of the clients can contact one of the **memcached** servers to request a given key. Each client is configured to talk to all of the servers shown in the illustration. Within the client, when the request is made to store the information, the key used to reference the data is hashed and this hash is then used to select one of the **memcached** servers. The selection of the **memcached** server takes place on the client before the server is contacted, keeping the process lightweight.

The same algorithm is used again when a client requests the same key. The same key generates the same hash, and the same **memcached** server is selected as the source for the data. Using this method, the cached data is spread among all of the **memcached** servers, and the cached information is accessible from any client. The result is a distributed, memory-based, cache that can return information, particularly complex data and structures, much faster than natively reading the information from the database.

The data held within a traditional **memcached** server is never stored on disk (only in RAM, which means there is no persistence of data), and the RAM cache is always populated from the backing store (a MySQL database). If a **memcached** server fails, the data can always be recovered from the MySQL database.

### 16.2.1 Installing **memcached**

You can build and install **memcached** from the source code directly, or you can use an existing operating system package or installation.

**Installing **memcached** from a Binary Distribution**

To install **memcached** on a Red Hat, or Fedora host, use **yum**:

```
root-shell> yum install memcached
```

- **Note**
  
  On CentOS, you may be able to obtain a suitable RPM from another source, or use the source tarball.

To install **memcached** on a Debian or Ubuntu host, use **apt-get**:

```
root-shell> apt-get install memcached
```

To install **memcached** on a Gentoo host, use **emerge**:

```
root-shell> emerge install memcached
```

**Building **memcached** from Source**
Installing memcached

On other Unix-based platforms, including Solaris, AIX, HP-UX and macOS, and Linux distributions not mentioned already, you must install from source. For Linux, make sure you have a 2.6-based kernel, which includes the improved epoll interface. For all platforms, ensure that you have libevent 1.1 or higher installed. You can obtain libevent from libevent web page.

You can obtain the source for memcached from memcached website.

To build memcached, follow these steps:

1. Extract the memcached source package:
   ```
   shell> gunzip -c memcached-1.2.5.tar.gz | tar xf -
   ```

2. Change to the memcached-1.2.5 directory:
   ```
   shell> cd memcached-1.2.5
   ```

3. Run configure
   ```
   shell> ./configure
   ```

Some additional options you might specify to the configure:

• --prefix
   To specify a different installation directory, use the --prefix option:
   ```
   shell> ./configure --prefix=/opt
   ```
   The default is to use the /usr/local directory.

• --with-libevent
   If you have installed libevent and configure cannot find the library, use the --with-libevent option to specify the location of the installed library.

• --enable-64bit
   To build a 64-bit version of memcached (which enables you to use a single instance with a large RAM allocation), use --enable-64bit.

• --enable-threads
   To enable multithreading support in memcached, which improves the response times on servers with a heavy load, use --enable-threads. You must have support for the POSIX threads within your operating system to enable thread support. For more information on the threading support, see Section 16.2.2.8, "memcached Thread Support".

• --enable-dtrace
   memcached includes a range of DTrace threads that can be used to monitor and benchmark a memcached instance. For more information, see Section 16.2.2.6, "Using memcached and DTrace".

4. Run make to build memcached:
   ```
   shell> make
   ```

5. Run make install to install memcached:
   ```
   shell> make install
   ```
16.2.2 Using **memcached**

To start using **memcached**, start the **memcached** service on one or more servers. Running **memcached** sets up the server, allocates the memory and starts listening for connections from clients.

**Note**

You do not need to be a privileged user (**root**) to run **memcached** except to listen on one of the privileged TCP/IP ports (below 1024). You must, however, use a user that has not had their memory limits restricted using **setrlimit** or similar.

To start the server, run **memcached** as a nonprivileged (that is, non-**root**) user:

```bash
shell> memcached
```

By default, **memcached** uses the following settings:

- Memory allocation of 64MB
- Listens for connections on all network interfaces, using port 11211
- Supports a maximum of 1024 simultaneous connections

Typically, you would specify the full combination of options that you want when starting **memcached**, and normally provide a startup script to handle the initialization of **memcached**. For example, the following line starts **memcached** with a maximum of 1024MB RAM for the cache, listening on port 11211 on the IP address 198.51.100.110, running as a background daemon:

```bash
shell> memcached -d -m 1024 -p 11211 -l 198.51.100.110
```

To ensure that **memcached** is started up on boot, check the init script and configuration parameters.

### 16.2.2.1 **memcached** Command-Line Options

**memcached** supports the following options:

- **-u user**
  
  If you start **memcached** as **root**, use the **-u** option to specify the user for executing **memcached**:

```bash
shell> memcached -u memcache
```

- **-m memory**

  Set the amount of memory allocated to **memcached** for object storage. Default is 64MB.

  To increase the amount of memory allocated for the cache, use the **-m** option to specify the amount of RAM to be allocated (in megabytes). The more RAM you allocate, the more data you can store and therefore the more effective your cache is.

**Warning**

Do not specify a memory allocation larger than your available RAM. If you specify too large a value, then some RAM allocated for **memcached** uses swap space, and not physical RAM. This may lead to delays when storing and retrieving values, because data is swapped to disk, instead of storing the data directly in RAM.

You can use the output of the **vmstat** command to get the free memory, as shown in **free** column:
For example, to allocate 3GB of RAM:

```
shell> memcached -m 3072
```

On 32-bit x86 systems where you are using PAE to access memory above the 4GB limit, you cannot allocate RAM beyond the maximum process size. You can get around this by running multiple instances of `memcached`, each listening on a different port:

```
shell> memcached -m 1024 -p11211
shell> memcached -m 1024 -p11212
shell> memcached -m 1024 -p11213
```

**Note**

On all systems, particularly 32-bit, ensure that you leave enough room for both `memcached` application in addition to the memory setting. For example, if you have a dedicated `memcached` host with 4GB of RAM, do not set the memory size above 3500MB. Failure to do this may cause either a crash or severe performance issues.

- `-l interface`

  Specify a network interface/address to listen for connections. The default is to listen on all available address (`INADDR_ANY`).

  ```
  shell> memcached -l 198.51.100.110
  ```

  Support for IPv6 address support was added in `memcached` 1.2.5.

- `-p port`

  Specify the TCP port to use for connections. Default is 18080.

  ```
  shell> memcached -p 18080
  ```

- `-U port`

  Specify the UDP port to use for connections. Default is 11211, 0 switches UDP off.

  ```
  shell> memcached -U 18080
  ```

- `-s socket`

  Specify a Unix socket to listen on.

  If you are running `memcached` on the same server as the clients, you can disable the network interface and use a local Unix socket using the `-s` option:

  ```
  shell> memcached -s /tmp/memcached
  ```

  Using a Unix socket automatically disables network support, and saves network ports (allowing more ports to be used by your web server or other process).
• **-a mask**
  
  Specify the access mask to be used for the Unix socket, in octal. Default is 0700.

• **-c connections**
  
  Specify the maximum number of simultaneous connections to the *memcached* service. The default is 1024.

  ```
  shell> memcached -c 2048
  ```

  Use this option, either to reduce the number of connections (to prevent overloading *memcached* service) or to increase the number to make more effective use of the server running *memcached* server.

• **-t threads**
  
  Specify the number of threads to use when processing incoming requests.

  By default, *memcached* is configured to use 4 concurrent threads. The threading improves the performance of storing and retrieving data in the cache, using a locking system to prevent different threads overwriting or updating the same values. To increase or decrease the number of threads, use the `-t` option:

  ```
  shell> memcached -t 8
  ```

• **-d**
  
  Run *memcached* as a daemon (background) process:

  ```
  shell> memcached -d
  ```

• **-r**
  
  Maximize the size of the core file limit. In the event of a failure, this attempts to dump the entire memory space to disk as a core file, up to any limits imposed by *setrlimit*.

• **-M**
  
  Return an error to the client when the memory has been exhausted. This replaces the normal behavior of removing older items from the cache to make way for new items.

• **-k**
  
  Lock down all paged memory. This reserves the memory before use, instead of allocating new slabs of memory as new items are stored in the cache.

  **Note**

  There is a user-level limit on how much memory you can lock. Trying to allocate more than the available memory fails. You can set the limit for the user you started the daemon with (not for the `-u user user`) within the shell by using

  ```
  ulimit -S -l NUM_KB
  ```

• **-v**
  
  Verbose mode. Prints errors and warnings while executing the main event loop.
• **-vv**
  
  Very verbose mode. In addition to information printed by **-v**, also prints each client command and the response.

• **-vvv**
  
  Extremely verbose mode. In addition to information printed by **-vv**, also show the internal state transitions.

• **-h**
  
  Print the help message and exit.

• **-i**
  
  Print the memcached and libevent license.

• **-I mem**
  
  Specify the maximum size permitted for storing an object within the memcached instance. The size supports a unit postfix (k for kilobytes, m for megabytes). For example, to increase the maximum supported object size to 32MB:

  ```shell
  shell> memcached -I 32m
  ```

  The maximum object size you can specify is 128MB, the default remains at 1MB.

  This option was added in 1.4.2.

• **-b**
  
  Set the backlog queue limit. The backlog queue configures how many network connections can be waiting to be processed by memcached. Increasing this limit may reduce errors received by the client that it is not able to connect to the memcached instance, but does not improve the performance of the server. The default is 1024.

• **-P pidfile**
  
  Save the process ID of the memcached instance into file.

• **-f**
  
  Set the chunk size growth factor. When allocating new memory chunks, the allocated size of new chunks is determined by multiplying the default slab size by this factor.

  To see the effects of this option without extensive testing, use the **-vv** command-line option to show the calculated slab sizes. For more information, see Section 16.2.2.9, “memcached Logs”.

• **-n bytes**
  
  The minimum space allocated for the key+value+flags information. The default is 48 bytes.

• **-L**
  
  On systems that support large memory pages, enables large memory page use. Using large memory pages enables memcached to allocate the item cache in one large chunk, which can improve the performance by reducing the number misses when accessing memory.
• **-C**

  Disable the use of compare and swap (CAS) operations.
  
  This option was added in memcached 1.3.x.

• **-D char**

  Set the default character to be used as a delimiter between the key prefixes and IDs. This is used for the per-prefix statistics reporting (see Section 16.2.4, “Getting memcached Statistics”). The default is the colon (:). If this option is used, statistics collection is turned on automatically. If not used, you can enable stats collection by sending the `stats detail on` command to the server.

  This option was added in memcached 1.3.x.

• **-R num**

  Sets the maximum number of requests per event process. The default is 20.

• **-B protocol**

  Set the binding protocol, that is, the default memcached protocol support for client connections. Options are ascii, binary or auto. Automatic (auto) is the default.

  This option was added in memcached 1.4.0.

### 16.2.2.2 memcached Deployment

When using memcached you can use a number of different potential deployment strategies and topologies. The exact strategy to use depends on your application and environment. When developing a system for deploying memcached within your system, keep in mind the following points:

• memcached is only a caching mechanism. It shouldn't be used to store information that you cannot otherwise afford to lose and then load from a different location.

• There is no security built into the memcached protocol. At a minimum, make sure that the servers running memcached are only accessible from inside your network, and that the network ports being used are blocked (using a firewall or similar). If the information that is being stored on the memcached servers is sensitive, encrypt it before storing it in memcached.

• memcached does not provide any sort of failover. Because there is no communication between different memcached instances. If an instance fails, your application must capable of removing it from the list, reloading the data and then writing data to another memcached instance.

• Latency between the clients and the memcached can be a problem if you are using different physical machines for these tasks. If you find that the latency is a problem, move the memcached instances to be on the clients.

• Key length is determined by the memcached server. The default maximum key size is 250 bytes.

• Try to use at least two memcached instances, especially for multiple clients, to avoid having a single point of failure. Ideally, create as many memcached nodes as possible. When adding and removing memcached instances from a pool, the hashing and distribution of key-value pairs may be affected. For information on how to avoid problems, see Section 16.2.2.5, “memcached Hashing/Distribution Types”.

### 16.2.2.3 Using Namespaces

The memcached cache is a very simple massive key-value storage system, and as such there is no way of compartmentalizing data automatically into different sections. For example, if you are storing information by
the unique ID returned from a MySQL database, then storing the data from two different tables could run into issues because the same ID might be valid in both tables.

Some interfaces provide an automated mechanism for creating namespaces when storing information into the cache. In practice, these namespaces are merely a prefix before a given ID that is applied every time a value is stored or retrieve from the cache.

You can implement the same basic principle by using keys that describe the object and the unique identifier within the key that you supply when the object is stored. For example, when storing user data, prefix the ID of the user with user: or user-.

Note

Using namespaces or prefixes only controls the keys stored/retrieved. There is no security within memcached, and therefore no way to enforce that a particular client only accesses keys with a particular namespace. Namespaces are only useful as a method of identifying data and preventing corruption of key-value pairs.

16.2.2.4 Data Expiry

There are two types of data expiry within a memcached instance. The first type is applied at the point when you store a new key-value pair into the memcached instance. If there is not enough space within a suitable slab to store the value, then an existing least recently used (LRU) object is removed (evicted) from the cache to make room for the new item.

The LRU algorithm ensures that the object that is removed is one that is either no longer in active use or that was used so long ago that its data is potentially out of date or of little value. However, in a system where the memory allocated to memcached is smaller than the number of regularly used objects required in the cache, a lot of expired items could be removed from the cache even though they are in active use. You use the statistics mechanism to get a better idea of the level of evictions (expired objects). For more information, see Section 16.2.4, “Getting memcached Statistics”.

You can change this eviction behavior by setting the -M command-line option when starting memcached. This option forces an error to be returned when the memory has been exhausted, instead of automatically eviction older data.

The second type of expiry system is an explicit mechanism that you can set when a key-value pair is inserted into the cache, or when deleting an item from the cache. Using an expiration time can be a useful way of ensuring that the data in the cache is up to date and in line with your application needs and requirements.

A typical scenario for explicitly setting the expiry time might include caching session data for a user when accessing a website. memcached uses a lazy expiry mechanism where the explicit expiry time that has been set is compared with the current time when the object is requested. Only objects that have not expired are returned.

You can also set the expiry time when explicitly deleting an object from the cache. In this case, the expiry time is really a timeout and indicates the period when any attempts to set the value for a given key are rejected.

16.2.2.5 memcached Hashing/Distribution Types

The memcached client interface supports a number of different distribution algorithms that are used in multi-server configurations to determine which host should be used when setting or getting data from a given memcached instance. When you get or set a value, a hash is constructed from the supplied key and
then used to select a host from the list of configured servers. Because the hashing mechanism uses the supplied key as the basis for the hash, the same server is selected during both set and get operations.

You can think of this process as follows. Given an array of servers (a, b, and c), the client uses a hashing algorithm that returns an integer based on the key being stored or retrieved. The resulting value is then used to select a server from the list of servers configured in the client. Most standard client hashing within memcache clients uses a simple modulus calculation on the value against the number of configured memcached servers. You can summarize the process in pseudocode as:

```plaintext
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash($key);
$chosen = $value % length(@memcservers);
```

Replacing the above with values:

```plaintext
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash('myid');
$chosen = 7009 % 3;
```

In the above example, the client hashing algorithm chooses the server at index 1 \((7009 \% 3 = 1)\), and stores or retrieves the key and value with that server.

**Note**

This selection and hashing process is handled automatically by the memcached client you are using; you need only provide the list of memcached servers to use.

You can see a graphical representation of this below in Figure 16.3, "memcached Hash Selection".

**Figure 16.3 memcached Hash Selection**

![Diagram showing memcached Hash Selection](image)

The same hashing and selection process takes place during any operation on the specified key within the memcached client.

Using this method provides a number of advantages:

- The hashing and selection of the server to contact is handled entirely within the client. This eliminates the need to perform network communication to determine the right machine to contact.
- Because the determination of the memcached server occurs entirely within the client, the server can be selected automatically regardless of the operation being executed (set, get, increment, etc.).
- Because the determination is handled within the client, the hashing algorithm returns the same value for a given key; values are not affected or reset by differences in the server environment.
- Selection is very fast. The hashing algorithm on the key value is quick and the resulting selection of the server is from a simple array of available machines.
Using client-side hashing simplifies the distribution of data over each memcached server. Natural distribution of the values returned by the hashing algorithm means that keys are automatically spread over the available servers.

Providing that the list of servers configured within the client remains the same, the same stored key returns the same value, and therefore selects the same server.

However, if you do not use the same hashing mechanism then the same data may be recorded on different servers by different interfaces, both wasting space on your memcached and leading to potential differences in the information.

**Note**

One way to use a multi-interface compatible hashing mechanism is to use the libmemcached library and the associated interfaces. Because the interfaces for the different languages (including C, Ruby, Perl and Python) use the same client library interface, they always generate the same hash code from the ID.

The problem with client-side selection of the server is that the list of the servers (including their sequential order) must remain consistent on each client using the memcached servers, and the servers must be available. If you try to perform an operation on a key when:

- A new memcached instance has been added to the list of available instances
- A memcached instance has been removed from the list of available instances
- The order of the memcached instances has changed

When the hashing algorithm is used on the given key, but with a different list of servers, the hash calculation may choose a different server from the list.

If a new memcached instance is added into the list of servers, as new.memc is in the example below, then a GET operation using the same key, myid, can result in a cache-miss. This is because the same value is computed from the key, which selects the same index from the array of servers, but index 2 now points to the new server, not the server c.memc where the data was originally stored. This would result in a cache miss, even though the key exists within the cache on another memcached instance.

**Figure 16.4** memcached Hash Selection with New memcached instance

This means that servers c.memc and new.memc both contain the information for key myid, but the information stored against the key in each server may be different in each instance. A more significant problem is a much higher number of cache-misses when retrieving data, as the addition of a new server changes the distribution of keys, and this in turn requires rebuilding the cached data on the memcached instances, causing an increase in database reads.
The same effect can occur if you actively manage the list of servers configured in your clients, adding and removing the configured memcached instances as each instance is identified as being available. For example, removing a memcached instance when the client notices that the instance can no longer be contacted can cause the server selection to fail as described here.

To prevent this causing significant problems and invalidating your cache, you can select the hashing algorithm used to select the server. There are two common types of hashing algorithm, consistent and modula.

With consistent hashing algorithms, the same key when applied to a list of servers always uses the same server to store or retrieve the keys, even if the list of configured servers changes. This means that you can add and remove servers from the config list and always use the same server for a given key. There are two types of consistent hashing algorithms available, Ketama and Wheel. Both types are supported by libmemcached, and implementations are available for PHP and Java.

Any consistent hashing algorithm has some limitations. When you add servers to an existing list of configured servers, keys are distributed to the new servers as part of the normal distribution. When you remove servers from the list, the keys are re-allocated to another server within the list, meaning that the cache needs to be re-populated with the information. Also, a consistent hashing algorithm does not resolve the issue where you want consistent selection of a server across multiple clients, but where each client contains a different list of servers. The consistency is enforced only within a single client.

With a modula hashing algorithm, the client selects a server by first computing the hash and then choosing a server from the list of configured servers. As the list of servers changes, so the server selected when using a modula hashing algorithm also changes. The result is the behavior described above; changes to the list of servers mean that different servers are selected when retrieving data, leading to cache misses and increase in database load as the cache is re-seeded with information.

If you use only a single memcached instance for each client, or your list of memcached servers configured for a client never changes, then the selection of a hashing algorithm is irrelevant, as it has no noticeable effect.

If you change your servers regularly, or you use a common set of servers that are shared among a large number of clients, then using a consistent hashing algorithm should help to ensure that your cache data is not duplicated and the data is evenly distributed.

### 16.2.2.6 Using memcached and DTrace

memcached includes a number of different DTrace probes that can be used to monitor the operation of the server. The probes included can monitor individual connections, slab allocations, and modifications to the hash table when a key-value pair is added, updated, or removed.

For more information on DTrace and writing DTrace scripts, read the DTrace User Guide.

Support for DTrace probes was added to memcached 1.2.6 includes a number of DTrace probes that can be used to help monitor your application. DTrace is supported on Solaris 10, OpenSolaris, OS X 10.5 and FreeBSD. To enable the DTrace probes in memcached, build from source and use the --enable-dtrace option. For more information, see Section 16.2.1, “Installing memcached”.

The probes supported by memcached are:

- **conn-allocate(connid)**
  
  Fired when a connection object is allocated from the connection pool.

- **connid**: The connection ID.
Using memcached

- **conn-release(connid)**
  Fired when a connection object is released back to the connection pool.
  Arguments:
  - **connid**: The connection ID.

- **conn-create(ptr)**
  Fired when a new connection object is being created (that is, there are no free connection objects in the connection pool).
  Arguments:
  - **ptr**: A pointer to the connection object

- **conn-destroy(ptr)**
  Fired when a connection object is being destroyed.
  Arguments:
  - **ptr**: A pointer to the connection object.

- **conn-dispatch(connid, threadid)**
  Fired when a connection is dispatched from the main or connection-management thread to a worker thread.
  Arguments:
  - **connid**: The connection ID.
  - **threadid**: The thread ID.

- **slabs-allocate(size, slabclass, slabsize, ptr)**
  Allocate memory from the slab allocator.
  Arguments:
  - **size**: The requested size.
  - **slabclass**: The allocation is fulfilled in this class.
  - **slabsize**: The size of each item in this class.
  - **ptr**: A pointer to allocated memory.

- **slabs-allocate-failed(size, slabclass)**
  Failed to allocate memory (out of memory).
  Arguments:
  - **size**: The requested size.
  - **slabclass**: The class that failed to fulfill the request.
- **slabs-slabclass-allocate(slabclass)**
  Fired when a slab class needs more space.
  Arguments:
  - *slabclass*: The class that needs more memory.

- **slabs-slabclass-allocate-failed(slabclass)**
  Failed to allocate memory (out of memory).
  Arguments:
  - *slabclass*: The class that failed to grab more memory.

- **slabs-free(size, slabclass, ptr)**
  Release memory.
  Arguments:
  - *size*: The amount of memory to release, in bytes.
  - *slabclass*: The class the memory belongs to.
  - *ptr*: A pointer to the memory to release.

- **assoc-find(key, depth)**
  Fired when we have searched the hash table for a named key. These two elements provide an insight into how well the hash function operates. Traversals are a sign of a less optimal function, wasting CPU capacity.
  Arguments:
  - *key*: The key searched for.
  - *depth*: The depth in the list of hash table.

- **assoc-insert(key, nokeys)**
  Fired when a new item has been inserted.
  Arguments:
  - *key*: The key just inserted.
  - *nokeys*: The total number of keys currently being stored, including the key for which insert was called.
• **assoc-delete(key, nokeys)**

  Fired when a new item has been removed.

  Arguments:
  - **key**: The key just deleted.
  - **nokeys**: The total number of keys currently being stored, excluding the key for which delete was called.

• **item-link(key, size)**

  Fired when an item is being linked in the cache.

  Arguments:
  - **key**: The items key.
  - **size**: The size of the data.

• **item-unlink(key, size)**

  Fired when an item is being deleted.

  Arguments:
  - **key**: The items key.
  - **size**: The size of the data.

• **item-remove(key, size)**

  Fired when the refcount for an item is reduced.

  Arguments:
  - **key**: The item's key.
  - **size**: The size of the data.

• **item-update(key, size)**

  Fired when the "last referenced" time is updated.

  Arguments:
  - **key**: The item's key.
  - **size**: The size of the data.
• `item-replace(oldkey, oldsize, newkey, newsize)`
  Fired when an item is being replaced with another item.
  Arguments:
  • `oldkey`: The key of the item to replace.
  • `oldsize`: The size of the old item.
  • `newkey`: The key of the new item.
  • `newsize`: The size of the new item.

• `process-command-start(connid, request, size)`
  Fired when the processing of a command starts.
  Arguments:
  • `connid`: The connection ID.
  • `request`: The incoming request.
  • `size`: The size of the request.

• `process-command-end(connid, response, size)`
  Fired when the processing of a command is done.
  Arguments:
  • `connid`: The connection ID.
  • `response`: The response to send back to the client.
  • `size`: The size of the response.

• `command-get(connid, key, size)`
  Fired for a `get` command.
  Arguments:
  • `connid`: The connection ID.
  • `key`: The requested key.
  • `size`: The size of the key's data (or -1 if not found).

• `command-gets(connid, key, size, casid)`
  Fired for a `gets` command.
  Arguments:
  • `connid`: The connection ID.
  • `key`: The requested key.
• **size**: The size of the key's data (or -1 if not found).
• **casid**: The casid for the item.

**command-add(connid, key, size)**

Fired for a **add** command.

Arguments:
• **connid**: The connection ID.
• **key**: The requested key.
• **size**: The new size of the key's data (or -1 if not found).

**command-set(connid, key, size)**

Fired for a **set** command.

Arguments:
• **connid**: The connection ID.
• **key**: The requested key.
• **size**: The new size of the key's data (or -1 if not found).

**command-replace(connid, key, size)**

Fired for a **replace** command.

Arguments:
• **connid**: The connection ID.
• **key**: The requested key.
• **size**: The new size of the key's data (or -1 if not found).

**command-prepend(connid, key, size)**

Fired for a **prepend** command.

Arguments:
• **connid**: The connection ID.
• **key**: The requested key.
• **size**: The new size of the key's data (or -1 if not found).
Using memcached

- **command-append(connid, key, size)**
  Fired for a **append** command.
  Arguments:
  - **connid**: The connection ID.
  - **key**: The requested key.
  - **size**: The new size of the key's data (or -1 if not found).

- **command-cas(connid, key, size, casid)**
  Fired for a **cas** command.
  Arguments:
  - **connid**: The connection ID.
  - **key**: The requested key.
  - **size**: The size of the key's data (or -1 if not found).
  - **casid**: The cas ID requested.

- **command-incr(connid, key, val)**
  Fired for **incr** command.
  Arguments:
  - **connid**: The connection ID.
  - **key**: The requested key.
  - **val**: The new value.

- **command-decr(connid, key, val)**
  Fired for **decr** command.
  Arguments:
  - **connid**: The connection ID.
  - **key**: The requested key.
  - **val**: The new value.

- **command-delete(connid, key, exptime)**
  Fired for a **delete** command.
  Arguments:
  - **connid**: The connection ID.
  - **key**: The requested key.
Using `memcached`

- **exptime**: The expiry time.

### 16.2.2.7 Memory Allocation within `memcached`

When you first start `memcached`, the memory that you have configured is not automatically allocated. Instead, `memcached` only starts allocating and reserving physical memory once you start saving information into the cache.

When you start to store data into the cache, `memcached` does not allocate the memory for the data on an item by item basis. Instead, a slab allocation is used to optimize memory usage and prevent memory fragmentation when information expires from the cache.

With slab allocation, memory is reserved in blocks of 1MB. The slab is divided up into a number of blocks of equal size. When you try to store a value into the cache, `memcached` checks the size of the value that you are adding to the cache and determines which slab contains the right size allocation for the item. If a slab with the item size already exists, the item is written to the block within the slab.

If the new item is bigger than the size of any existing blocks, then a new slab is created, divided up into blocks of a suitable size. If an existing slab with the right block size already exists, but there are no free blocks, a new slab is created. If you update an existing item with data that is larger than the existing block allocation for that key, then the key is re-allocated into a suitable slab.

For example, the default size for the smallest block is 88 bytes (40 bytes of value, and the default 48 bytes for the key and flag data). If the size of the first item you store into the cache is less than 40 bytes, then a slab with a block size of 88 bytes is created and the value stored.

If the size of the data that you intend to store is larger than this value, then the block size is increased by the chunk size factor until a block size large enough to hold the value is determined. The block size is always a function of the scale factor, rounded up to a block size which is exactly divisible into the chunk size.

For a sample of the structure, see Figure 16.5, “Memory Allocation in `memcached`”.

**Figure 16.5 Memory Allocation in `memcached`**

![Memory Allocation Diagram](image)

The result is that you have multiple pages allocated within the range of memory allocated to `memcached`. Each page is 1MB in size (by default), and is split into a different number of chunks, according to the chunk size required to store the key-value pairs. Each instance has multiple pages allocated, and a page is always created when a new item needs to be created requiring a chunk of a particular size. A slab may consist of multiple pages, and each page within a slab contains an equal number of chunks.
The chunk size of a new slab is determined by the base chunk size combined with the chunk size growth factor. For example, if the initial chunks are 104 bytes in size, and the default chunk size growth factor is used (1.25), then the next chunk size allocated would be the best power of 2 fit for 104*1.25, or 136 bytes.

Allocating the pages in this way ensures that memory does not get fragmented. However, depending on the distribution of the objects that you store, it may lead to an inefficient distribution of the slabs and chunks if you have significantly different sized items. For example, having a relatively small number of items within each chunk size may waste a lot of memory with just few chunks in each allocated page.

You can tune the growth factor to reduce this effect by using the `-f` command line option, which adapts the growth factor applied to make more effective use of the chunks and slabs allocated. For information on how to determine the current slab allocation statistics, see Section 16.2.4.2, “memcached Slabs Statistics”.

If your operating system supports it, you can also start `memcached` with the `-L` command line option. This option preallocates all the memory during startup using large memory pages. This can improve performance by reducing the number of misses in the CPU memory cache.

### 16.2.2.8 memcached Thread Support

If you enable the thread implementation within when building `memcached` from source, then `memcached` uses multiple threads in addition to the `libevent` system to handle requests.

When enabled, the threading implementation operates as follows:

- Threading is handled by wrapping functions within the code to provide basic protection from updating the same global structures at the same time.

- Each thread uses its own instance of the `libevent` to help improve performance.

- TCP/IP connections are handled with a single thread listening on the TCP/IP socket. Each connection is then distributed to one of the active threads on a simple round-robin basis. Each connection then operates solely within this thread while the connection remains open.

- For UDP connections, all the threads listen to a single UDP socket for incoming requests. Threads that are not currently dealing with another request ignore the incoming packet. One of the remaining, nonbusy, threads reads the request and sends the response. This implementation can lead to increased CPU load as threads wake from sleep to potentially process the request.

Using threads can increase the performance on servers that have multiple CPU cores available, as the requests to update the hash table can be spread between the individual threads. To minimize overhead from the locking mechanism employed, experiment with different thread values to achieve the best performance based on the number and type of requests within your given workload.

### 16.2.2.9 memcached Logs

If you enable verbose mode, using the `-v`, `-vv`, or `-vvv` options, then the information output by `memcached` includes details of the operations being performed.

Without the verbose options, `memcached` normally produces no output during normal operating.

- **Output when using `-v`**

  The lowest verbosity level shows you:

  - Errors and warnings
  - Transient errors
  - Protocol and socket errors, including exhausting available connections
• Each registered client connection, including the socket descriptor number and the protocol used.

For example:

• 32: Client using the ascii protocol
• 33: Client using the ascii protocol

The socket descriptor is only valid while the client remains connected. Non-persistent connections may not be effectively represented.

Examples of the error messages output at this level include:

- Can't listen for events on fd $d
- Can't read from libevent pipe
- Catastrophic: event fd doesn't match conn fd!
- Couldn't build response
- Couldn't realloc input buffer
- Couldn't update event
- Failed to build UDP headers
- Failed to read, and not due to blocking
- Too many open connections
- Unexpected state $d

• Output when using -vv

When using the second level of verbosity, you get more detailed information about protocol operations, keys updated, chunk and network operatings and details.

During the initial start-up of memcached with this level of verbosity, you are shown the sizes of the individual slab classes, the chunk sizes, and the number of entries per slab. These do not show the allocation of the slabs, just the slabs that would be created when data is added. You are also given information about the listen queues and buffers used to send information. A sample of the output generated for a TCP/IP based system with the default memory and growth factors is given below:

```
shell> memcached -vv
slab class 1: chunk size  80 perslab 13107
slab class 2: chunk size  104 perslab 10082
slab class 3: chunk size  136 perslab  7710
slab class 4: chunk size  176 perslab  5957
slab class 5: chunk size  224 perslab  4681
slab class 6: chunk size  280 perslab  3744
slab class 7: chunk size  352 perslab  2978
slab class 8: chunk size  440 perslab  2383
slab class 9: chunk size  552 perslab  1899
slab class 10: chunk size  696 perslab  1506
slab class 11: chunk size  872 perslab  1202
slab class 12: chunk size 1096 perslab   956
slab class 13: chunk size 1376 perslab   762
slab class 14: chunk size 1720 perslab   609
slab class 15: chunk size 2152 perslab   487
slab class 16: chunk size 2696 perslab   388
slab class 17: chunk size 3376 perslab   310
slab class 18: chunk size 4224 perslab   248
slab class 19: chunk size 5280 perslab   198
slab class 20: chunk size 6600 perslab   158
slab class 21: chunk size 8256 perslab   127
slab class 22: chunk size 10320 perslab  101
slab class 23: chunk size 12904 perslab   81
slab class 24: chunk size 16136 perslab   64
slab class 25: chunk size 20176 perslab   51
slab class 26: chunk size 25224 perslab   41
slab class 27: chunk size 31536 perslab   33
```
Using **memcached**

```
slab class 28: chunk size  39424 perslab  26
slab class 29: chunk size  49280 perslab  21
slab class 30: chunk size  61600 perslab  17
slab class 31: chunk size  77000 perslab  13
slab class 32: chunk size  96256 perslab  10
slab class 33: chunk size 120320 perslab   8
slab class 34: chunk size 150400 perslab   6
slab class 35: chunk size 188000 perslab   5
slab class 36: chunk size 235000 perslab   4
slab class 37: chunk size 293752 perslab   3
slab class 38: chunk size 367192 perslab   2
slab class 39: chunk size 458992 perslab   2
<26 server listening (auto-negotiate)
<29 server listening (auto-negotiate)
<30 send buffer was 57344, now 2097152
<31 send buffer was 57344, now 2097152
<30 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
```

Using this verbosity level can be a useful way to check the effects of the growth factor used on slabs with different memory allocations, which in turn can be used to better tune the growth factor to suit the data you are storing in the cache. For example, if you set the growth factor to 4 (quadrupling the size of each slab):

```
shell> memcached -f 4 -m 1g -vv
slab class  1: chunk size     80 perslab 13107
slab class  2: chunk size    320 perslab  3276
slab class  3: chunk size   1280 perslab   819
slab class  4: chunk size   5120 perslab   204
slab class  5: chunk size  20480 perslab    51
slab class  6: chunk size  81920 perslab    12
slab class  7: chunk size 327680 perslab     3
...
```

During use of the cache, this verbosity level also prints out detailed information on the storage and recovery of keys and other information. An example of the output during a typical set/get and increment/decrement operation is shown below.

```
32: Client using the ascii protocol
<32 set my_key 0 0 10
>32 STORED
<32 set object_key 1 0 36
>32 STORED
<32 get my_key
>32 sending key my_key
>32 END
<32 get object_key
>32 sending key object_key
>32 END
<32 set key 0 0 6
>32 STORED
<32 incr key 1
>32 789544
<32 decr key 1
>32 789543
<32 incr key 2
>32 789545
<32 set my_key 0 0 10
>32 STORED
```

1951
Developing a memcached Application

During client communication, for each line, the initial character shows the direction of flow of the information. The < for communication from the client to the memcached server and > for communication back to the client. The number is the numeric socket descriptor for the connection.

- **Output when using -vvv**

This level of verbosity includes the transitions of connections between different states in the event library while reading and writing content to/from the clients. It should be used to diagnose and identify issues in client communication. For example, you can use this information to determine if memcached is taking a long time to return information to the client, during the read of the client operation or before returning and completing the operation. An example of the typical sequence for a set operation is provided below:

All of the verbosity levels in memcached are designed to be used during debugging or examination of issues. The quantity of information generated, particularly when using -vvv, is significant, particularly on a busy server. Also be aware that writing the error information out, especially to disk, may negate some of the performance gains you achieve by using memcached. Therefore, use in production or deployment environments is not recommended.

16.2.3 Developing a memcached Application

A number of language interfaces let applications store and retrieve information with memcached servers. You can write memcached applications in popular languages such as Perl, PHP, Python, Ruby, C, and Java.

Data stored into a memcached server is referred to by a single string (the key), with storage into the cache and retrieval from the cache using the key as the reference. The cache therefore operates like a large associative array or hash table. It is not possible to structure or otherwise organize the information stored
Developing a memcached Application

in the cache. To emulate database notions such as multiple tables or composite key values, you must encode the extra information into the strings used as keys. For example, to store or look up the address corresponding to a specific latitude and longitude, you might turn those two numeric values into a single comma-separated string to use as a key.

16.2.3.1 Basic memcached Operations

The interface to memcached supports the following methods for storing and retrieving information in the cache, and these are consistent across all the different APIs, although the language specific mechanics might be different:

- **get(key)**: Retrieves information from the cache. Returns the value associated with the key if the specified key exists. Returns NULL, nil, undefined, or the closest equivalent in the corresponding language, if the specified key does not exist.

- **set(key, value [, expiry])**: Sets the item associated with a key in the cache to the specified value. This either updates an existing item if the key already exists, or adds a new key-value pair if the key doesn't exist. If the expiry time is specified, then the item expires (and is deleted) when the expiry time is reached. The time is specified in seconds, and is taken as a relative time if the value is less than 30 days (30*24*60*60), or an absolute time (epoch) if larger than this value.

- **add(key, value [, expiry])**: Adds the key and associated value to the cache, if the specified key does not already exist.

- **replace(key, value [, expiry])**: Replaces the item associated with the specified key, only if the key already exists. The new value is given by the value parameter.

- **delete(key [, time])**: Deletes the key and its associated item from the cache. If you supply a time, then adding another item with the specified key is blocked for the specified period.

- **incr(key , value)**: Increments the item associated with the key by the specified value.

- **decr(key , value)**: Decrements the item associated with the key by the specified value.

- **flush_all**: Invalidates (or expires) all the current items in the cache. Technically they still exist (they are not deleted), but they are silently destroyed the next time you try to access them.

In all implementations, most or all of these functions are duplicated through the corresponding native language interface.

When practical, use memcached to store full items, rather than caching a single column value from the database. For example, when displaying a record about an object (invoice, user history, or blog post), load all the data for the associated entry from the database, and compile it into the internal structure that would normally be required by the application. Save the complete object in the cache.

Complex data structures cannot be stored directly. Most interfaces serialize the data for you, that is, put it in a textual form that can reconstruct the original pointers and nesting. Perl uses Storable, PHP uses serialize, Python uses cPickle (or Pickle) and Java uses the Serializable interface. In most cases, the serialization interface used is customizable. To share data stored in memcached instances between different language interfaces, consider using a common serialization solution such as JSON (Javascript Object Notation).

16.2.3.2 Using memcached as a MySQL Caching Layer

When using memcached to cache MySQL data, your application must retrieve data from the database and load the appropriate key-value pairs into the cache. Then, subsequent lookups can be done directly from the cache.
Developing a `memcached` Application

Because MySQL has its own in-memory caching mechanisms for queried data, such as the `InnoDB buffer pool` and the MySQL query cache, look for opportunities beyond loading individual column values or rows into the cache. Prefer to cache composite values, such as those retrieved from multiple tables through a join query, or result sets assembled from multiple rows.

**Caution**

Limit the information in the cache to non-sensitive data, because there is no security required to access or update the information within a `memcached` instance. Anybody with access to the machine has the ability to read, view and potentially update the information. To keep the data secure, encrypt the information before caching it. To restrict the users capable of connecting to the server, either disable network access, or use IPTables or similar techniques to restrict access to the `memcached` ports to a select set of hosts.

You can introduce `memcached` to an existing application, even if caching was not part of the original design. In many languages and environments the changes to the application will be just a few lines, first to attempt to read from the cache when loading data, fall back to the old method if the information is not cached, and to update the cache with information once the data has been read.

The general sequence for using `memcached` in any language as a caching solution for MySQL is as follows:

1. Request the item from the cache.
2. If the item exists, use the item data.
3. If the item does not exist, load the data from MySQL, and store the value into the cache. This means the value is available to the next client that requests it from the cache.

For a flow diagram of this sequence, see Figure 16.6, "Typical `memcached` Application Flowchart".

**Figure 16.6 Typical `memcached` Application Flowchart**

![Flowchart Image](image-url)
Adapting Database Best Practices to memcached Applications

The most direct way to cache MySQL data is to use a 2-column table, where the first column is a primary key. Because of the uniqueness requirements for memcached keys, make sure your database schema makes appropriate use of primary keys and unique constraints.

If you combine multiple column values into a single memcached item value, choose data types to make it easy to parse the value back into its components, for example by using a separator character between numeric values.

The queries that map most easily to memcached lookups are those with a single WHERE clause, using an = or IN operator. For complicated WHERE clauses, or those using operators such as <, >, BETWEEN, or LIKE, memcached does not provide a simple or efficient way to scan through or filter the keys or associated values, so typically you perform those operations as SQL queries on the underlying database.

16.2.3.3 Using libmemcached with C and C++

The libmemcached library provides both C and C++ interfaces to memcached and is also the basis for a number of different additional API implementations, including Perl, Python and Ruby. Understanding the core libmemcached functions can help when using these other interfaces.

The C library is the most comprehensive interface library for memcached and provides functions and operational systems not always exposed in interfaces not based on the libmemcached library.

The different functions can be divided up according to their basic operation. In addition to functions that interface to the core API, a number of utility functions provide extended functionality, such as appending and prepending data.

To build and install libmemcached, download the libmemcached package, run configure, and then build and install:

```
shell> tar xjf libmemcached-0.21.tar.gz
shell> cd libmemcached-0.21
shell> ./configure
shell> make
shell> make install
```

On many Linux operating systems, you can install the corresponding libmemcached package through the usual yum, apt-get, or similar commands.

To build an application that uses the library, first set the list of servers. Either directly manipulate the servers configured within the main memcached_st structure, or separately populate a list of servers, and then add this list to the memcached_st structure. The latter method is used in the following example. Once the server list has been set, you can call the functions to store or retrieve data. A simple application for setting a preset value to localhost is provided here:

```c
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{
    memcached_server_st *servers = NULL;
    memcached_st *memc;
    memcached_return rc;
    char *key= "keystring"
    char *value= "keyvalue"
```
Developing a memcached Application

```c
memcached_server_st *memcached_servers_parse (char *server_strings);
memc= memcached_create(NULL);
servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
rc= memcached_server_push(memc, servers);
if (rc == MEMCACHED_SUCCESS)
  fprintf(stderr,"Added server successfully\n");
else
  fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));
rc= memcached_set(memc, key, strlen(key), value, strlen(value), (time_t)0, (uint32_t)0);
if (rc == MEMCACHED_SUCCESS)
  fprintf(stderr,"Key stored successfully\n");
else
  fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));
return 0;
}
```

To test the success of an operation, use the return value, or populated result code, for a given function. The value is always set to MEMCACHED_SUCCESS if the operation succeeded. In the event of a failure, use the memcached_strerror() function to translate the result code into a printable string.

To build the application, specify the memcached library:

```
shell> gcc -o memc_basic memc_basic.c -lmemcached
```

Running the above sample application, after starting a memcached server, should return a success message:

```
shell> memc_basic
Added server successfully
Key stored successfully
```

**libmemcached Base Functions**

The base libmemcached functions let you create, destroy and clone the main memcached_st structure that is used to interface with the memcached servers. The main functions are defined below:

```c
memcached_st *memcached_create (memcached_st *ptr);
void memcached_free (memcached_st *ptr);
memcached_st *memcached_clone(memcached_st *clone, memcached_st *source);
```

Creates a new memcached_st structure for use with the other libmemcached API functions. You can supply an existing, static, memcached_st structure, or NULL to have a new structured allocated. Returns a pointer to the created structure, or NULL on failure.

Frees the structure and memory allocated to a previously created memcached_st structure.

Clones an existing memcached structure from the specified source, copying the defaults and list of servers defined in the structure.

**libmemcached Server Functions**

The libmemcached API uses a list of servers, stored within the memcached_server_st structure, to act as the list of servers used by the rest of the functions. To use memcached, you first create the server list, and then apply the list of servers to a valid libmemcached object.
Because the list of servers, and the list of servers within an active libmemcached object can be manipulated separately, you can update and manage server lists while an active libmemcached interface is running.

The functions for manipulating the list of servers within a memcached_st structure are:

```c
memcached_return
memcached_server_add (memcached_st *ptr,
    char *hostname,
    unsigned int port);
```

Adds a server, using the given hostname and port into the memcached_st structure given in ptr.

```c
memcached_return
memcached_server_add_unix_socket (memcached_st *ptr,
    char *socket);
```

Adds a Unix socket to the list of servers configured in the memcached_st structure.

```c
unsigned int memcached_server_count (memcached_st *ptr);
```

Returns a count of the number of configured servers within the memcached_st structure.

```c
memcached_server_st *
memcached_server_list (memcached_st *ptr);
```

Returns an array of all the defined hosts within a memcached_st structure.

```c
memcached_return
memcached_server_push (memcached_st *ptr,
    memcached_server_st *list);
```

Pushes an existing list of servers onto list of servers configured for a current memcached_st structure. This adds servers to the end of the existing list, and duplicates are not checked.

The memcached_server_st structure can be used to create a list of memcached servers which can then be applied individually to memcached_st structures.

```c
memcached_server_st *
memcached_server_list_append (memcached_server_st *ptr,
    char *hostname,
    unsigned int port,
    memcached_return *error);
```

Adds a server, with hostname and port, to the server list in ptr. The result code is handled by the error argument, which should point to an existing memcached_return variable. The function returns a pointer to the returned list.

```c
unsigned int memcached_server_list_count (memcached_server_st *ptr);
```

Returns the number of the servers in the server list.

```c
void memcached_server_list_free (memcached_server_st *ptr);
```

Frees the memory associated with a server list.

```c
memcached_server_st *memcached_servers_parse (char *server_strings);
```

 Parses a string containing a list of servers, where individual servers are separated by a comma, space, or both, and where individual servers are of the form server[:port]. The return value is a server list structure.
Developing a memcached Application

**libmemcached Set Functions**

The set-related functions within libmemcached provide the same functionality as the core functions supported by the memcached protocol. The full definition for the different functions is the same for all the base functions (add, replace, prepend, append). For example, the function definition for `memcached_set()` is:

```c
memcached_return
    memcached_set (memcached_st *ptr,
        const char *key,
        size_t key_length,
        const char *value,
        size_t value_length,
        time_t expiration,
        uint32_t flags);
```

The `ptr` is the `memcached_st` structure. The `key` and `key_length` define the key name and length, and `value` and `value_length` the corresponding value and length. You can also set the expiration and optional flags. For more information, see Controlling libmemcached Behaviors.

The following table outlines the remainder of the set-related libmemcached functions and the equivalent core functions supported by the memcached protocol.

<table>
<thead>
<tr>
<th>libmemcached Function</th>
<th>Equivalent Core Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>memcached_set(mmc, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Generic set() operation.</td>
</tr>
<tr>
<td><code>memcached_add(mmc, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Generic add() function.</td>
</tr>
<tr>
<td><code>memcached_replace(mmc, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Generic replace().</td>
</tr>
<tr>
<td><code>memcached_prepend(mmc, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Prepends the specified value before the current value of the specified key.</td>
</tr>
<tr>
<td><code>memcached_append(mmc, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Appends the specified value after the current value of the specified key.</td>
</tr>
<tr>
<td><code>memcached_cas(mmc, key, key_length, value, value_length, expiration, flags, cas)</code></td>
<td>Overwrites the data for a given key as long as the corresponding cas value is still the same within the server.</td>
</tr>
<tr>
<td><code>memcached_set_by_key(mmc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the generic set(), but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
<tr>
<td><code>memcached_add_by_key(mmc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the generic add(), but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
<tr>
<td><code>memcached_replace_by_key(mmc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the generic replace(), but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
</tbody>
</table>
Developing a **memcached** Application

<table>
<thead>
<tr>
<th><strong>libmemcached</strong> Function</th>
<th>Equivalent Core Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>key_length, value, value_length, expiration, flags)</code></td>
<td></td>
</tr>
<tr>
<td><code>memcached_prepend_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the <code>memcached_prepend()</code>, but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
<tr>
<td><code>memcached_append_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the <code>memcached_append()</code>, but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
<tr>
<td><code>memcached_cas_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)</code></td>
<td>Similar to the <code>memcached_cas()</code>, but has the option of an additional master key that can be used to identify an individual server.</td>
</tr>
</tbody>
</table>

The by_key methods add two further arguments that define the master key, to be used and applied during the hashing stage for selecting the servers. You can see this in the following definition:

```c
memcached_return
    memcached_set_by_key(memcached_st *ptr,
    const char *master_key,
    size_t master_key_length,
    const char *key,
    size_t key_length,
    const char *value,
    size_t value_length,
    time_t expiration,
    uint32_t flags);
```

All the functions return a value of type `memcached_return`, which you can compare against the `MEMCACHED_SUCCESS` constant.

**libmemcached** Get Functions

The **libmemcached** functions provide both direct access to a single item, and a multiple-key request mechanism that provides much faster responses when fetching a large number of keys simultaneously.

The main get-style function, which is equivalent to the generic `get()` is `memcached_get()`. This function returns a string pointer, pointing to the value associated with the specified key.

```
char *memcached_get (memcached_st *ptr,
    const char *key, size_t key_length,
    size_t *value_length,
    uint32_t *flags,
    memcached_return *error);
```

A multi-key get, `memcached_mget()`, is also available. Using a multiple key get operation is much quicker to do in one block than retrieving the key values with individual calls to `memcached_get()`. To start the multi-key get, call `memcached_mget()`:

```
memcached_return
    memcached_mget (memcached_st *ptr,
    char **keys, size_t *key_length,
    unsigned int number_of_keys);
```

The return value is the success of the operation. The `keys` parameter should be an array of strings containing the keys, and `key_length` an array containing the length of each corresponding key. `number_of_keys` is the number of keys supplied in the array.
Developing a memcached Application

To fetch the individual values, use `memcached_fetch()` to get each corresponding value.

```c
char *memcached_fetch (memcached_st *ptr,
                   const char *key, size_t *key_length,
                   size_t *value_length,
                   uint32_t *flags,
                   memcached_return *error);
```

The function returns the key value, with the `key`, `key_length` and `value_length` parameters being populated with the corresponding key and length information. The function returns NULL when there are no more values to be returned. A full example, including the populating of the key data and the return of the information is provided here.

```c
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{

    memcached_server_st *servers = NULL;
    memcached_st *memc;
    memcached_return rc;
    char *keys[] = {"huey", "dewey", "louie"};
    size_t key_length[3];
    char *values[] = {"red", "blue", "green"};
    size_t value_length[3];
    unsigned int x;
    uint32_t flags;
    char return_key[MEMCACHED_MAX_KEY];
    size_t return_key_length;
    char *return_value;
    size_t return_value_length;
    memc = memcached_create(NULL);
    servers = memcached_server_list_append(servers, "localhost", 11211, &rc);
    rc = memcached_server_push(memc, servers);
    if (rc == MEMCACHED_SUCCESS)
        fprintf(stderr,"Added server successfully\n");
    else
        fprintf(stderr,"Couldn't add server: %s\n", memcached_strerror(memc, rc));

    for(x= 0; x < 3; x++)
    {
        key_length[x] = strlen(keys[x]);
        value_length[x] = strlen(values[x]);
        rc = memcached_set(memc, keys[x], key_length[x], values[x],
                     value_length[x], (time_t)0, (uint32_t)0);
        if (rc == MEMCACHED_SUCCESS)
            fprintf(stderr,"Key %s stored successfully\n", keys[x]);
        else
            fprintf(stderr,"Couldn't store key: %s\n", memcached_strerror(memc, rc));
    }
    rc = memcached_mget(memc, keys, key_length, 3);
    if (rc == MEMCACHED_SUCCESS)
    {
        while ((return_value= memcached_fetch(memc, return_key, &return_key_length,
                     &return_value_length, &flags, &rc)) != NULL)
        {
            if (rc == MEMCACHED_SUCCESS)
```
Developing a memcached Application

```c
{    fprintf(stderr,"Key %s returned %s\n",return_key, return_value);
}    
return 0;
}`

Running the above application produces the following output:

```
shell> memc_multi_fetch
Added server successfully
Key huey stored successfully
Key dewey stored successfully
Key louie stored successfully
Key huey returned red
Key dewey returned blue
Key louie returned green
```

Controlling libmemcached Behaviors

The behavior of libmemcached can be modified by setting one or more behavior flags. These can either be set globally, or they can be applied during the call to individual functions. Some behaviors also accept an additional setting, such as the hashing mechanism used when selecting servers.

To set global behaviors:

```c
memcached_return
    memcached_behavior_set (memcached_st *ptr,
                        memcached_behavior flag,
                        uint64_t data);
```

To get the current behavior setting:

```c
uint64_t
    memcached_behavior_get (memcached_st *ptr,
                        memcached_behavior flag);
```

The following table describes libmemcached behavior flags.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMCACHED_BEHAVIOR_NO_BLOCK</td>
<td>Caused libmemcached to use asynchronous I/O.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_TCP_NODELAY</td>
<td>Turns on no-delay for network sockets.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_HASH</td>
<td>Without a value, sets the default hashing algorithm for keys to use MD5.</td>
</tr>
<tr>
<td></td>
<td>Other valid values include MEMCACHED_HASH_DEFAULT, MEMCACHED_HASH_MD5,</td>
</tr>
<tr>
<td></td>
<td>MEMCACHED_HASH_CRC, MEMCACHED_HASH_FNV1_64, MEMCACHED_HASH_FNV1A_64,</td>
</tr>
<tr>
<td></td>
<td>MEMCACHED_HASH_FNV1_32, and MEMCACHED_HASH_FNV1A_32.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_DISTRIBUTION</td>
<td>Changes the method of selecting the server used to store a given value.</td>
</tr>
<tr>
<td></td>
<td>The default method is MEMCACHED_DISTRIBUTION_MODULA. You can enable</td>
</tr>
<tr>
<td></td>
<td>consistent hashing by setting MEMCACHED_DISTRIBUTIONCONSISTENT.</td>
</tr>
<tr>
<td></td>
<td>MEMCACHED_DISTRIBUTIONCONSISTENT is an alias for the value</td>
</tr>
<tr>
<td></td>
<td>MEMCACHED_DISTRIBUTIONCONSISTENT_KETAMA.</td>
</tr>
</tbody>
</table>
Developing a *memcached* Application

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMCACHED_BEHAVIOR_CACHE_LOOKUP</td>
<td>Cache the lookups made to the DNS service. This can improve the performance if you are using names instead of IP addresses for individual hosts.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_SUPPORT_CAS</td>
<td>Support CAS operations. By default, this is disabled because it imposes a performance penalty.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_KETAMA</td>
<td>Sets the default distribution to MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA and the hash to MEMCACHED_HASH_MD5.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_POLL_TIMEOUT</td>
<td>Modify the timeout value used by <code>poll()</code>. Supply a signed int pointer for the timeout value.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_BUFFER_REQUESTS</td>
<td>Buffers IO requests instead of them being sent. A get operation, or closing the connection causes the data to be flushed.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_VERIFY_KEY</td>
<td>Forces <em>libmemcached</em> to verify that a specified key is valid.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_SORT_HOSTS</td>
<td>If set, hosts added to the list of configured hosts for a <em>memcached_st</em> structure are placed into the host list in sorted order. This breaks consistent hashing if that behavior has been enabled.</td>
</tr>
<tr>
<td>MEMCACHED_BEHAVIOR_CONNECT_TIMEOUT</td>
<td>In nonblocking mode this changes the value of the timeout during socket connection.</td>
</tr>
</tbody>
</table>

*libmemcached* Command-Line Utilities

In addition to the main C library interface, *libmemcached* also includes a number of command-line utilities that can be useful when working with and debugging *memcached* applications.

All of the command-line tools accept a number of arguments, the most critical of which is *servers*, which specifies the list of servers to connect to when returning information.

The main tools are:

- **memcat**: Display the value for each ID given on the command line:

  ```shell
  shell> memcat --servers=localhost hwkey
  Hello world
  ```

- **memcp**: Copy the contents of a file into the cache, using the file name as the key:

  ```shell
  shell> echo "Hello World" > hwkey
  shell> memcp --servers=localhost hwkey
  shell> memcat --servers=localhost hwkey
  Hello world
  ```

- **memrm**: Remove an item from the cache:

  ```shell
  shell> memcat --servers=localhost hwkey
  Hello world
  shell> memrm --servers=localhost hwkey
  shell> memcat --servers=localhost hwkey
  ```

- **memslap**: Test the load on one or more *memcached* servers, simulating get/set and multiple client operations. For example, you can simulate the load of 100 clients performing get operations:

  ```shell
  shell> memslap --servers=localhost --concurrency=100 --flush --test=get
  ```
Developing a memcached Application

memslap --servers=localhost --concurrency=100 --flush --test=get Threads connecting to servers 100
  Took 13.571 seconds to read data

• memflush: Flush (empty) the contents of the memcached cache.
  shell> memflush --servers=localhost

16.2.3.4 Using MySQL and memcached with Perl

The Cache::Memcached module provides a native interface to the Memcache protocol, and provides support for the core functions offered by memcached. Install the module using your operating system's package management system, or using CPAN:

root-shell> perl -MCPAN -e 'install Cache::Memcached'

To use memcached from Perl through the Cache::Memcached module, first create a new Cache::Memcached object that defines the list of servers and other parameters for the connection. The only argument is a hash containing the options for the cache interface. For example, to create a new instance that uses three memcached servers:

use Cache::Memcached;
my $cache = new Cache::Memcached {
  'servers' => [
    '198.51.100.100:11211',
    '198.51.100.101:11211',
    '198.51.100.102:11211',
  ],
};

Note

When using the Cache::Memcached interface with multiple servers, the API automatically performs certain operations across all the servers in the group. For example, getting statistical information through Cache::Memcached returns a hash that contains data on a host-by-host basis, as well as generalized statistics for all the servers in the group.

You can set additional properties on the cache object instance when it is created by specifying the option as part of the option hash. Alternatively, you can use a corresponding method on the instance:

• servers or method set_servers(): Specifies the list of the servers to be used. The servers list should be a reference to an array of servers, with each element as the address and port number combination (separated by a colon). You can also specify a local connection through a Unix socket (for example /tmp/sock/memcached). To specify the server with a weight (indicating how much more frequently the server should be used during hashing), specify an array reference with the memcached server instance and a weight number. Higher numbers give higher priority.

• compress_threshold or method set_compress_threshold(): Specifies the threshold when values are compressed. Values larger than the specified number are automatically compressed (using zlib) during storage and retrieval.

• no_rehash or method set_norehash(): Disables finding a new server if the original choice is unavailable.

• readonly or method set_readonly(): Disables writes to the memcached servers.

Once the Cache::Memcached object instance has been configured, you can use the set() and get() methods to store and retrieve information from the memcached servers. Objects stored in the cache are automatically serialized and deserialized using the Storable module.
The Cache::Memcached interface supports the following methods for storing/retrieving data, and relate to the generic methods as shown in the table.

<table>
<thead>
<tr>
<th>Cache::Memcached Function</th>
<th>Equivalent Generic Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>get()</td>
<td>Generic get().</td>
</tr>
<tr>
<td>get_multi(keys)</td>
<td>Gets multiple keys from memcache using just one query. Returns a hash reference of key-value pairs.</td>
</tr>
<tr>
<td>set()</td>
<td>Generic set().</td>
</tr>
<tr>
<td>add()</td>
<td>Generic add().</td>
</tr>
<tr>
<td>replace()</td>
<td>Generic replace().</td>
</tr>
<tr>
<td>delete()</td>
<td>Generic delete().</td>
</tr>
<tr>
<td>incr()</td>
<td>Generic incr().</td>
</tr>
<tr>
<td>decr()</td>
<td>Generic decr().</td>
</tr>
</tbody>
</table>

Below is a complete example for using memcached with Perl and the Cache::Memcached module:

```perl
#!/usr/bin/perl
use Cache::Memcached;
use DBI;
use Data::Dumper;

# Configure the memcached server
my $cache = new Cache::Memcached {
    'servers' => [
        'localhost:11211',
    ],
};

# Get the film name from the command line
# memcached keys must not contain spaces, so create
# a key name by replacing spaces with underscores
my $filmname = shift or die "Must specify the film name\n";
my $filmkey = $filmname;
$filmkey =~ s/ /_/;

# Load the data from the cache
my $filmdata = $cache->get($filmkey);

# If the data wasn't in the cache, then we load it from the database
if (!defined($filmdata))
{
    $filmdata = load_filmdata($filmname);
    if (defined($filmdata))
    {
        # Set the data into the cache, using the key
        if ($cache->set($filmkey,$filmdata))
        {
            print STDERR "Film data loaded from database and cached\n";
        }
        else
        {
```

1964
The example uses the Sakila database, obtaining film data from the database and writing a composite record of the film and actors to memcached. When calling it for a film does not exist, you get this result:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from database and cached
```

When accessing a film that has already been added to the cache:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from Memcached
```

### 16.2.3.5 Using MySQL and memcached with Python

The Python memcache module interfaces to memcached servers, and is written in pure Python (that is, without using one of the C APIs). You can download and install a copy from Python Memcached.

To install, download the package and then run the Python installer:

```
python setup.py install
running install
running bdist_egg
running egg_info
creating python_memcached.egg-info
...
removing 'build/bdist.linux-x86_64/egg' (and everything under it)
```
Once installed, the `memcache` module provides a class-based interface to your `memcached` servers. When you store Python data structures as `memcached` items, they are automatically serialized (turned into string values) using the Python `cPickle` or `pickle` modules.

To create a new `memcache` interface, import the `memcache` module and create a new instance of the `memcache.Client` class. For example, if the `memcached` daemon is running on localhost using the default port:

```python
import memcache
memc = memcache.Client(['127.0.0.1:11211'])
```

The first argument is an array of strings containing the server and port number for each `memcached` instance to use. To enable debugging, set the optional `debug` parameter to 1.

By default, the hashing mechanism used to divide the items among multiple servers is `crc32`. To change the function used, set the value of `memcache.serverHashFunction` to the alternate function to use. For example:

```python
from zlib import adler32
memcache.serverHashFunction = adler32
```

Once you have defined the servers to use within the `memcache` instance, the core functions provide the same functionality as in the generic interface specification. The following table provides a summary of the supported functions.

<table>
<thead>
<tr>
<th>Python <code>memcache</code> Function</th>
<th>Equivalent Generic Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>get()</code></td>
<td>Generic <code>get()</code></td>
</tr>
<tr>
<td><code>get_multi(keys)</code></td>
<td>Gets multiple values from the supplied array of <code>keys</code>. Returns a hash reference of key-value pairs.</td>
</tr>
<tr>
<td><code>set()</code></td>
<td>Generic <code>set()</code></td>
</tr>
<tr>
<td><code>set_multi(dict [, expiry [, key_prefix]])</code></td>
<td>Sets multiple key-value pairs from the supplied <code>dict</code>.</td>
</tr>
<tr>
<td><code>add()</code></td>
<td>Generic <code>add()</code></td>
</tr>
<tr>
<td><code>replace()</code></td>
<td>Generic <code>replace()</code></td>
</tr>
<tr>
<td><code>prepend(key, value [, expiry])</code></td>
<td>Prepends the supplied <code>value</code> to the value of the existing <code>key</code>.</td>
</tr>
<tr>
<td><code>append(key, value [, expiry])</code></td>
<td>Appends the supplied <code>value</code> to the value of the existing <code>key</code>.</td>
</tr>
<tr>
<td><code>delete()</code></td>
<td>Generic <code>delete()</code></td>
</tr>
<tr>
<td><code>delete_multi(keys [, expiry [, key_prefix]])</code></td>
<td>Deletes all the keys from the hash matching each string in the array <code>keys</code>.</td>
</tr>
<tr>
<td><code>incr()</code></td>
<td>Generic <code>incr()</code></td>
</tr>
<tr>
<td><code>decr()</code></td>
<td>Generic <code>decr()</code></td>
</tr>
</tbody>
</table>
Note

Within the Python `memcache` module, all the `*_multi()` functions support an optional `key_prefix` parameter. If supplied, then the string is used as a prefix to all key lookups. For example, if you call:

```python
memc.get_multi(['a','b'], key_prefix='users:');
```

The function retrieves the keys `users:a` and `users:b` from the servers.

Here is an example showing the storage and retrieval of information to a `memcache` instance, loading the raw data from MySQL:

```python
import sys
import MySQLdb
import memcache

memc = memcache.Client(['127.0.0.1:11211'], debug=1);

try:
    conn = MySQLdb.connect (host = "localhost",
                            user = "sakila",
                            passwd = "password",
                            db = "sakila")
except MySQLdb.Error, e:
    print "Error %d: %s" % (e.args[0], e.args[1])
    sys.exit (1)

popularfilms = memc.get('top5films')

if not popularfilms:
    cursor = conn.cursor()
    cursor.execute('select film_id,title from film order by rental_rate desc limit 5')
    rows = cursor.fetchall()
    memc.set('top5films',rows,60)
    print "Updated memcached with MySQL data"
else:
    print "Loaded data from memcached"
    for row in popularfilms:
        print "%s, %s" % (row[0], row[1])
```

When executed for the first time, the data is loaded from the MySQL database and stored to the `memcached` server.

```
shell> python memc_python.py
Updated memcached with MySQL data
```

Because the data is automatically serialized using `cPickle/pickle`, when you load the data back from `memcached`, you can use the object directly. In the example above, the information stored to `memcached` is in the form of rows from a Python DB cursor. When accessing the information (within the 60 second expiry time), the data is loaded from `memcached` and dumped:

```
shell> python memc_python.py
Loaded data from memcached
2, ACE GOLDFINGER
7, AIRPLANE SIERRA
8, AIRPORT POLLOCK
10, ALADDIN CALENDAR
13, ALI FOREVER
```

The serialization and deserialization happens automatically. Because serialization of Python data may be incompatible with other interfaces and languages, you can change the serialization module used during initialization. For example, you might use JSON format when you store complex data structures using a script written in one language, and access them in a script written in a different language.
16.2.3.6 Using MySQL and **memcached** with PHP

PHP provides support for the Memcache functions through a PECL extension. To enable the PHP **memcache** extensions, build PHP using the `--enable-memcache` option to `configure` when building from source.

If you are installing on a Red Hat-based server, you can install the **php-pear-memcache** RPM:

```bash
root-shell> yum --install php-pecl-memcache
```

On Debian-based distributions, use the **php-memcache** package.

To set global runtime configuration options, specify the configuration option values within your **php.ini** file. The following table provides the name, default value, and a description for each global runtime configuration option.

<table>
<thead>
<tr>
<th>Configuration option</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>memcache.allow_failover</code></td>
<td>1</td>
<td>Specifies whether another server in the list should be queried if the first server selected fails.</td>
</tr>
<tr>
<td><code>memcache.max_failover_attempts</code></td>
<td>20</td>
<td>Specifies the number of servers to try before returning a failure.</td>
</tr>
<tr>
<td><code>memcache.chunk_size</code></td>
<td>8192</td>
<td>Defines the size of network chunks used to exchange data with the <strong>memcached</strong> server.</td>
</tr>
<tr>
<td><code>memcache.default_port</code></td>
<td>11211</td>
<td>Defines the default port to use when communicating with the <strong>memcached</strong> servers.</td>
</tr>
<tr>
<td><code>memcache.hash_strategy</code></td>
<td>standard</td>
<td>Specifies which hash strategy to use. Set to <code>consistent</code> to enable servers to be added or removed from the pool without causing the keys to be remapped to other servers. When set to <code>standard</code>, an older (modula) strategy is used that potentially uses different servers for storage.</td>
</tr>
<tr>
<td><code>memcache.hash_function</code></td>
<td>crc32</td>
<td>Specifies which function to use when mapping keys to servers. <strong>crc32</strong> uses the standard CRC32 hash. <strong>fnv</strong> uses the FNV-1a hashing algorithm.</td>
</tr>
</tbody>
</table>

To create a connection to a **memcached** server, create a new **Memcache** object and then specify the connection options. For example:

```php
<?php
$cache = new Memcache;
$cache->connect('localhost',11211);
?>
```

This opens an immediate connection to the specified server.

To use multiple **memcached** servers, you need to add servers to the memcache object using `addServer()`:

```php
bool Memcache::addServer ( string $host [, int $port [, bool $persistent [, int $weight [, int $timeout [, int $retry_interval [, bool $status [, callback $failure_callback ]]]]]]] ]]
```
Developing a memcached Application

The server management mechanism within the php-memcache module is a critical part of the interface as it controls the main interface to the memcached instances and how the different instances are selected through the hashing mechanism.

To create a simple connection to two memcached instances:

```php
<?php
$cache = new Memcache;
$cache->addServer('198.51.100.100',11211);
$cache->addServer('198.51.100.101',11211);
?>
```

In this scenario, the instance connection is not explicitly opened, but only opened when you try to store or retrieve a value. To enable persistent connections to memcached instances, set the $persistent argument to true. This is the default setting, and causes the connections to remain open.

To help control the distribution of keys to different instances, use the global memcache.hash_strategy setting. This sets the hashing mechanism used to select. You can also add another weight to each server, which effectively increases the number of times the instance entry appears in the instance list, therefore increasing the likelihood of the instance being chosen over other instances. To set the weight, set the value of the $weight argument to more than one.

The functions for setting and retrieving information are identical to the generic functional interface offered by memcached, as shown in the following table.

<table>
<thead>
<tr>
<th>PECL memcache Function</th>
<th>Generic Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>get()</td>
<td>Generic get().</td>
</tr>
<tr>
<td>set()</td>
<td>Generic set().</td>
</tr>
<tr>
<td>add()</td>
<td>Generic add().</td>
</tr>
<tr>
<td>replace()</td>
<td>Generic replace().</td>
</tr>
<tr>
<td>delete()</td>
<td>Generic delete().</td>
</tr>
<tr>
<td>increment()</td>
<td>Generic incr().</td>
</tr>
<tr>
<td>decrement()</td>
<td>Generic decr().</td>
</tr>
</tbody>
</table>

A full example of the PECL memcache interface is provided below. The code loads film data from the Sakila database when the user provides a film name. The data stored into the memcached instance is recorded as a mysqli result row, and the API automatically serializes the information for you.

```php
<?php
$meme = new Memcache;
$meme->addServer('localhost','11211');
if(empty($_POST['film'])) {
    ?></html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en">
    <head>
        <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
        <title>Simple Memcache Lookup</title>
    </head>
    <body>
        <form method="post">
            <p><b>Film</b>: <input type="text" size="20" name="film"></p>
            <input type="submit">
        </form>
    </body>
</html>
```
With PHP, the connections to the memcached instances are kept open as long as the PHP and associated Apache instance remain running. When adding or removing servers from the list in a running instance (for example, when starting another script that mentions additional servers), the connections are shared, but the script only selects among the instances explicitly configured within the script.

To ensure that changes to the server list within a script do not cause problems, make sure to use the consistent hashing mechanism.

16.2.3.7 Using MySQL and memcached with Ruby

There are a number of different modules for interfacing to memcached within Ruby. The Ruby-MemCache client library provides a native interface to memcached that does not require any external libraries, such as libmemcached. You can obtain the installer package from http://www.deveiate.org/projects/RMemCache.

To install, extract the package and then run install.rb:

```shell> install.rb```
Developing a `memcached` Application

If you have RubyGems, you can install the `Ruby-MemCache` gem:

```
shell> gem install Ruby-MemCache
Bulk updating Gem source index for: http://gems.rubyforge.org
Install required dependency io-reactor? [Yn]  y
Successfully installed Ruby-MemCache-0.0.1
Successfully installed io-reactor-0.05
Installing ri documentation for io-reactor-0.05...
Installing RDoc documentation for io-reactor-0.05...
```

To use a `memcached` instance from within Ruby, create a new instance of the `MemCache` object.

```
require 'memcache'
memc = MemCache::new '198.51.100.100:11211'
```

You can add a weight to each server to increase the likelihood of the server being selected during hashing by appending the weight count to the server host name/port string:

```
require 'memcache'
memc = MemCache::new '198.51.100.100:11211:3'
```

To add servers to an existing list, you can append them directly to the `MemCache` object:

```
memc += ['198.51.100.101:11211']
```

To set data into the cache, you can just assign a value to a key within the new cache object, which works just like a standard Ruby hash object:

```
memc['key'] = "value"
```

Or to retrieve the value:

```
print memc['key']
```

For more explicit actions, you can use the method interface, which mimics the main `memcached` API functions, as summarized in the following table.

<table>
<thead>
<tr>
<th>Ruby <code>MemCache</code> Method</th>
<th>Equivalent <code>memcached</code> API Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>get()</td>
<td>Generic <code>get()</code></td>
</tr>
<tr>
<td>get_hash(keys)</td>
<td>Get the values of multiple keys, returning the information as a hash of the keys and their values.</td>
</tr>
<tr>
<td>set()</td>
<td>Generic <code>set()</code></td>
</tr>
<tr>
<td>set_many(pairs)</td>
<td>Set the values of the keys and values in the hash pairs.</td>
</tr>
<tr>
<td>add()</td>
<td>Generic <code>add()</code></td>
</tr>
<tr>
<td>replace()</td>
<td>Generic <code>replace()</code></td>
</tr>
<tr>
<td>delete()</td>
<td>Generic <code>delete()</code></td>
</tr>
<tr>
<td>incr()</td>
<td>Generic <code>incr()</code></td>
</tr>
<tr>
<td>decr()</td>
<td>Generic <code>decr()</code></td>
</tr>
</tbody>
</table>

### 16.2.3.8 Using MySQL and `memcached` with Java

The `com.danga.MemCached` class within Java provides a native interface to `memcached` instances. You can obtain the client from https://github.com/gwhalin/Memcached-Java-Client/downloads. The Java class uses hashes that are compatible with `libmemcached`, so you can mix and match Java and `libmemcached` applications accessing the same `memcached` instances. The serialization between Java
and other interfaces are not compatible. If this is a problem, use JSON or a similar nonbinary serialization format.

On most systems, you can download the package and use the jar directly.

To use the com.danga.MemCached interface, you create a MemCachedClient instance and then configure the list of servers by configuring the SockIOPool. Through the pool specification you set up the server list, weighting, and the connection parameters to optimized the connections between your client and the memcached instances that you configure.

Generally, you can configure the memcached interface once within a single class, then use this interface throughout the rest of your application.

For example, to create a basic interface, first configure the MemCachedClient and base SockIOPool settings:

```java
public class MyClass {
    protected static MemCachedClient mcc = new MemCachedClient();
    static {
        String[] servers = {
            "localhost:11211",
        };
        Integer[] weights = { 1 };
        SockIOPool pool = SockIOPool.getInstance();
        pool.setServers( servers );
        pool.setWeights( weights );
    }
    pool.setHashingAlg( SockIOPool.NEW_COMPAT_HASH );
    pool.setInitConn( 5 );
    pool.setMinConn( 5 );
    pool.setMaxConn( 250 );
    pool.setMaxIdle( 1000 * 60 * 60 * 6 );
    mcc = new MemCachedClient(
        pool
    );
}
```

In the above sample, the list of servers is configured by creating an array of the memcached instances to use. You can then configure individual weights for each server.

The remainder of the properties for the connection are optional, but you can set the connection numbers (initial connections, minimum connections, maximum connections, and the idle timeout) by setting the pool parameters:

```java
pool.setInitConn( 5 );
pool.setMinConn( 5 );
pool.setMaxConn( 250 );
pool.setMaxIdle( 1000 * 60 * 60 * 6 );
```

Once the parameters have been configured, initialize the connection pool:

```java
pool.initialize();
```

The pool, and the connection to your memcached instances should now be ready to use.

To set the hashing algorithm used to select the server used when storing a given key, use `pool.setHashingAlg()`:

```java
pool.setHashingAlg( SockIOPool.NEW_COMPAT_HASH );
```

Valid values are NEW_COMPAT_HASH, OLD_COMPAT_HASH and NATIVE_HASH are also basic modula hashing algorithms. For a consistent hashing algorithm, use CONSISTENT_HASH. These constants are equivalent to the corresponding hash settings within libmemcached.

The following table outlines the Java com.danga.MemCached methods and the equivalent generic methods in the memcached interface specification.
Developing a **memcached** Application

<table>
<thead>
<tr>
<th>Java <code>com.danga.MemCached</code> Method</th>
<th>Equivalent Generic Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>get()</code></td>
<td>Generic <code>get()</code></td>
</tr>
<tr>
<td><code>getMulti(keys)</code></td>
<td>Get the values of multiple keys, returning the information as HashMap using <code>java.lang.String</code> for the keys and <code>java.lang.Object</code> for the corresponding values.</td>
</tr>
<tr>
<td><code>set()</code></td>
<td>Generic <code>set()</code></td>
</tr>
<tr>
<td><code>add()</code></td>
<td>Generic <code>add()</code></td>
</tr>
<tr>
<td><code>replace()</code></td>
<td>Generic <code>replace()</code></td>
</tr>
<tr>
<td><code>delete()</code></td>
<td>Generic <code>delete()</code></td>
</tr>
<tr>
<td><code>incr()</code></td>
<td>Generic <code>incr()</code></td>
</tr>
<tr>
<td><code>decr()</code></td>
<td>Generic <code>decr()</code></td>
</tr>
</tbody>
</table>

### 16.2.3.9 Using the **memcached** TCP Text Protocol

Communicating with a **memcached** server can be achieved through either the TCP or UDP protocols. When using the TCP protocol, you can use a simple text based interface for the exchange of information.

When communicating with **memcached**, you can connect to the server using the port configured for the server. You can open a connection with the server without requiring authorization or login. As soon as you have connected, you can start to send commands to the server. When you have finished, you can terminate the connection without sending any specific disconnection command. Clients are encouraged to keep their connections open to decrease latency and improve performance.

Data is sent to the **memcached** server in two forms:

- **Text lines**, which are used to send commands to the server, and receive responses from the server.
- **Unstructured data**, which is used to receive or send the value information for a given key. Data is returned to the client in exactly the format it was provided.

Both text lines (commands and responses) and unstructured data are always terminated with the string `\r\n`. Because the data being stored may contain this sequence, the length of the data (returned by the client before the unstructured data is transmitted) should be used to determine the end of the data.

Commands to the server are structured according to their operation:

- **Storage commands**: `set, add, replace, append, prepend, cas`

  Storage commands to the server take the form:

  ```
  command key [flags] [exptime] length [noreply]
  ```

  Or when using compare and swap (cas):

  ```
  cas key [flags] [exptime] length [casunique] [noreply]
  ```

  Where:

  - **command**: The command name.
  - **set**: Store value against key
  - **add**: Store this value against key if the key does not already exist
Developing a **memcached** Application

- **replace**: Store this value against key if the key already exists
- **append**: Append the supplied value to the end of the value for the specified key. The **flags** and **exptime** arguments should not be used.
- **prepend**: Append value currently in the cache to the end of the supplied value for the specified key. The **flags** and **exptime** arguments should not be used.
- **cas**: Set the specified key to the supplied value, only if the supplied **casunique** matches. This is effectively the equivalent of change the information if nobody has updated it since I last fetched it.
- **key**: The key. All data is stored using a the specific key. The key cannot contain control characters or whitespace, and can be up to 250 characters in size.
- **flags**: The flags for the operation (as an integer). Flags in **memcached** are transparent. The **memcached** server ignores the contents of the flags. They can be used by the client to indicate any type of information. In **memcached 1.2.0** and lower the value is a 16-bit integer value. In **memcached 1.2.1** and higher the value is a 32-bit integer.
- **exptime**: The expiry time, or zero for no expiry.
- **length**: The length of the supplied value block in bytes, excluding the terminating \r\n characters.
- **casunique**: A unique 64-bit value of an existing entry. This is used to compare against the existing value. Use the value returned by the **gets** command when issuing **cas** updates.
- **noreply**: Tells the server not to reply to the command.

For example, to store the value \texttt{abcdef} into the key \texttt{xyzkey}, you would use:

\begin{verbatim}
set xyzkey 0 0 6\r\nabcdef\r\n
The return value from the server is one line, specifying the status or error information. For more information, see \textit{Table 16.3, “memcached Protocol Responses”}.

- **Retrieval commands**: **get**, **gets**

Retrieval commands take the form:

\begin{verbatim}
get key1 [key2 .... keyn]
\end{verbatim}
Developing a `memcached` Application

gets key1 [key2 ... keyn]

You can supply multiple keys to the commands, with each requested key separated by whitespace.

The server responds with an information line of the form:

```
VALUE key flags bytes \[casunique\]
```

Where:

- **key**: The key name.
- **flags**: The value of the flag integer supplied to the `memcached` server when the value was stored.
- **bytes**: The size (excluding the terminating \r\n character sequence) of the stored value.
- **casunique**: The unique 64-bit integer that identifies the item.

The information line is immediately followed by the value data block. For example:

```
get xyzkey\r\nVALUE xyzkey 0 6\r\nabcdef\r
```

If you have requested multiple keys, an information line and data block is returned for each key found. If a requested key does not exist in the cache, no information is returned.

- **Delete commands**: delete

Deletion commands take the form:

```
delete key \[time\] \[noreply\]
```

Where:

- **key**: The key name.
- **time**: The time in seconds (or a specific Unix time) for which the client wishes the server to refuse add or replace commands on this key. All add, replace, get, and gets commands fail during this period. set operations succeed. After this period, the key is deleted permanently and all commands are accepted.

  If not supplied, the value is assumed to be zero (delete immediately).

- **noreply**: Tells the server not to reply to the command.

Responses to the command are either `DELETED` to indicate that the key was successfully removed, or `NOT_FOUND` to indicate that the specified key could not be found.

- **Increment/Decrement**: incr, decr

The increment and decrement commands change the value of a key within the server without performing a separate get/set sequence. The operations assume that the currently stored value is a 64-bit integer. If the stored value is not a 64-bit integer, then the value is assumed to be zero before the increment or decrement operation is applied.

Increment and decrement commands take the form:

```
incr key value \[noreply\]
```
Developing a memcached Application

```
decr key value [noreply]
```

Where:

- **key**: The key name.
- **value**: An integer to be used as the increment or decrement value.
- **noreply**: Tells the server not to reply to the command.

The response is:

- **NOT_FOUND**: The specified key could not be located.
- **value**: The new value associated with the specified key.

Values are assumed to be unsigned. For **decr** operations, the value is never decremented below 0. For **incr** operations, the value wraps around the 64-bit maximum.

- **Statistics commands**: **stats**

  The **stats** command provides detailed statistical information about the current status of the memcached instance and the data it is storing.

  Statistics commands take the form:

  ```
  STAT [name] [value]
  ```

  Where:

  - **name**: The optional name of the statistics to return. If not specified, the general statistics are returned.
  - **value**: A specific value to be used when performing certain statistics operations.

  The return value is a list of statistics data, formatted as follows:

  ```
  STAT name value
  ```

  The statistics are terminated with a single line, **END**.

  For more information, see Section 16.2.4, “Getting memcached Statistics”.

  For reference, a list of the different commands supported and their formats is provided below.

### Table 16.2 memcached Command Reference

<table>
<thead>
<tr>
<th>Command</th>
<th>Command Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>set</td>
<td>set key flags exptime length, set key flags exptime length noreply</td>
</tr>
<tr>
<td>add</td>
<td>add key flags exptime length, add key flags exptime length noreply</td>
</tr>
<tr>
<td>replace</td>
<td>replace key flags exptime length, replace key flags exptime length noreply</td>
</tr>
<tr>
<td>append</td>
<td>append key length, append key length noreply</td>
</tr>
<tr>
<td>prepend</td>
<td>prepend key length, prepend key length noreply</td>
</tr>
</tbody>
</table>
### Command Formats

<table>
<thead>
<tr>
<th>Command</th>
<th>Command Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>cas</td>
<td>cas key flags exptime length casunique, cas key flags exptime length casunique noreply</td>
</tr>
<tr>
<td>get</td>
<td>get key1 [key2 ... keyn]</td>
</tr>
<tr>
<td>gets</td>
<td></td>
</tr>
<tr>
<td>delete</td>
<td>delete key, delete key noreply, delete key expiry, delete key expiry noreply</td>
</tr>
<tr>
<td>incr</td>
<td>incr key, incr key noreply, incr key value, incr key value noreply</td>
</tr>
<tr>
<td>decr</td>
<td>decr key, decr key noreply, decr key value, decr key value noreply</td>
</tr>
<tr>
<td>stat</td>
<td>stat, stat name, stat name value</td>
</tr>
</tbody>
</table>

When sending a command to the server, the response from the server is one of the settings in the following table. All response values from the server are terminated by \r\n:

#### Table 16.3 memcached Protocol Responses

<table>
<thead>
<tr>
<th>String</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STORED</td>
<td>Value has successfully been stored.</td>
</tr>
<tr>
<td>NOT_STORED</td>
<td>The value was not stored, but not because of an error. For commands where you are adding a or updating a value if it exists (such as <code>add</code> and <code>replace</code>), or where the item has already been set to be deleted.</td>
</tr>
<tr>
<td>EXISTS</td>
<td>When using a <code>cas</code> command, the item you are trying to store already exists and has been modified since you last checked it.</td>
</tr>
<tr>
<td>NOT_FOUND</td>
<td>The item you are trying to store, update or delete does not exist or has already been deleted.</td>
</tr>
<tr>
<td>ERROR</td>
<td>You submitted a nonexistent command name.</td>
</tr>
<tr>
<td>CLIENT_ERROR</td>
<td>There was an error in the input line, the detail is contained in <code>errorstring</code>.</td>
</tr>
<tr>
<td>SERVER_ERROR</td>
<td>There was an error in the server that prevents it from returning the information. In extreme conditions, the server may disconnect the client after this error occurs.</td>
</tr>
<tr>
<td>VALUE keys flags</td>
<td>The requested key has been found, and the stored <code>key</code>, <code>flags</code> and data block are returned, of the specified <code>length</code>.</td>
</tr>
<tr>
<td>length</td>
<td></td>
</tr>
<tr>
<td>DELETED</td>
<td>The requested key was deleted from the server.</td>
</tr>
<tr>
<td>STAT name value</td>
<td>A line of statistics data.</td>
</tr>
<tr>
<td>END</td>
<td>The end of the statistics data.</td>
</tr>
</tbody>
</table>

#### 16.2.4 Getting memcached Statistics

The memcached system has a built-in statistics system that collects information about the data being stored into the cache, cache hit ratios, and detailed information on the memory usage and distribution of information through the slab allocation used to store individual items. Statistics are provided at both a basic level that provide the core statistics, and more specific statistics for specific areas of the memcached server.
Getting **memcached** Statistics

This information can be useful to ensure that you are getting the correct level of cache and memory usage, and that your slab allocation and configuration properties are set at an optimal level.

The stats interface is available through the standard **memcached** protocol, so the reports can be accessed by using **telnet** to connect to the **memcached**. The supplied **memcached-tool** includes support for obtaining the Section 16.2.4.2, “**memcached** Slabs Statistics” and Section 16.2.4.1, “**memcached** General Statistics” information. For more information, see Section 16.2.4.6, “Using **memcached-tool**”.

Alternatively, most of the language API interfaces provide a function for obtaining the statistics from the server.

For example, to get the basic stats using **telnet**:

shell> telnet localhost 11211
Trying ::1...
Connected to localhost.
Escape character is '^]'.
stats
STAT pid 23599
STAT uptime 675
STAT time 1211439587
STAT version 1.2.5
STAT pointer_size 32
STAT rusage_user 1.404992
STAT rusage_system 4.694685
STAT curr_items 32
STAT total_items 56361
STAT bytes 2642
STAT curr_connections 53
STAT total_connections 438
STAT connection_structures 55
STAT cmd_get 113482
STAT cmd_set 80519
STAT get_hits 34556
STAT get_misses 0
STAT evictions 0
STAT bytes_read 6379783
STAT bytes_written 4860179
STAT limit_maxbytes 67108864
STAT threads 1
END

When using Perl and the **Cache::Memcached** module, the **stats()** function returns information about all the servers currently configured in the connection object, and total statistics for all the **memcached** servers as a whole.

For example, the following Perl script obtains the stats and dumps the hash reference that is returned:

```perl
use Cache::Memcached;
use Data::Dumper;

my $memc = new Cache::Memcached;
$memc->set_servers(@ARGV);
print Dumper($memc->stats());
```

When executed on the same **memcached** as used in the **Telnet** example above we get a hash reference with the host by host and total statistics:

```
$VAR1 = {
    'hosts' => {
        'localhost:11211' => {
            'misc' => {
                'bytes' => '2421',
            }
        }
    }
};
```

1978
The statistics are divided up into a number of distinct sections, and then can be requested by adding the type to the `stats` command. Each statistics output is covered in more detail in the following sections.

- General statistics, see Section 16.2.4.1, "memcached General Statistics".
- Slab statistics (slabs), see Section 16.2.4.2, "memcached Slabs Statistics".
- Item statistics (items), see Section 16.2.4.3, "memcached Item Statistics".
- Size statistics (sizes), see Section 16.2.4.4, "memcached Size Statistics".
- Detailed status (detail), see Section 16.2.4.5, "memcached Detail Statistics".

### 16.2.4.1 memcached General Statistics

The output of the general statistics provides an overview of the performance and use of the memcached instance. The statistics returned by the command and their meaning is shown in the following table.

The following terms are used to define the value type for each statistics value:

- **32u**: 32-bit unsigned integer
• **64u**: 64-bit unsigned integer

• **32u:32u**: Two 32-bit unsigned integers separated by a colon

• **String**: Character string

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Data type</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>pid</td>
<td>32u</td>
<td>Process ID of the memcached instance.</td>
<td></td>
</tr>
<tr>
<td>uptime</td>
<td>32u</td>
<td>Uptime (in seconds) for this memcached instance.</td>
<td></td>
</tr>
<tr>
<td>time</td>
<td>32u</td>
<td>Current time (as epoch).</td>
<td></td>
</tr>
<tr>
<td>version</td>
<td>string</td>
<td>Version string of this instance.</td>
<td></td>
</tr>
<tr>
<td>pointer_size</td>
<td>string</td>
<td>Size of pointers for this host specified in bits (32 or 64).</td>
<td></td>
</tr>
<tr>
<td>rusage_user</td>
<td>32u:32u</td>
<td>Total user time for this instance (seconds:microseconds).</td>
<td></td>
</tr>
<tr>
<td>rusage_system</td>
<td>32u:32u</td>
<td>Total system time for this instance (seconds:microseconds).</td>
<td></td>
</tr>
<tr>
<td>curr_items</td>
<td>32u</td>
<td>Current number of items stored by this instance.</td>
<td></td>
</tr>
<tr>
<td>total_items</td>
<td>32u</td>
<td>Total number of items stored during the life of this instance.</td>
<td></td>
</tr>
<tr>
<td>bytes</td>
<td>64u</td>
<td>Current number of bytes used by this server to store items.</td>
<td></td>
</tr>
<tr>
<td>curr_connections</td>
<td>32u</td>
<td>Current number of open connections.</td>
<td></td>
</tr>
<tr>
<td>total_connections</td>
<td>32u</td>
<td>Total number of connections opened since the server started running.</td>
<td></td>
</tr>
<tr>
<td>connection_structs</td>
<td>32ures</td>
<td>Number of connection structures allocated by the server.</td>
<td></td>
</tr>
<tr>
<td>cmd_get</td>
<td>64u</td>
<td>Total number of retrieval requests (get operations).</td>
<td></td>
</tr>
<tr>
<td>cmd_set</td>
<td>64u</td>
<td>Total number of storage requests (set operations).</td>
<td></td>
</tr>
<tr>
<td>get_hits</td>
<td>64u</td>
<td>Number of keys that have been requested and found present.</td>
<td></td>
</tr>
<tr>
<td>get_misses</td>
<td>64u</td>
<td>Number of items that have been requested and not found.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>delete_hits</td>
<td>64u</td>
<td>Number of keys that have been deleted and found present.</td>
<td></td>
</tr>
<tr>
<td>delete_misses</td>
<td>64u</td>
<td>Number of items that have been delete and not found.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>incr_hits</td>
<td>64u</td>
<td>Number of keys that have been incremented and found present.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>incr_misses</td>
<td>64u</td>
<td>Number of items that have been incremented and not found.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>decr_hits</td>
<td>64u</td>
<td>Number of keys that have been decremented and found present.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>decr_misses</td>
<td>64u</td>
<td>Number of items that have been decremented and not found.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>cas_hits</td>
<td>64u</td>
<td>Number of keys that have been compared and swapped and found present.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>cas_misses</td>
<td>64u</td>
<td>Number of items that have been compared and swapped and not found.</td>
<td>1.3.x</td>
</tr>
</tbody>
</table>
### Getting memcached Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Data type</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>cas_badvalue</td>
<td>64u</td>
<td>Number of keys that have been compared and swapped, but the comparison (original) value did not match the supplied value.</td>
<td>1.3.x</td>
</tr>
<tr>
<td>evictions</td>
<td>64u</td>
<td>Number of valid items removed from cache to free memory for new items.</td>
<td></td>
</tr>
<tr>
<td>bytes_read</td>
<td>64u</td>
<td>Total number of bytes read by this server from network.</td>
<td></td>
</tr>
<tr>
<td>bytes_written</td>
<td>64u</td>
<td>Total number of bytes sent by this server to network.</td>
<td></td>
</tr>
<tr>
<td>limit_maxbytes</td>
<td>32u</td>
<td>Number of bytes this server is permitted to use for storage.</td>
<td></td>
</tr>
<tr>
<td>threads</td>
<td>32u</td>
<td>Number of worker threads requested.</td>
<td></td>
</tr>
<tr>
<td>conn_yields</td>
<td>64u</td>
<td>Number of yields for connections (related to the -R option).</td>
<td>1.4.0</td>
</tr>
</tbody>
</table>

The most useful statistics from those given here are the number of cache hits, misses, and evictions.

A large number of `get_misses` may just be an indication that the cache is still being populated with information. The number should, over time, decrease in comparison to the number of cache `get_hits`. If, however, you have a large number of cache misses compared to cache hits after an extended period of execution, it may be an indication that the size of the cache is too small and you either need to increase the total memory size, or increase the number of the `memcached` instances to improve the hit ratio.

A large number of `evictions` from the cache, particularly in comparison to the number of items stored is a sign that your cache is too small to hold the amount of information that you regularly want to keep cached. Instead of items being retained in the cache, items are being evicted to make way for new items keeping the turnover of items in the cache high, reducing the efficiency of the cache.

### 16.2.4.2 memcached Slabs Statistics

To get the `slabs` statistics, use the `stats slabs` command, or the API equivalent.

The slab statistics provide you with information about the slabs that have created and allocated for storing information within the cache. You get information both on each individual slab-class and total statistics for the whole slab.

```
STAT 1:chunk_size 104
STAT 1:chunks_per_page 10082
STAT 1:total_pages 1
STAT 1:total_chunks 10082
STAT 1:used_chunks 10081
STAT 1:free_chunks 1
STAT 1:free_chunks_end 10079
STAT 9:chunk_size 696
STAT 9:chunks_per_page 1506
STAT 9:total_pages 63
STAT 9:total_chunks 94878
STAT 9:used_chunks 94878
STAT 9:free_chunks 0
STAT 9:free_chunks_end 0
STAT active_slabs 2
STAT total_malloced 67083616
END
```

Individual stats for each slab class are prefixed with the slab ID. A unique ID is given to each allocated slab from the smallest size up to the largest. The prefix number indicates the slab class number in relation to
the calculated chunk from the specified growth factor. Hence in the example, 1 is the first chunk size and 9 is the 9th chunk allocated size.

The parameters returned for each chunk size and a description of each parameter are provided in the following table.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>chunk_size</td>
<td>Space allocated to each chunk within this slab class.</td>
<td></td>
</tr>
<tr>
<td>chunks_per_page</td>
<td>Number of chunks within a single page for this slab class.</td>
<td></td>
</tr>
<tr>
<td>total_pages</td>
<td>Number of pages allocated to this slab class.</td>
<td></td>
</tr>
<tr>
<td>total_chunks</td>
<td>Number of chunks allocated to the slab class.</td>
<td></td>
</tr>
<tr>
<td>used_chunks</td>
<td>Number of chunks allocated to an item.</td>
<td></td>
</tr>
<tr>
<td>free_chunks</td>
<td>Number of chunks not yet allocated to items.</td>
<td></td>
</tr>
<tr>
<td>free_chunks_end</td>
<td>Number of free chunks at the end of the last allocated page.</td>
<td></td>
</tr>
<tr>
<td>get_hits</td>
<td>Number of get hits to this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>cmd_set</td>
<td>Number of set commands on this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>delete_hits</td>
<td>Number of delete hits to this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>incr_hits</td>
<td>Number of increment hits to this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>decr_hits</td>
<td>Number of decrement hits to this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>cas_hits</td>
<td>Number of CAS hits to this chunk</td>
<td>1.3.x</td>
</tr>
<tr>
<td>cas_badval</td>
<td>Number of CAS hits on this chunk where the existing value did not match</td>
<td>1.3.x</td>
</tr>
<tr>
<td>mem_requested</td>
<td>The true amount of memory of memory requested within this chunk</td>
<td>1.4.1</td>
</tr>
</tbody>
</table>

The following additional statistics cover the information for the entire server, rather than on a chunk by chunk basis:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>active_slabs</td>
<td>Total number of slab classes allocated.</td>
<td></td>
</tr>
<tr>
<td>total_malloced</td>
<td>Total amount of memory allocated to slab pages.</td>
<td></td>
</tr>
</tbody>
</table>

The key values in the slab statistics are the `chunk_size`, and the corresponding `total_chunks` and `used_chunks` parameters. These given an indication of the size usage of the chunks within the system. Remember that one key-value pair is placed into a chunk of a suitable size.

From these stats, you can get an idea of your size and chunk allocation and distribution. If you store many items with a number of largely different sizes, consider adjusting the chunk size growth factor to increase in larger steps to prevent chunk and memory wastage. A good indication of a bad growth factor is a high number of different slab classes, but with relatively few chunks actually in use within each slab. Increasing the growth factor creates fewer slab classes and therefore makes better use of the allocated pages.

### 16.2.4.3 memcached Item Statistics

To get the `items` statistics, use the `stats items` command, or the API equivalent.

The `items` statistics give information about the individual items allocated within a given slab class.
Getting memcached Statistics

```
STAT items:2:number 1
STAT items:2:age 452
STAT items:2:evicted 0
STAT items:2:evicted_nonzero 0
STAT items:2:evicted_time 2
STAT items:2:outofmemory 0
STAT items:2:tailrepairs 0
...
STAT items:27:number 1
STAT items:27:age 452
STAT items:27:evicted 0
STAT items:27:evicted_nonzero 0
STAT items:27:evicted_time 2
STAT items:27:outofmemory 0
STAT items:27:tailrepairs 0
```

The prefix number against each statistics relates to the corresponding chunk size, as returned by the `stats slabs` statistics. The result is a display of the number of items stored within each chunk within each slab size, and specific statistics about their age, eviction counts, and out of memory counts. A summary of the statistics is given in the following table.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>The number of items currently stored in this slab class.</td>
</tr>
<tr>
<td>age</td>
<td>The age of the oldest item within the slab class, in seconds.</td>
</tr>
<tr>
<td>evicted</td>
<td>The number of items evicted to make way for new entries.</td>
</tr>
<tr>
<td>evicted_time</td>
<td>The time of the last evicted entry</td>
</tr>
<tr>
<td>evicted_nonzero</td>
<td>The time of the last evicted non-zero entry</td>
</tr>
<tr>
<td>outofmemory</td>
<td>The number of items for this slab class that have triggered an out of memory error (only value when the <code>-M</code> command line option is in effect).</td>
</tr>
<tr>
<td>tailrepairs</td>
<td>Number of times the entries for a particular ID need repairing</td>
</tr>
</tbody>
</table>

Item level statistics can be used to determine how many items are stored within a given slab and their freshness and recycle rate. You can use this to help identify whether there are certain slab classes that are triggering a much larger number of evictions that others.

### 16.2.4.4 memcached Size Statistics

To get size statistics, use the `stats sizes` command, or the API equivalent.

The size statistics provide information about the sizes and number of items of each size within the cache. The information is returned as two columns, the first column is the size of the item (rounded up to the nearest 32 byte boundary), and the second column is the count of the number of items of that size within the cache:

```
96 35
128 38
160 807
192 804
224 410
256 222
288 83
320 39
352 53
384 33
416 64
448 51
480 30
```
Getting memcached Statistics

Caution
Running this statistic locks up your cache as each item is read from the cache and its size calculated. On a large cache, this may take some time and prevent any set or get operations until the process completes.

The item size statistics are useful only to determine the sizes of the objects you are storing. Since the actual memory allocation is relevant only in terms of the chunk size and page size, the information is only useful during a careful debugging or diagnostic session.

16.2.4.5 memcached Detail Statistics

For memcached 1.3.x and higher, you can enable and obtain detailed statistics about the get, set, and del operations on the individual keys stored in the cache, and determine whether the attempts hit (found) a particular key. These operations are only recorded while the detailed stats analysis is turned on.

To enable detailed statistics, you must send the stats detail on command to the memcached server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail on
OK
```

Individual statistics are recorded for every get, set and del operation on a key, including keys that are not currently stored in the server. For example, if an attempt is made to obtain the value of key abckey and it does not exist, the get operating on the specified key are recorded while detailed statistics are in effect, even if the key is not currently stored. The hits, that is, the number of get or del operations for a key that exists in the server are also counted.

To turn detailed statistics off, send the stats detail off command to the memcached server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail off
OK
```

To obtain the detailed statistics recorded during the process, send the stats detail dump command to the memcached server:

```
stats detail dump
PREFIX hykkey get 0 hit 0 set 1 del 0
PREFIX xyzkey get 0 hit 0 set 1 del 0
PREFIX yukkey get 1 hit 0 set 0 del 0
PREFIX abckey get 3 hit 3 set 1 del 0
END
```

You can use the detailed statistics information to determine whether your memcached clients are using a large number of keys that do not exist in the server by comparing the hit and get or del counts. Because the information is recorded by key, you can also determine whether the failures or operations are clustered around specific keys.

16.2.4.6 Using memcached-tool

The memcached-tool, located within the scripts directory within the memcached source directory. The tool provides convenient access to some reports and statistics from any memcached instance.
The basic format of the command is:

```
shell> ./memcached-tool hostname:port [command]
```

The default output produces a list of the slab allocations and usage. For example:

```
shell> memcached-tool localhost:11211 display

#  Item_Size  Max_age   Pages   Count   Full?  Evicted Evict_Time OOM
1      80B        93s       1      20      no        0        0    0
2     104B        93s       1      16      no        0        0    0
3     136B      1335s       1      28      no        0        0    0
4     176B      1335s       1      24      no        0        0    0
5     224B      1335s       1      32      no        0        0    0
6     280B      1335s       1      34      no        0        0    0
7     352B      1335s       1      36      no        0        0    0
8     440B      1335s       1      46      no        0        0    0
9     552B      1335s       1      58      no        0        0    0
10    696B      1335s       1      66      no        0        0    0
11    872B      1335s       1      89      no        0        0    0
12    1.1K      1335s       1     112      no        0        0    0
13    1.3K      1335s       1     145      no        0        0    0
14    1.7K      1335s       1     123      no        0        0    0
15    2.1K      1335s       1     198      no        0        0    0
16    2.6K      1335s       1     199      no        0        0    0
17    3.3K      1335s       1     229      no        0        0    0
18    4.1K      1335s       1     248   yes       36        2    0
19    5.2K      1335s       2     328      no        0        0    0
20    6.4K      1335s       2     316   yes       387        1    0
21    8.1K      1335s       3     381   yes       492        1    0
22   10.1K      1335s       3     303   yes       598        2    0
23   12.6K      1335s       5     405   yes       605        1    0
24   15.8K      1335s       6     384   yes       766        2    0
25   19.7K      1335s       7     357   yes       908       170    0
26   24.6K      1335s       7     287   yes      1012        1    0
27   30.8K      1335s       7     231   yes      1193       169    0
28   38.5K      1335s       4     104   yes      1323       169    0
29   48.1K      1335s       1     21   yes      1287        1    0
30   60.2K      1335s       1     17   yes      1093       169    0
31   75.2K      1335s       1     13   yes      713       168    0
32   94.0K      1335s       1     10   yes      278       168    0
33  117.5K      1335s       1      3   no        0        0    0
```

This output is the same if you specify the **command** as **display**:

```
shell> memcached-tool localhost:11211 display

#  Item_Size  Max_age   Pages   Count   Full?  Evicted Evict_Time OOM
1      80B        93s       1      20      no        0        0    0
2     104B        93s       1      16      no        0        0    0
...  
```

The output shows a summarized version of the output from the **slabs** statistics. The columns provided in the output are shown below:

- **#: The slab number**
- **Item_Size**: The size of the slab
- **Max_age**: The age of the oldest item in the slab
- **Pages**: The number of pages allocated to the slab
- **Count**: The number of items in this slab
- **Full?**: Whether the slab is fully populated
• **Evicted**: The number of objects evicted from this slab

• **Evict_Time**: The time (in seconds) since the last eviction

• **OOM**: The number of items that have triggered an out of memory error

You can also obtain a dump of the general statistics for the server using the `stats` command:

```shell
shell> memcached-tool localhost:11211 stats
#localhost:11211 Field Value
accepting_conns 1
bytes 162
bytes_read 485
bytes_written 6820
cas_badval 0
cas_hits 0
cas_misses 0
cmd_flush 0
cmd_get 4
cmd_set 2
curr_connections 10
curr_items 2
decr_hits 0
decr_misses 1
delete_hits 0
delete_misses 0
evictions 0
get_hits 4
get_misses 0
incr_hits 0
incr_misses 2
limit_maxbytes 67108864
listen_disabled_num 0
pid 12981
pointer_size 32
rusage_system 0.013911
rusage_user 0.011876
threads 4
time 1255518565
total_connections 20
total_items 2
uptime 880
version 1.4.2
```

### 16.2.5 memcached FAQ

16.2.5.1 Can memcached be run on a Windows environment? ........................................ 1987
16.2.5.2 What is the maximum size of an object you can store in memcached? Is that configurable? .. 1987
16.2.5.3 Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications? .................................................... 1987
16.2.5.4 Is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (for example, locking up)? .................................................. 1987
16.2.5.5 How is an event such as a crash of one of the memcached servers handled by the **memcached** client? ................................................................. 1987
16.2.5.6 What is a recommended hardware configuration for a memcached server? ........................................ 1988
16.2.5.7 Is memcached more effective for video and audio as opposed to textual read/writes? ........ 1988
16.2.5.8 Can memcached work with ASPX? ................................................................. 1988
16.2.5.9 How expensive is it to establish a memcache connection? Should those connections be pooled? ................................................................. 1988
16.2.5.10 How is the data handled when the **memcached** server is down? ........................................ 1988
16.2.5.11 How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached? ................................................................. 1988
16.2.5.12 Is compression available? ......................................................................................... 1988
16.2.5.13 Can we implement different types of memcached as different nodes in the same server, so can there be deterministic and non-deterministic in the same server? ........................................... 1989
16.2.5.14 What are best practices for testing an implementation, to ensure that it improves performance, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start? ........................................... 1989

16.2.5.15 Can memcached be run on a Windows environment?

No. Currently memcached is available only on the Unix/Linux platform. There is an unofficial port available, see http://www.codeplex.com/memcachedproviders.

16.2.5.16 What is the maximum size of an object you can store in memcached? Is that configurable?

The default maximum object size is 1MB. In memcached 1.4.2 and later, you can change the maximum size of an object using the -I command line option.

For versions before this, to increase this size, you have to re-compile memcached. You can modify the value of the POWER_BLOCK within the slabs.c file within the source.

In memcached 1.4.2 and higher, you can configure the maximum supported object size by using the -I command-line option. For example, to increase the maximum object size to 5MB:

```bash
$ memcached -I 5m
```

If an object is larger than the maximum object size, you must manually split it. memcached is very simple: you give it a key and some data, it tries to cache it in RAM. If you try to store more than the default maximum size, the value is just truncated for speed reasons.

16.2.5.17 Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications?

Yes. memcached plays no role in database writes, it is a method of caching data already read from the database in RAM.

16.2.5.18 Is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (for example, locking up)?

If you don't use persistent connections when communicating with memcached, there will be a small increase in the latency of opening the connection each time. The effect is comparable to use nonpersistent connections with MySQL.

In general, the chance of locking or other issues with persistent connections is minimal, because there is very little locking within memcached. If there is a problem, eventually your request will time out and return no result, so your application will need to load from MySQL again.

16.2.5.19 How is an event such as a crash of one of the memcached servers handled by the memcached client?

There is no automatic handling of this. If your client fails to get a response from a server, code a fallback mechanism to load the data from the MySQL database.

The client APIs all provide the ability to add and remove memcached instances on the fly. If within your application you notice that memcached server is no longer responding, you can remove the server from the list of servers, and keys will automatically be redistributed to another memcached
server in the list. If retaining the cache content on all your servers is important, make sure you use an API that supports a consistent hashing algorithm. For more information, see Section 16.2.2.5, “memcached Hashing/Distribution Types.”

16.2.5.6 What is a recommended hardware configuration for a memcached server?

`memcached` has a very low processing overhead. All that is required is spare physical RAM capacity. A `memcached` server does not require a dedicated machine. If you have web, application, or database servers that have spare RAM capacity, then use them with `memcached`.

To build and deploy a dedicated `memcached` server, use a relatively low-power CPU, lots of RAM, and one or more Gigabit Ethernet interfaces.

16.2.5.7 Is `memcached` more effective for video and audio as opposed to textual read/writes?

`memcached` works equally well for all kinds of data. To `memcached`, any value you store is just a stream of data. Remember, though, that the maximum size of an object you can store in `memcached` is 1MB, but can be configured to be larger by using the `-i` option in `memcached` 1.4.2 and later, or by modifying the source in versions before 1.4.2. If you plan on using `memcached` with audio and video content, you will probably want to increase the maximum object size. Also remember that `memcached` is a solution for caching information for reading. It shouldn't be used for writes, except when updating the information in the cache.

16.2.5.8 Can `memcached` work with ASPX?

There are ports and interfaces for many languages and environments. ASPX relies on an underlying language such as C# or VisualBasic, and if you are using ASP.NET then there is a C# `memcached` library. For more information, see https://sourceforge.net/projects/memcacheddotnet/.

16.2.5.9 How expensive is it to establish a memcache connection? Should those connections be pooled?

Opening the connection is relatively inexpensive, because there is no security, authentication or other handshake taking place before you can start sending requests and getting results. Most APIs support a persistent connection to a `memcached` instance to reduce the latency. Connection pooling would depend on the API you are using, but if you are communicating directly over TCP/IP, then connection pooling would provide some small performance benefit.

16.2.5.10 How is the data handled when the `memcached` server is down?

The behavior is entirely application dependent. Most applications fall back to loading the data from the database (just as if they were updating the `memcached` information). If you are using multiple `memcached` servers, you might also remove a downed server from the list to prevent it from affecting performance. Otherwise, the client will still attempt to communicate with the `memcached` server that corresponds to the key you are trying to load.

16.2.5.11 How are auto-increment columns in the MySQL database coordinated across multiple instances of `memcached`?

They aren't. There is no relationship between MySQL and `memcached` unless your application (or, if you are using the MySQL UDFs for `memcached`, your database definition) creates one.

If you are storing information based on an auto-increment key into multiple instances of `memcached`, the information is only stored on one of the `memcached` instances anyway. The client uses the key value to determine which `memcached` instance to store the information. It doesn't store the same information across all the instances, as that would be a waste of cache memory.

16.2.5.12 Is compression available?
Yes. Most of the client APIs support some sort of compression, and some even allow you to specify the threshold at which a value is deemed appropriate for compression during storage.

**16.2.5.13.** Can we implement different types of memcached as different nodes in the same server, so can there be deterministic and non-deterministic in the same server?

Yes. You can run multiple instances of memcached on a single server, and in your client configuration you choose the list of servers you want to use.

**16.2.5.14.** What are best practices for testing an implementation, to ensure that it improves performance, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start?

The best way to test the performance is to start up a memcached instance. First, modify your application so that it stores the data just before the data is about to be used or displayed into memcached. Since the APIs handle the serialization of the data, it should just be a one-line modification to your code. Then, modify the start of the process that would normally load that information from MySQL with the code that requests the data from memcached. If the data cannot be loaded from memcached, default to the MySQL process.

All of the changes required will probably amount to just a few lines of code. To get the best benefit, make sure you cache entire objects (for example, all the components of a web page, blog post, discussion thread, and so on), rather than using memcached as a simple cache of individual rows of MySQL tables.

Keeping the configuration simple at the start, or even over the long term, is easy with memcached. Once you have the basic structure up and running, often the only ongoing change is to add more servers into the list of servers used by your applications. You don't need to manage the memcached servers, and there is no complex configuration; just add more servers to the list and let the client API and the memcached servers make the decisions.
Chapter 17 Replication

Table of Contents

17.1 Replication Configuration ........................................................................................................... 1992
  17.1.1 How to Set Up Replication .................................................................................................. 1993
  17.1.2 Replication Formats ............................................................................................................ 2002
  17.1.3 Replication and Binary Logging Options and Variables ................................................... 2010
  17.1.4 Common Replication Administration Tasks ....................................................................... 2052
17.2 Replication Implementation ....................................................................................................... 2055
  17.2.1 Replication Implementation Details .................................................................................... 2055
  17.2.2 Replication Relay and Status Logs ..................................................................................... 2057
  17.2.3 How Servers Evaluate Replication Filtering Rules ............................................................ 2060
17.3 Replication Solutions .................................................................................................................. 2065
  17.3.1 Using Replication for Backups ........................................................................................... 2066
  17.3.2 Using Replication with Different Master and Slave Storage Engines ............................ 2069
  17.3.3 Using Replication for Scale-Out ........................................................................................ 2071
  17.3.4 Replicating Different Databases to Different Slaves ......................................................... 2072
  17.3.5 Improving Replication Performance ................................................................................. 2073
  17.3.6 Switching Masters During Failover ................................................................................. 2074
  17.3.7 Setting Up Replication to Use Encrypted Connections ................................................... 2076
  17.3.8 Semisynchronous Replication ......................................................................................... 2078
17.4 Replication Notes and Tips ......................................................................................................... 2083
  17.4.1 Replication Features and Issues ......................................................................................... 2083
  17.4.2 Replication Compatibility Between MySQL Versions .................................................... 2107
  17.4.3 Upgrading a Replication Setup ......................................................................................... 2108
  17.4.4 Troubleshooting Replication ........................................................................................... 2109
  17.4.5 How to Report Replication Bugs or Problems ................................................................. 2110

Replication enables data from one MySQL database server (the master) to be replicated to one or more MySQL database servers (the slaves). Replication is asynchronous by default, therefore slaves do not need to be connected permanently to receive updates from the master. This means that updates can occur over long-distance connections and even over temporary or intermittent connections such as a dial-up service. Depending on the configuration, you can replicate all databases, selected databases, or even selected tables within a database.

For answers to some questions often asked by those who are new to MySQL Replication, see Section A.14, "MySQL 5.5 FAQ: Replication".

Advantages of replication in MySQL include:

- Scale-out solutions - spreading the load among multiple slaves to improve performance. In this environment, all writes and updates must take place on the master server. Reads, however, may take place on one or more slaves. This model can improve the performance of writes (since the master is dedicated to updates), while dramatically increasing read speed across an increasing number of slaves.

- Data security - because data is replicated to the slave, and the slave can pause the replication process, it is possible to run backup services on the slave without corrupting the corresponding master data.

- Analytics - live data can be created on the master, while the analysis of the information can take place on the slave without affecting the performance of the master.
• Long-distance data distribution - if a branch office would like to work with a copy of your main data, you can use replication to create a local copy of the data for their use without requiring permanent access to the master.

Replication in MySQL features support for one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves. This is in contrast to the synchronous replication which is a characteristic of NDB Cluster (see Chapter 18, MySQL NDB Cluster 7.2). In MySQL 5.5, an interface to semisynchronous replication is supported in addition to the built-in asynchronous replication. With semisynchronous replication, a commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction. See Section 17.3.8, “Semisynchronous Replication”.

There are a number of solutions available for setting up replication between two servers, but the best method to use depends on the presence of data and the engine types you are using. For more information on the available options, see Section 17.1.1, “How to Set Up Replication”.

There are two core types of replication format, Statement Based Replication (SBR), which replicates entire SQL statements, and Row Based Replication (RBR), which replicates only the changed rows. You may also use a third variety, Mixed Based Replication (MBR). For more information on the different replication formats, see Section 17.1.2, “Replication Formats”. In MySQL 5.5, statement-based format is the default.

Replication is controlled through a number of different options and variables. These control the core operation of the replication, timeouts, and the databases and filters that can be applied on databases and tables. For more information on the available options, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

You can use replication to solve a number of different problems, including problems with performance, supporting the backup of different databases, and as part of a larger solution to alleviate system failures. For information on how to address these issues, see Section 17.3, “Replication Solutions”.

For notes and tips on how different data types and statements are treated during replication, including details of replication features, version compatibility, upgrades, and problems and their resolution, including an FAQ, see Section 17.4, “Replication Notes and Tips”.

For detailed information on the implementation of replication, how replication works, the process and contents of the binary log, background threads and the rules used to decide how statements are recorded and replication, see Section 17.2, “Replication Implementation”.

17.1 Replication Configuration

Replication between servers in MySQL is based on the binary logging mechanism. The MySQL instance operating as the master (the source of the database changes) writes updates and changes as “events” to the binary log. The information in the binary log is stored in different logging formats according to the database changes being recorded. Slaves are configured to read the binary log from the master and to execute the events in the binary log on the slave's local database.

The master is “dumb” in this scenario. Once binary logging has been enabled, all statements are recorded in the binary log. Each slave receives a copy of the entire contents of the binary log. It is the responsibility of the slave to decide which statements in the binary log should be executed; you cannot configure the master to log only certain events. If you do not specify otherwise, all events in the master binary log are executed on the slave. If required, you can configure the slave to process only events that apply to particular databases or tables.

Each slave keeps a record of the binary log coordinates: The file name and position within the file that it has read and processed from the master. This means that multiple slaves can be connected to the master
and executing different parts of the same binary log. Because the slaves control this process, individual
slaves can be connected and disconnected from the server without affecting the master’s operation.
Also, because each slave remembers the position within the binary log, it is possible for slaves to be
disconnected, reconnect and then “catch up” by continuing from the recorded position.

The master and each slave must be configured with a unique ID (using the `server_id` system variable).
In addition, each slave must be configured with information about the master host name, log file name, and
position within that file. These details can be controlled from within a MySQL session using the `CHANGE
MASTER TO` statement on the slave. The details are stored within the slave’s `master.info` file.

This section describes the setup and configuration required for a replication environment, including step-
by-step instructions for creating a new replication environment. The major components of this section are:

- For a guide to setting up two or more servers for replication, Section 17.1.1, “How to Set Up Replication”,
deals with the configuration of the systems and provides methods for copying data between the master
and slaves.

- Events in the binary log are recorded using a number of formats. These are referred to as statement-
based replication (SBR) or row-based replication (RBR). A third type, mixed-format replication (MIXED),
uses SBR or RBR replication automatically to take advantage of the benefits of both SBR and RBR
formats when appropriate. The different formats are discussed in Section 17.1.2, “Replication Formats”.

- Detailed information on the different configuration options and variables that apply to replication is
provided in Section 17.1.3, “Replication and Binary Logging Options and Variables”.

- Once started, the replication process should require little administration or monitoring. However, for
advice on common tasks that you may want to execute, see Section 17.1.4, “Common Replication
Administration Tasks”.

### 17.1.1 How to Set Up Replication

This section describes how to set up complete replication of a MySQL server. There are a number of
different methods for setting up replication, and the exact method to use depends on how you are setting
up replication, and whether you already have data within your master database.

There are some generic tasks that are common to all replication setups:

- On the master, you must enable binary logging and configure a unique server ID. This might require a
server restart. See Section 17.1.1.1, “Setting the Replication Master Configuration”.

- On each slave that you want to connect to the master, you must configure a unique server ID. This might
require a server restart. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.

- You may want to create a separate user that will be used by your slaves to authenticate with the master
to read the binary log for replication. The step is optional. See Section 17.1.1.3, “Creating a User for
Replication”.

- Before creating a data snapshot or starting the replication process, you should record the position
of the binary log on the master. You will need this information when configuring the slave so that the
slave knows where within the binary log to start executing events. See Section 17.1.1.4, “Obtaining the
Replication Master Binary Log Coordinates”.

- If you already have data on your master and you want to use it to synchronize your slave, you will
need to create a data snapshot. You can create a snapshot using `mysqldump` (see Section 17.1.1.5,
“Creating a Data Snapshot Using mysqldump”) or by copying the data files directly (see Section 17.1.1.6,
“Creating a Data Snapshot Using Raw Data Files”).
• You will need to configure the slave with settings for connecting to the master, such as the host name, login credentials, and binary log file name and position. See Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

Once you have configured the basic options, you will need to follow the instructions for your replication setup. A number of alternatives are provided:

• If you are establishing a new MySQL master and one or more slaves, you need only set up the configuration, as you have no data to exchange. For guidance on setting up replication in this situation, see Section 17.1.1.7, “Setting Up Replication with New Master and Slaves”.

• If you are already running a MySQL server, and therefore already have data that must be transferred to your slaves before replication starts, have not previously configured the binary log and are able to shut down your MySQL server for a short period during the process, see Section 17.1.1.8, “Setting Up Replication with Existing Data”.

• If you are adding slaves to an existing replication environment, you can set up the slaves without affecting the master. See Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”.

If you will be administering MySQL replication servers, we suggest that you read this entire chapter through and try all statements mentioned in Section 13.4.1, “SQL Statements for Controlling Master Servers”, and Section 13.4.2, “SQL Statements for Controlling Slave Servers”. You should also familiarize yourself with the replication startup options described in Section 17.1.3, “Replication and Binary Logging Options and Variables”.

Note
Note that certain steps within the setup process require the SUPER privilege. If you do not have this privilege, it might not be possible to enable replication.

17.1.1.1 Setting the Replication Master Configuration

On a replication master, you must enable binary logging and establish a unique server ID. If this has not already been done, this part of master setup requires a server restart.

Binary logging must be enabled on the master because the binary log is the basis for sending data changes from the master to its slaves. If binary logging is not enabled, replication will not be possible.

Each server within a replication group must be configured with a unique server ID. This ID is used to identify individual servers within the group, and must be a positive integer between 1 and \((2^{32}) - 1\). How you organize and select the numbers is entirely up to you.

To configure the binary log and server ID options, you will need to shut down your MySQL server and edit the my.cnf or my.ini file. Add the following options to the configuration file within the [mysqld] section. If these options already exist, but are commented out, uncomment the options and alter them according to your needs. For example, to enable binary logging using a log file name prefix of mysql-bin, and configure a server ID of 1, use these lines:

```
[mysqld]
log-bin=mysql-bin
server-id=1
```

After making the changes, restart the server.

Note
If you do not set server_id (or set it explicitly to its default value of 0), a master refuses connections from all slaves.
How to Set Up Replication

Note
For the greatest possible durability and consistency in a replication setup using InnoDB with transactions, you should use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in the master `my.cnf` file.

Note
Ensure that the `skip_networking` system variable is not enabled on your replication master. If networking has been disabled, your slave will not be able to communicate with the master and replication will fail.

17.1.1.2 Setting the Replication Slave Configuration

On a replication slave, you must establish a unique server ID. If this has not already been done, this part of slave setup requires a server restart.

If the slave server ID is not already set, or the current value conflicts with the value that you have chosen for the master server, you should shut down your slave server and edit the configuration to specify a unique server ID. For example:

```
[mysqld]
server-id=2
```

After making the changes, restart the server.

If you are setting up multiple slaves, each one must have a unique `server_id` value that differs from that of the master and from each of the other slaves. Think of `server_id` values as something similar to IP addresses: These IDs uniquely identify each server instance in the community of replication partners.

Note
If you do not set `server_id` (or set it explicitly to its default value of 0), a slave refuses to connect to a master.

You do not have to enable binary logging on the slave for replication to be enabled. However, if you enable binary logging on the slave, you can use the binary log for data backups and crash recovery on the slave, and also use the slave as part of a more complex replication topology (for example, where the slave acts as a master to other slaves).

17.1.1.3 Creating a User for Replication

Each slave must connect to the master using a MySQL user name and password, so there must be a user account on the master that the slave can use to connect. Any account can be used for this operation, providing it has been granted the `REPLICATION SLAVE` privilege. You may wish to create a different account for each slave, or connect to the master using the same account for each slave.

You need not create an account specifically for replication. However, you should be aware that the user name and password will be stored in plain text within the `master.info` file (see Section 17.2.2.2, “Slave Status Logs”). Therefore, you may want to create a separate account that has privileges only for the replication process, to minimize the possibility of compromise to other accounts.

To create a new account, use `CREATE USER`. To grant this account the privileges required for replication, use the `GRANT` statement. If you create an account solely for the purposes of replication, that account
How to Set Up Replication

needs only the `REPLICATION_SLAVE` privilege. For example, to set up a new user, `repl`, that can connect for replication from any host within the `example.com` domain, issue these statements on the master:

```sql
mysql> CREATE USER 'repl'@'%.example.com' IDENTIFIED BY 'password';
mysql> GRANT REPLICATION SLAVE ON *.* TO 'repl'@'%.example.com';
```

See Section 13.7.1, “Account Management Statements”, for more information on statements for manipulation of user accounts.

17.1.1.4 Obtaining the Replication Master Binary Log Coordinates

To configure replication on the slave you must determine the master's current coordinates within its binary log. You will need this information so that when the slave starts the replication process, it is able to start processing events from the binary log at the correct point.

If you have existing data on your master that you want to synchronize on your slaves before starting the replication process, you must stop processing statements on the master, and then obtain its current binary log coordinates and dump its data, before permitting the master to continue executing statements. If you do not stop the execution of statements, the data dump and the master status information that you use will not match and you will end up with inconsistent or corrupted databases on the slaves.

To obtain the master binary log coordinates, follow these steps:

1. Start a session on the master by connecting to it with the command-line client, and flush all tables and block write statements by executing the `FLUSH TABLES WITH READ LOCK` statement:

   ```sql
   mysql> FLUSH TABLES WITH READ LOCK;
   ```

   For InnoDB tables, note that `FLUSH TABLES WITH READ LOCK` also blocks `COMMIT` operations.

   **Warning**

   Leave the client from which you issued the `FLUSH TABLES` statement running so that the read lock remains in effect. If you exit the client, the lock is released.

2. In a different session on the master, use the `SHOW MASTER STATUS` statement to determine the current binary log file name and position:

   ```sql
   mysql > SHOW MASTER STATUS;
   +-------------------+----------+--------------+------------------+
   | File              | Position | Binlog_Do_DB | Binlog_Ignore_DB |
   +-------------------+----------+--------------+------------------+
   | mysql-bin.000003  | 73       | test         | manual,mysql     |
   +-------------------+----------+--------------+------------------+
   ```

   The `File` column shows the name of the log file and `Position` shows the position within the file. In this example, the binary log file is `mysql-bin.000003` and the position is 73. Record these values. You need them later when you are setting up the slave. They represent the replication coordinates at which the slave should begin processing new updates from the master.

   If the master has been running previously without binary logging enabled, the log file name and position values displayed by `SHOW MASTER STATUS` or `mysqldump --master-data` will be empty. In that case, the values that you need to use later when specifying the slave's log file and position are the empty string ("") and 4.

You now have the information you need to enable the slave to start reading from the binary log in the correct place to start replication.
If you have existing data that needs to be synchronized with the slave before you start replication, leave the client running so that the lock remains in place and then proceed to Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”, or Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”. The idea here is to prevent any further changes so that the data copied to the slaves is in synchrony with the master.

If you are setting up a brand new master and slave replication group, you can exit the first session to release the read lock.

17.1.1.5 Creating a Data Snapshot Using mysqldump

One way to create a snapshot of the data in an existing master database is to use the mysqldump tool to create a dump of all the databases you want to replicate. Once the data dump has been completed, you then import this data into the slave before starting the replication process.

The example shown here dumps all databases to a file named dbdump.db, and includes the --master-data option which automatically appends the CHANGE MASTER TO statement required on the slave to start the replication process:

```
shell> mysqldump --all-databases --master-data > dbdump.db
```

If you do not use --master-data, then it is necessary to lock all tables in a separate session manually (using FLUSH TABLES WITH READ LOCK) prior to running mysqldump, then exiting or running UNLOCK TABLES from the second session to release the locks. You must also obtain binary log position information matching the snapshot, using SHOW MASTER STATUS, and use this to issue the appropriate CHANGE MASTER TO statement when starting the slave.

When choosing databases to include in the dump, remember that you need to filter out databases on each slave that you do not want to include in the replication process.

To import the data, either copy the dump file to the slave, or access the file from the master when connecting remotely to the slave.

17.1.1.6 Creating a Data Snapshot Using Raw Data Files

If your database is large, copying the raw data files can be more efficient than using mysqldump and importing the file on each slave. This technique skips the overhead of updating indexes as the INSERT statements are replayed.

Using this method with tables in storage engines with complex caching or logging algorithms requires extra steps to produce a perfect “point in time” snapshot: the initial copy command might leave out cache information and logging updates, even if you have acquired a global read lock. How the storage engine responds to this depends on its crash recovery abilities.

This method also does not work reliably if the master and slave have different values for ft_stopword_file, ft_min_word_len, or ft_max_word_len and you are copying tables having full-text indexes.

If you use InnoDB tables, you can use the mysqlbackup command from the MySQL Enterprise Backup component to produce a consistent snapshot. This command records the log name and offset corresponding to the snapshot to be later used on the slave. MySQL Enterprise Backup is a commercial product that is included as part of a MySQL Enterprise subscription. See Section 25.2, “MySQL Enterprise Backup Overview” for detailed information.

Otherwise, use the cold backup technique to obtain a reliable binary snapshot of InnoDB tables: copy all data files after doing a slow shutdown of the MySQL Server.
To create a raw data snapshot of MyISAM tables, you can use standard copy tools such as `cp` or `copy`, a remote copy tool such as `scp` or `rsync`, an archiving tool such as `zip` or `tar`, or a file system snapshot tool such as `dump`, providing that your MySQL data files exist on a single file system. If you are replicating only certain databases, copy only those files that relate to those tables. (For InnoDB, all tables in all databases are stored in the system tablespace files, unless you have the `innodb_file_per_table` option enabled.)

You might want to specifically exclude the following files from your archive:

- Files relating to the `mysql` database.
- The `master.info` file.
- The master’s binary log files.
- Any relay log files.

To get the most consistent results with a raw data snapshot, shut down the master server during the process, as follows:

1. Acquire a read lock and get the master's status. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
2. In a separate session, shut down the master server:

   ```shell
   mysqladmin shutdown
   ```

3. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```shell
   tar cf /tmp/db.tar ./data
   zip -r /tmp/db.zip ./data
   rsync --recursive ./data /tmp/dbdata
   ```

4. Restart the master server.

If you are not using InnoDB tables, you can get a snapshot of the system from a master without shutting down the server as described in the following steps:

1. Acquire a read lock and get the master's status. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
2. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```shell
   tar cf /tmp/db.tar ./data
   zip -r /tmp/db.zip ./data
   rsync --recursive ./data /tmp/dbdata
   ```

3. In the client where you acquired the read lock, release the lock:

   ```mysql
   UNLOCK TABLES;
   ```

Once you have created the archive or copy of the database, copy the files to each slave before starting the slave replication process.

### 17.1.1.7 Setting Up Replication with New Master and Slaves

The easiest and most straightforward method for setting up replication is to use new master and slave servers.
You can also use this method if you are setting up new servers but have an existing dump of the databases from a different server that you want to load into your replication configuration. By loading the data into a new master, the data will be automatically replicated to the slaves.

To set up replication between a new master and slave:

1. Configure the MySQL master with the necessary configuration properties. See Section 17.1.1.1, “Setting the Replication Master Configuration”.

2. Start up the MySQL master.

3. Set up a user. See Section 17.1.1.3, “Creating a User for Replication”.

4. Obtain the master status information. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.

5. On the master, release the read lock:

```
mysql> UNLOCK TABLES;
```

6. On the slave, edit the MySQL configuration. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.

7. Start up the MySQL slave.

8. Execute a `CHANGE MASTER TO` statement to set the master replication server configuration. See Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

Perform the slave setup steps on each slave.

Because there is no data to load or exchange on a new server configuration you do not need to copy or import any information.

If you are setting up a new replication environment using the data from a different existing database server, you will now need to run the dump file generated from that server on the new master. The database updates will automatically be propagated to the slaves:

```
shell> mysql -h master < fulldb.dump
```

### 17.1.1.8 Setting Up Replication with Existing Data

When setting up replication with existing data, you will need to decide how best to get the data from the master to the slave before starting the replication service.

The basic process for setting up replication with existing data is as follows:

1. With the MySQL master running, create a user to be used by the slave when connecting to the master during replication. See Section 17.1.1.3, “Creating a User for Replication”.

2. If you have not already configured the `server_id` system variable and enabled binary logging on the master server, you will need to shut it down to configure these options. See Section 17.1.1.1, “Setting the Replication Master Configuration”.

If you have to shut down your master server, this is a good opportunity to take a snapshot of its databases. You should obtain the master status (see Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”) before taking down the master, updating the configuration and taking a snapshot. For information on how to create a snapshot using raw data files, see Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

1999
3. If your master server is already correctly configured, obtain its status (see Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”) and then use mysqldump to take a snapshot (see Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”) or take a raw snapshot of the live server using the guide in Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

4. Update the configuration of the slave. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.

5. The next step depends on how you created the snapshot of data on the master.

   If you used mysqldump:
   a. Start the slave, using the --skip-slave-start option so that replication does not start.
   b. Import the dump file:

```
shell> mysql < fulldb.dump
```

   If you created a snapshot using the raw data files:
   a. Extract the data files into your slave data directory. For example:

```
shell> tar xvf dbdump.tar
```

       You may need to set permissions and ownership on the files so that the slave server can access and modify them.

   b. Start the slave, using the --skip-slave-start option so that replication does not start.

6. Configure the slave with the replication coordinates from the master. This tells the slave the binary log file and position within the file where replication needs to start. Also, configure the slave with the login credentials and host name of the master. For more information on the CHANGE MASTER TO statement required, see Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

7. Start the slave threads:

```
mysql> START SLAVE;
```

After you have performed this procedure, the slave should connect to the master and catch up on any updates that have occurred since the snapshot was taken.

If you have forgotten to set the server_id system variable for the master, slaves cannot connect to it.

If you have forgotten to set the server_id system variable for the slave, you get the following error in the slave’s error log:

```
Warning: You should set server-id to a non-0 value if master_host is set; we will force server id to 2, but this MySQL server will not act as a slave.
```

You also find error messages in the slave’s error log if it is not able to replicate for any other reason.

Once a slave is replicating, you can find in its data directory one file named master.info and another named relay-log.info. The slave uses these two files to keep track of how much of the master’s binary log it has processed. Do not remove or edit these files unless you know exactly what you are doing and fully understand the implications. Even in that case, it is preferred that you use the CHANGE MASTER TO statement to change replication parameters. The slave will use the values specified in the statement to update the status files automatically.
How to Set Up Replication

**Note**

The content of `master.info` overrides some of the server options specified on the command line or in `my.cnf`. See Section 17.1.3, “Replication and Binary Logging Options and Variables”, for more details.

A single snapshot of the master suffices for multiple slaves. To set up additional slaves, use the same master snapshot and follow the slave portion of the procedure just described.

### 17.1.1.9 Introducing Additional Slaves to an Existing Replication Environment

To add another slave to an existing replication configuration, you can do so without stopping the master. Instead, set up the new slave by making a copy of an existing slave, except that you configure the new slave with a different `server_id` value.

To duplicate an existing slave:

1. Shut down the existing slave:
   ```bash
   mysqladmin shutdown
   ```

2. Copy the data directory from the existing slave to the new slave. You can do this by creating an archive using `tar` or WinZip, or by performing a direct copy using a tool such as `cp` or `rsync`. Ensure that you also copy the log files and relay log files.

A common problem that is encountered when adding new replication slaves is that the new slave fails with a series of warning and error messages like these:

071118 16:44:10 [Warning] Neither --relay-log nor --relay-log-index were used; so replication may break when this MySQL server acts as a slave and has his hostname changed!! Please use '--relay-log=new_slave_hostname-relay-bin' to avoid this problem.

071118 16:44:10 [ERROR] Failed to open the relay log './old_slave_hostname-relay-bin.003525' (relay_log_pos 22940879)
071118 16:44:10 [ERROR] Could not find target log during relay log initialization
071118 16:44:10 [ERROR] Failed to initialize the master info structure

This is due to the fact that, if the `relay_log` system variable is not specified, the relay log files contain the host name as part of their file names. This is also true of the relay log index file if the `relay_log_index` system variable is not used. For more information about these variables, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

To avoid this problem, use the same value for `relay_log` on the new slave that was used on the existing slave. (If this option was not set explicitly on the existing slave, use `existing_slave_hostname-relay-bin`.) If this is not feasible, copy the existing slave's relay log index file to the new slave and set the `relay_log_index` system variable on the new slave to match what was used on the existing slave. (If this option was not set explicitly on the existing slave, use `existing_slave_hostname-relay-bin.index`.) Alternatively—if you have already tried to start the new slave (after following the remaining steps in this section) and have encountered errors like those described previously—then perform the following steps:

a. If you have not already done so, issue a `STOP SLAVE` on the new slave.

   If you have already started the existing slave again, issue a `STOP SLAVE` on the existing slave as well.

b. Copy the contents of the existing slave's relay log index file into the new slave's relay log index file, making sure to overwrite any content already in the file.

c. Proceed with the remaining steps in this section.
3. Copy the `master.info` and `relay-log.info` files from the existing slave to the new slave if they were not located in the data directory. These files hold the current log coordinates for the master's binary log and the slave's relay log.

4. Start the existing slave.

5. On the new slave, edit the configuration and give the new slave a unique server ID (using the `server_id` system variable) that is not used by the master or any of the existing slaves.

6. Start the new slave. The slave will use the information in its `master.info` file to start the replication process.

### 17.1.10 Setting the Master Configuration on the Slave

To set up the slave to communicate with the master for replication, you must tell the slave the necessary connection information. To do this, execute the following statement on the slave, replacing the option values with the actual values relevant to your system:

```sql
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_host_name',
    -> MASTER_USER='replication_user_name',
    -> MASTER_PASSWORD='replication_password',
    -> MASTER_LOG_FILE='recorded_log_file_name',
    -> MASTER_LOG_POS=recorded_log_position;
```

**Note**

Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

The `CHANGE MASTER TO` statement has other options as well. For example, it is possible to set up secure replication using SSL. For a full list of options, and information about the maximum permissible length for the string-valued options, see Section 13.4.2.1, “CHANGE MASTER TO Statement”.

### 17.1.2 Replication Formats

Replication works because events written to the binary log are read from the master and then processed on the slave. The events are recorded within the binary log in different formats according to the type of event. The different replication formats used correspond to the binary logging format used when the events were recorded in the master's binary log. The correlation between binary logging formats and the terms used during replication are:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called **statement-based replication** (often abbreviated as **SBR**), which corresponds to the standard statement-based binary logging format. In older versions of MySQL (5.1.4 and earlier), binary logging and replication used this format exclusively.

- Row-based binary logging logs changes in individual table rows. When used with MySQL replication, this is known as **row-based replication** (often abbreviated as **RBR**). In row-based replication, the master writes **events** to the binary log that indicate how individual table rows are changed.

- The server can change the binary logging format in real time according to the type of event using **mixed-format logging**.

When the mixed format is in effect, statement-based logging is used by default, but automatically switches to row-based logging in particular cases as described later. Replication using the mixed format
is often referred to as *mixed-based replication* or *mixed-format replication*. For more information, see Section 5.4.4.3, “Mixed Binary Logging Format”.

In MySQL 5.5, statement-based format is the default.

**NDB Cluster.** The default binary logging format in all MySQL NDB Cluster 7.2 releases, beginning with MySQL NDB Cluster 7.2.1, is *STATEMENT*. (This is a change from previous versions of NDB Cluster.) You should note that NDB Cluster Replication always uses row-based replication, and that the NDB storage engine is incompatible with statement-based replication. This means that you must manually set the format to *ROW* prior to enabling NDB Cluster Replication. See Section 18.6.2, “General Requirements for NDB Cluster Replication”, for more information.

When using *MIXED* format, the binary logging format is determined in part by the storage engine being used and the statement being executed. For more information on mixed-format logging and the rules governing the support of different logging formats, see Section 5.4.4.3, “Mixed Binary Logging Format”.

The logging format in a running MySQL server is controlled by setting the `binlog_format` server system variable. This variable can be set with session or global scope. The rules governing when and how the new setting takes effect are the same as for other MySQL server system variables. Setting the variable for the current session lasts only until the end of that session, and the change is not visible to other sessions. Setting the variable globally takes effect for clients that connect after the change, but not for any current client sessions, including the session where the variable setting was changed. To make the global system variable setting permanent so that it applies across server restarts, you must set it in an option file. For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”.

There are conditions under which you cannot change the binary logging format at runtime or doing so causes replication to fail. See Section 5.4.4.2, “Setting The Binary Log Format”.

Changing the global `binlog_format` value requires privileges sufficient to set global system variables. Changing the session `binlog_format` value requires privileges sufficient to set restricted session system variables. See Section 5.1.8.1, “System Variable Privileges”.

The statement-based and row-based replication formats have different issues and limitations. For a comparison of their relative advantages and disadvantages, see Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

With statement-based replication, you may encounter issues with replicating stored routines or triggers. You can avoid these issues by using row-based replication instead. For more information, see Section 20.7, “Stored Program Binary Logging”.

### 17.1.2.1 Advantages and Disadvantages of Statement-Based and Row-Based Replication

Each binary logging format has advantages and disadvantages. For most users, the mixed replication format should provide the best combination of data integrity and performance. If, however, you want to take advantage of the features specific to the statement-based or row-based replication format when performing certain tasks, you can use the information in this section, which provides a summary of their relative advantages and disadvantages, to determine which is best for your needs.

- **Advantages of statement-based replication**
- **Disadvantages of statement-based replication**
- **Advantages of row-based replication**
- **Disadvantages of row-based replication**
Advantages of statement-based replication

- Proven technology.
- Less data written to log files. When updates or deletes affect many rows, this results in much less storage space required for log files. This also means that taking and restoring from backups can be accomplished more quickly.
- Log files contain all statements that made any changes, so they can be used to audit the database.

Disadvantages of statement-based replication

- **Statements that are unsafe for SBR.**
  Not all statements which modify data (such as `INSERT`, `DELETE`, `UPDATE`, and `REPLACE` statements) can be replicated using statement-based replication. Any nondeterministic behavior is difficult to replicate when using statement-based replication. Examples of such DML (Data Modification Language) statements include the following:

  - A statement that depends on a UDF or stored program that is nondeterministic, since the value returned by such a UDF or stored program or depends on factors other than the parameters supplied to it. (Row-based replication, however, simply replicates the value returned by the UDF or stored program, so its effect on table rows and data is the same on both the master and slave.) See Section 17.4.1.15, “Replication of Invoked Features”, for more information.

  - `DELETE` and `UPDATE` statements that use a `LIMIT` clause without an `ORDER BY` are nondeterministic. See Section 17.4.1.16, “Replication and LIMIT”.

  - Statements using any of the following functions cannot be replicated properly using statement-based replication:
    - `LOAD_FILE()`
    - `UUID()`, `UUID_SHORT()`
    - `USER()`
    - `FOUND_ROWS()`
    - `SYSDATE()` (unless both the master and the slave are started with the `--sysdate-is-now` option)
    - `GET_LOCK()`
    - `IS_FREE_LOCK()`
    - `IS_USED_LOCK()`
    - `MASTER_POS_WAIT()`
    - `RAND()`
    - `RELEASE_LOCK()`
    - `SLEEP()`
    - `VERSION()`

  However, all other functions are replicated correctly using statement-based replication, including `NOW()` and so forth.
Replication Formats

For more information, see Section 17.4.1.14, “Replication and System Functions”.

Statements that cannot be replicated correctly using statement-based replication are logged with a warning like the one shown here:

```
[Warning] Statement is not safe to log in statement format.
```

A similar warning is also issued to the client in such cases. The client can display it using `SHOW WARNINGS`.

- `INSERT ... SELECT` requires a greater number of row-level locks than with row-based replication.
- `UPDATE` statements that require a table scan (because no index is used in the `WHERE` clause) must lock a greater number of rows than with row-based replication.
- For InnoDB: An `INSERT` statement that uses `AUTO_INCREMENT` blocks other nonconflicting `INSERT` statements.
- For complex statements, the statement must be evaluated and executed on the slave before the rows are updated or inserted. With row-based replication, the slave only has to modify the affected rows, not execute the full statement.
- If there is an error in evaluation on the slave, particularly when executing complex statements, statement-based replication may slowly increase the margin of error across the affected rows over time. See Section 17.4.1.28, “Slave Errors During Replication”.
- Stored functions execute with the same `NOW()` value as the calling statement. However, this is not true of stored procedures.
- Deterministic UDFs must be applied on the slaves.
- Table definitions must be (nearly) identical on master and slave. See Section 17.4.1.9, “Replication with Differing Table Definitions on Master and Slave”, for more information.

**Advantages of row-based replication**

- All changes can be replicated. This is the safest form of replication.
  
  The `mysql` database is not replicated. The `mysql` database is instead seen as a node-specific database. Row-based replication is not supported on tables in this database. Instead, statements that would normally update this information—such as `GRANT, REVOKE` and the manipulation of triggers, stored routines (including stored procedures), and views—are all replicated to slaves using statement-based replication.

  For statements such as `CREATE TABLE ... SELECT`, a `CREATE` statement is generated from the table definition and replicated using statement-based format, while the row insertions are replicated using row-based format.

  - The technology is the same as in most other database management systems; knowledge about other systems transfers to MySQL.
  - Fewer row locks are required on the master, which thus achieves higher concurrency, for the following types of statements:
    - `INSERT ... SELECT`
    - `INSERT` statements with `AUTO_INCREMENT`
Replication Formats

- **UPDATE** or **DELETE** statements with **WHERE** clauses that do not use keys or do not change most of the examined rows.
- Fewer row locks are required on the slave for any **INSERT**, **UPDATE**, or **DELETE** statement.

Disadvantages of row-based replication

- RBR tends to generate more data that must be logged. To replicate a DML statement (such as an **UPDATE** or **DELETE** statement), statement-based replication writes only the statement to the binary log. By contrast, row-based replication writes each changed row to the binary log. If the statement changes many rows, row-based replication may write significantly more data to the binary log; this is true even for statements that are rolled back. This also means that taking and restoring from backup can require more time. In addition, the binary log is locked for a longer time to write the data, which may cause concurrency problems.
- Deterministic UDFs that generate large **BLOB** values take longer to replicate with row-based replication than with statement-based replication. This is because the **BLOB** column value is logged, rather than the statement generating the data.
- You cannot examine the logs to see what statements were executed, nor can you see on the slave what statements were received from the master and executed.
  
  However, you can see what data was changed using `mysqlbinlog` with the options `--base64-output=DECODE-ROWS` and `--verbose`.
- For tables using the **MyISAM** storage engine, a stronger lock is required on the slave for **INSERT** statements when applying them as row-based events to the binary log than when applying them as statements. This means that concurrent inserts on **MyISAM** tables are not supported when using row-based replication.

17.1.2.2 Usage of Row-Based Logging and Replication

Major changes in the replication environment and in the behavior of applications can result from using row-based logging (RBL) or row-based replication (RBR) rather than statement-based logging or replication. This section describes a number of issues known to exist when using row-based logging or replication, and discusses some best practices for taking advantage of row-based logging and replication.

For additional information, see `Section 17.1.2, “Replication Formats”`, and `Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”`.

For information about issues specific to NDB Cluster Replication (which depends on row-based replication), see `Section 18.6.3, “Known Issues in NDB Cluster Replication”`.

- **RBL, RBR, and temporary tables.** As noted in `Section 17.4.1.30, “Replication and Temporary Tables”`, temporary tables are not replicated when using row-based format. When mixed format is in effect, “safe” statements involving temporary tables are logged using statement-based format. For more information, see `Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”`.

  Temporary tables are not replicated when using row-based format because there is no need. In addition, because temporary tables can be read only from the thread which created them, there is seldom if ever any benefit obtained from replicating them, even when using statement-based format.

  Beginning with MySQL 5.5.5, you can switch from statement-based to row-based binary logging mode even when temporary tables have been created. However, while using the row-based format, the MySQL server cannot determine the logging mode that was in effect when a given temporary table
was created. For this reason, the server in such cases logs a `DROP TEMPORARY TABLE IF EXISTS` statement for each temporary table that still exists for a given client session when that session ends. (Bug #11760229, Bug #11762267) While this means that it is possible that an unnecessary `DROP TEMPORARY TABLE` statement might be logged in some cases, the statement is harmless, and does not cause an error even if the table does not exist, due to the presence of the `IF EXISTS` option.

- **RBL and synchronization of nontransactional tables.** When many rows are affected, the set of changes is split into several events; when the statement commits, all of these events are written to the binary log. When executing on the slave, a table lock is taken on all tables involved, and then the rows are applied in batch mode. (This may or may not be effective, depending on the engine used for the slave’s copy of the table.)

- **Latency and binary log size.** Because RBL writes changes for each row to the binary log, its size can increase quite rapidly. In a replication environment, this can significantly increase the time required to make changes on the slave that match those on the master. You should be aware of the potential for this delay in your applications.

- **Reading the binary log.** `mysqlbinlog` displays row-based events in the binary log using the `BINLOG` statement (see Section 13.7.6.1, “BINLOG Statement”). This statement displays an event in printable form, but as a base 64-encoded string the meaning of which is not evident. When invoked with the `--base64-output=DECODE-ROWS` and `--verbose` options, `mysqlbinlog` formats the contents of the binary log in a manner that is easily human readable. This is helpful when binary log events were written in row-based format if you want to read or recover from a replication or database failure using the contents of the binary log. For more information, see Section 4.6.7.2, “mysqlbinlog Row Event Display”.

- **Binary log execution errors and slave_exec_mode.** If `slave_exec_mode` is `IDEMPOTENT`, a failure to apply changes from RBL because the original row cannot be found does not trigger an error or cause replication to fail. This means that it is possible that updates are not applied on the slave, so that the master and slave are no longer synchronized. Latency issues and use of nontransactional tables with RBR when `slave_exec_mode` is `IDEMPOTENT` can cause the master and slave to diverge even further. For more information about `slave_exec_mode`, see Section 5.1.7, “Server System Variables”.

- **Lack of binary log checksums.** RBL uses no checksums. This means that network, disk, and other errors may not be identified when processing the binary log. To ensure that data is transmitted without network corruption, you may want to consider using SSL, which adds another layer of checksumming, for replication connections. The `CHANGE MASTER TO` statement has options to enable replication over SSL. See also Section 13.4.2.1, “CHANGE MASTER TO Statement”, for general information about setting up MySQL with SSL.

This is not an issue in MySQL 5.6 and later, which support checksums for the binary log; see Checksum options.

- **Filtering based on server ID not supported.** A common practice is to filter out changes on some slaves by using a `WHERE` clause that includes the relation `@@server_id <> id_value` clause with `UPDATE` and `DELETE` statements, a simple example of such a clause being `WHERE @@server_id <> 1`. However, this does not work correctly with row-based logging. If you must use the `server_id` system variable for statement filtering, you must also use `--binlog_format=STATEMENT`. 

<table>
<thead>
<tr>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>slave_exec_mode=IDEMPOTENT</code> is generally useful only for circular replication or multi-master replication with NDB Cluster, for which <code>IDEMPOTENT</code> is the default value (see Section 18.6, “NDB Cluster Replication”). For other scenarios, setting <code>slave_exec_mode</code> to <code>STRICT</code> is normally sufficient; this is the default value for storage engines other than NDB.</td>
</tr>
</tbody>
</table>
In MySQL 5.5, you can do filtering based on server ID by using the `IGNORE_SERVER_IDS` option for the `CHANGE MASTER TO` statement. This option works with the statement-based and row-based logging formats.

**Database-level replication options.** The effects of the `--replicate-do-db`, `--replicate-ignore-db`, and `--replicate-rewrite-db` options differ considerably depending on whether row-based or statement-based logging is used. Because of this, it is recommended to avoid database-level options and instead use table-level options such as `--replicate-do-table` and `--replicate-ignore-table`. For more information about these options and the impact that your choice of replication format has on how they operate, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

**RBL, nontransactional tables, and stopped slaves.** When using row-based logging, if the slave server is stopped while a slave thread is updating a nontransactional table, the slave database may reach an inconsistent state. For this reason, it is recommended that you use a transactional storage engine such as InnoDB for all tables replicated using the row-based format.

Use of `STOP_SLAVE` (or `STOP_SLAVE SQL_THREAD` in MySQL 5.5.9 and later) prior to shutting down the slave MySQL server helps prevent such issues from occurring, and is always recommended regardless of the logging format or storage engines employed.

### 17.1.2.3 Determination of Safe and Unsafe Statements in Binary Logging

When speaking of the “safeness” of a statement in MySQL Replication, we are referring to whether a statement and its effects can be replicated correctly using statement-based format. If this is true of the statement, we refer to the statement as safe; otherwise, we refer to it as unsafe.

In general, a statement is safe if it deterministic, and unsafe if it is not. However, certain nondeterministic functions are not considered unsafe (see Nondeterministic functions not considered unsafe, later in this section). In addition, statements using results from floating-point math functions—which are hardware-dependent—are always considered unsafe (see Section 17.4.1.12, “Replication and Floating-Point Values”).

**Handling of safe and unsafe statements.** A statement is treated differently depending on whether the statement is considered safe, and with respect to the binary logging format (that is, the current value of `binlog_format`).

- No distinction is made in the treatment of safe and unsafe statements when the binary logging mode is `ROW`.
- If the binary logging format is `MIXED`, statements flagged as unsafe are logged using the row-based format; statements regarded as safe are logged using the statement-based format.
- If the binary logging format is `STATEMENT`, statements flagged as being unsafe generate a warning to this effect. (Safe statements are logged normally.)

Each statement flagged as unsafe generates a warning. Formerly, in cases where a great many such statements were executed on the master, this could lead to very large error log files, sometimes even filling up an entire disk unexpectedly. To guard against this, MySQL 5.5.27 introduced a warning suppression mechanism, which behaves as follows: Whenever the 50 most recent `ER_BINLOG_UNSAFE_STATEMENT` warnings have been generated more than 50 times in any 50-second period, warning suppression is enabled. When activated, this causes such warnings not to be written to the error log; instead, for each 50 warnings of this type, a note “The last warning was repeated N times in last S seconds” is written to the error log. This continues as long as the 50 most recent such warnings were issued in 50 seconds or less; once the rate has decreased below this threshold, the warnings are once again logged normally. Warning suppression has no effect on how the safety of statements for statement-based logging
is determined, nor on how warnings are sent to the client (MySQL clients still receive one warning for each such statement).

For more information, see Section 17.1.2, “Replication Formats”.

**Statements considered unsafe.**
Statements having the following characteristics are considered unsafe:

- **Statements containing system functions that may return a different value on slave.** These functions include `FOUND_ROWS()`, `GET_LOCK()`, `IS_FREE_LOCK()`, `IS_USED_LOCK()`, `LOAD_FILE()`, `MASTER_POS_WAIT()`, `RAND()`, `RELEASE_LOCK()`, `ROW_COUNT()`, `SESSION_USER()`, `SLEEP()`, `SYSDATE()`, `SYSTEM_USER()`, `USER()`, `UUID()`, and `UUID_SHORT()`.

  **Nondeterministic functions not considered unsafe.** Although these functions are not deterministic, they are treated as safe for purposes of logging and replication: `CONNECTION_ID()`, `CURDATE()`, `CURRENT_DATE()`, `CURRENT_TIME()`, `CURRENT_TIMESTAMP()`, `CURTIME()`, `LOCALTIME()`, `LOCALTIMESTAMP()`, `NOW()`, `UNIX_TIMESTAMP()`, `UTC_DATE()`, `UTC_TIME()`, `UTC_TIMESTAMP()`, and `LAST_INSERT_ID()`.

  For more information, see Section 17.4.1.14, “Replication and System Functions”.

- **References to system variables.** Most system variables are not replicated correctly using the statement-based format. For exceptions, see Section 5.4.4.3, “Mixed Binary Logging Format”.

  See Section 17.4.1.37, “Replication and Variables”.

- **UDFs.** Since we have no control over what a UDF does, we must assume that it is executing unsafe statements.

- **Updates a table having an AUTO_INCREMENT column.** Prior to MySQL 5.5.3, all such statements were always considered unsafe because the order in which the rows are updated could differ on the master and the slave. In MySQL 5.3.3 and later, these statements are unsafe only when they are executed by a trigger or stored program (Bug #50192, Bug #11758052).

  An `INSERT` into a table that has a composite primary key containing an `AUTO_INCREMENT` column that is not the first column of this composite key is unsafe.

  For more information, see Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- **INSERT DELAYED statement.** This statement is considered unsafe because the insertion of the rows may interleave with concurrently executing statements.

- **INSERT ... ON DUPLICATE KEY UPDATE statements on tables with multiple primary or unique keys.** When executed against a table that contains more than one primary or unique key, this statement is considered unsafe, being sensitive to the order in which the storage engine checks the keys, which is not deterministic, and on which the choice of rows updated by the MySQL Server depends.

  An `INSERT ... ON DUPLICATE KEY UPDATE` statement against a table having more than one unique or primary key is marked as unsafe for statement-based replication beginning with MySQL 5.5.24. (Bug #11765650, Bug #58637)

- **Updates using LIMIT.** The order in which rows are retrieved is not specified.

  See Section 17.4.1.16, “Replication and LIMIT”.

- **Accesses or references log tables.** The contents of the system log table may differ between master and slave.
• **Nontransactional operations after transactional operations.** Within a transaction, allowing any nontransactional reads or writes to execute after any transactional reads or writes is considered unsafe.

  For more information, see Section 17.4.1.34, “Replication and Transactions”.

• **Accesses or references self-logging tables.** All reads and writes to self-logging tables are considered unsafe. Within a transaction, any statement following a read or write to self-logging tables is also considered unsafe.

• **LOAD DATA statements.** Beginning with MySQL 5.5.6, `LOAD DATA` is treated as unsafe and when `binlog_format=mixed` the statement is logged in row-based format. When `binlog_format=statement` `LOAD DATA` does not generate a warning, unlike other unsafe statements.

  For additional information, see Section 17.4.1, “Replication Features and Issues”.

### 17.1.3 Replication and Binary Logging Options and Variables

The next few sections contain information about `mysqld` options and server variables that are used in replication and for controlling the binary log. Options and variables for use on replication masters and replication slaves are covered separately, as are options and variables relating to binary logging. A set of quick-reference tables providing basic information about these options and variables is also included (in the next section following this one).

Of particular importance is the `server_id` system variable.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--server-id=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>server_id</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This variable specifies the server ID.

On a replication master and each replication slave, you must specify `server_id` to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique”, means that each ID must be different from every other ID in use by any other replication master or slave. For additional information, see Section 17.1.3.2, “Replication Master Options and Variables”, and Section 17.1.3.3, “Replication Slave Options and Variables”.

If you do not specify `server_id`, the default server ID is 0. If the server ID is set to 0, binary logging takes place, but a master with a server ID of 0 refuses any connections from slaves, and a slave with a server ID of 0 refuses to connect to a master. Note that although you can change the server ID dynamically to a nonzero value, doing so does not enable replication to start immediately. You must change the server ID and then restart the server to initialize the replication slave.

In MySQL 5.5, whether the server ID is set to 0 explicitly or the default is allowed to be used, the server sets the `server_id` system variable to 1; this is a known issue that is fixed in MySQL 5.7.
Replication and Binary Logging Options and Variables

For more information, see Section 17.1.2, “Setting the Replication Slave Configuration”.

17.1.3.1 Replication and Binary Logging Option and Variable Reference

The following lists provide basic information about the MySQL command-line options and system variables applicable to replication and the binary log.

- **abort-slave-event-count**: Option used by mysql-test for debugging and testing of replication.
- **auto_increment_increment**: AUTO_INCREMENT columns are incremented by this value.
- **auto_increment_offset**: Offset added to AUTO_INCREMENT columns.
- **Com_change_master**: Count of CHANGE MASTER TO statements.
- **Com_show_master_status**: Count of SHOW MASTER STATUS statements.
- **Com_show_new_master**: Count of SHOW NEW MASTER statements.
- **Com_show_slave_hosts**: Count of SHOW SLAVE HOSTS statements.
- **Com_show_slave_status**: Count of SHOW SLAVE STATUS statements.
- **Com_slave_start**: Count of START SLAVE statements.
- **Com_slave_stop**: Count of STOP SLAVE statements.
- **disconnect-slave-event-count**: Option used by mysql-test for debugging and testing of replication.
- **expire_logs_days**: Purge binary logs after this many days.
- **init_slave**: Statements that are executed when a slave connects to a master.
- **log_bin_trust_function_creators**: If equal to 0 (the default), then when --log-bin is used, creation of a stored function is allowed only to users having the SUPER privilege and only if the function created does not break binary logging.
- **master-info-file**: The location and name of the file that remembers the master and where the I/O replication thread is in the master's binary logs.
- **master-retry-count**: Number of tries the slave makes to connect to the master before giving up.
- **max_relay_log_size**: If nonzero, relay log is rotated automatically when its size exceeds this value. If zero, size at which rotation occurs is determined by the value of max_binlog_size.
- **relay_log**: The location and base name to use for relay logs.
- **relay_log_index**: The location and name to use for the file that keeps a list of the last relay logs.
- **relay_log_info_file**: File in which the slave records information about the relay logs.
- **relay_log_purge**: Determines whether relay logs are purged.
- **relay_log_recovery**: Whether automatic recovery of relay log files from master at startup is enabled; must be enabled for a crash-safe slave.
- **relay_log_space_limit**: Maximum space to use for all relay logs.
• **replicate-do-db**: Tells the slave SQL thread to restrict replication to the specified database.
• **replicate-do-table**: Tells the slave SQL thread to restrict replication to the specified table.
• **replicate-ignore-db**: Tells the slave SQL thread not to replicate to the specified database.
• **replicate-ignore-table**: Tells the slave SQL thread not to replicate to the specified table.
• **replicate-rewrite-db**: Updates to a database with a different name than the original.
• **replicate-same-server-id**: In replication, if enabled, do not skip events having our server id.
• **replicate-wild-do-table**: Tells the slave thread to restrict replication to the tables that match the specified wildcard pattern.
• **replicate-wild-ignore-table**: Tells the slave thread not to replicate to the tables that match the given wildcard pattern.

• **report_host**: Host name or IP of the slave to be reported to the master during slave registration.
• **report_password**: An arbitrary password that the slave server should report to the master. Not the same as the password for the MySQL replication user account.
• **report_port**: Port for connecting to slave reported to the master during slave registration.
• **report_user**: An arbitrary user name that a slave server should report to the master. Not the same as the name used with the MySQL replication user account.
• **rpl_recovery_rank**: Not used; removed in later versions.
• **Rpl_semi_sync_master_clients**: Number of semisynchronous slaves.
• **rpl_semi_sync_master_enabled**: Whether semisynchronous replication is enabled on the master.
• **Rpl_semi_sync_master_net_avg_wait_time**: The average time the master waited for a slave reply.
• **Rpl_semi_sync_master_net_wait_time**: The total time the master waited for slave replies.
• **Rpl_semi_sync_master_net_waits**: The total number of times the master waited for slave replies.
• **Rpl_semi_sync_master_no_times**: Number of times the master turned off semisynchronous replication.
• **Rpl_semi_sync_master_no_tx**: Number of commits not acknowledged successfully.
• **Rpl_semi_sync_master_status**: Whether semisynchronous replication is operational on the master.
• **Rpl_semi_sync_master_timefunc_failures**: Number of times the master failed when calling time functions.
• **rpl_semi_sync_master_timeout**: Number of milliseconds to wait for slave acknowledgment.
• **rpl_semi_sync_master_trace_level**: The semisynchronous replication debug trace level on the master.
• **Rpl_semi_sync_master_tx_avg_wait_time**: The average time the master waited for each transaction.
• **Rpl_semi_sync_master_tx_wait_time**: The total time the master waited for transactions.
• **Rpl_semi_sync_master_tx_waits**: The total number of times the master waited for transactions.
• **rpl_semi_sync_master_wait_no_slave**: Whether master waits for timeout even with no slaves.
• **Rpl_semi_sync_master_wait_pos_backtraverse**: The total number of times the master waited for an event with binary coordinates lower than events waited for previously.
• **Rpl_semi_sync_master_wait_sessions**: Number of sessions currently waiting for slave replies.
• **Rpl_semi_sync_master_yes_tx**: Number of commits acknowledged successfully.
• **rpl_semi_sync_slave_enabled**: Whether semisynchronous replication is enabled on slave.
• **Rpl_semi_sync_slave_status**: Whether semisynchronous replication is operational on slave.
• **rpl_semi_sync_slave_trace_level**: The semisynchronous replication debug trace level on the slave.
• **Rpl_status**: The status of fail-safe replication (not implemented).
• **show-slave-auth-info**: Show user name and password in SHOW SLAVE HOSTS on this master.
• **skip-slave-start**: If set, slave is not autostarted.
• **slave_load_tmpdir**: The location where the slave should put its temporary files when replicating LOAD DATA statements.
• **slave_net_timeout**: Number of seconds to wait for more data from a master/slave connection before aborting the read.
• **slave_skip_errors**: Tells the slave thread to continue replication when a query returns an error from the provided list.
• **slave_compressed_protocol**: Use compression of master/slave protocol.
• **slave_exec_mode**: Allows for switching the slave thread between IDEMPOTENT mode (key and some other errors suppressed) and STRICT mode; STRICT mode is the default, except for NDB Cluster, where IDEMPOTENT is always used.
• **Slave_heartbeat_period**: The slave's replication heartbeat interval, in seconds.
• **slave_max_allowed_packet**: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.
• **Slave_open_temp_tables**: Number of temporary tables that the slave SQL thread currently has open.
• **Slave_received_heartbeats**: Number of heartbeats received by a replication slave since previous reset.
• **Slave_retried_transactions**: The total number of times since startup that the replication slave SQL thread has retried transactions.
• **Slave_running**: The state of this server as a replication slave (slave I/O thread status).
• **slave_transaction_retries**: Number of times the slave SQL thread will retry a transaction in case it failed with a deadlock or elapsed lock wait timeout, before giving up and stopping.
Replication and Binary Logging Options and Variables

- **slave_type_conversions**: Controls type conversion mode on replication slave. Value is a list of zero or more elements from the list: ALL_LOSSY, ALL_NON_LOSSY. Set to an empty string to disallow type conversions between master and slave.

- **sql_log_bin**: Controls binary logging for the current session.

- **sql_slave_skip_counter**: Number of events from the master that a slave server should skip. Not compatible with GTID replication.

- **sync_master_info**: Synchronize master.info to disk after every #th event.

- **sync_relay_log**: Synchronize relay log to disk after every #th event.

- **sync_relay_log_info**: Synchronize relay.info file to disk after every #th event.

Section 17.1.3.2, “Replication Master Options and Variables”, provides more detailed information about options and variables relating to replication master servers. For more information about options and variables relating to replication slaves, see Section 17.1.3.3, “Replication Slave Options and Variables”.

- **binlog-do-db**: Limits binary logging to specific databases.

- **binlog_format**: Specifies the format of the binary log.

- **binlog-ignore-db**: Tells the master that updates to the given database should not be logged to the binary log.

- **binlog-row-event-max-size**: Binary log max event size.

- **Binlog_cache_disk_use**: Number of transactions that used a temporary file instead of the binary log cache.

- **binlog_cache_size**: Size of the cache to hold the SQL statements for the binary log during a transaction.

- **Binlog_cache_use**: Number of transactions that used the temporary binary log cache.

- **binlog_direct_non_transactional_updates**: Causes updates using statement format to nontransactional engines to be written directly to binary log. See documentation before using.

- **Binlog_stmt_cache_disk_use**: Number of nontransactional statements that used a temporary file instead of the binary log statement cache.

- **binlog_stmt_cache_size**: Size of the cache to hold nontransactional statements for the binary log during a transaction.

- **Binlog_stmt_cache_use**: Number of statements that used the temporary binary log statement cache.

- **Com_show_binlog_events**: Count of SHOW BINLOG EVENTS statements.

- **Com_show_binlogs**: Count of SHOW BINLOGS statements.

- **log-bin**: Specifies the base name for binary log files.

- **log-bin-index**: Specifies the name for the binary log index file.

- **log_bin**: Whether the binary log is enabled.

- **log_bin_use_v1_row_events**: Whether server is using version 1 binary log row events.
Replication and Binary Logging Options and Variables

- **log_slave_updates**: Whether the slave should log the updates performed by its SQL thread to its own binary log.

- **max-binlog-dump-events**: Option used by mysql-test for debugging and testing of replication.

- **max_binlog_cache_size**: Can be used to restrict the total size used to cache a multi-statement transaction.

- **max_binlog_size**: Binary log will be rotated automatically when size exceeds this value.

- **max_binlog_stmt_cache_size**: Can be used to restrict the total size used to cache all nontransactional statements during a transaction.

- **sporadic-binlog-dump-fail**: Option used by mysql-test for debugging and testing of replication.

- **sync_binlog**: Synchronously flush binary log to disk after every #th event.

Section 17.1.3.4, “Binary Log Options and Variables”, provides more detailed information about options and variables relating to binary logging. For additional general information about the binary log, see Section 5.4.4, “The Binary Log”.

For information about the sql_log_bin and sql_log_off variables, see Section 5.1.7, “Server System Variables”.

For a listing with all command-line options, system and status variables used with mysql, see Section 5.1.3, “Server Option, System Variable, and Status Variable Reference”.

### 17.1.3.2 Replication Master Options and Variables

This section describes the server options and system variables that you can use on replication master servers. You can specify the options either on the command line or in an option file. You can specify system variable values using `SET`.

On the master and each slave, you must set the server_id system variable to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} - 1$, and each ID must be different from every other ID in use by any other replication master or slave. Example: server_id=3.

For options used on the master for controlling binary logging, see Section 17.1.3.4, “Binary Log Options and Variables”.

#### Startup Options for Replication Masters

The following list describes startup options for controlling replication master servers. Replication-related system variables are discussed later in this section.

- **--show-slave-auth-info**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--show-slave-auth-info=[(OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Display slave user names and passwords in the output of `SHOW SLAVE HOSTS` on the master server for slaves started with the `--report-user` and `--report-password` options.
System Variables Used on Replication Masters

The following system variables are used in controlling replication masters:

- **auto_increment_increment**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--auto-increment-increment=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>auto_increment_increment</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

`auto_increment_increment` and `auto_increment_offset` are intended for use with master-to-master replication, and can be used to control the operation of AUTO_INCREMENT columns. Both variables have global and session values, and each can assume an integer value between 1 and 65,535 inclusive. Setting the value of either of these two variables to 0 causes its value to be set to 1 instead. Attempting to set the value of either of these two variables to an integer greater than 65,535 or less than 0 causes its value to be set to 65,535 instead. Attempting to set the value of `auto_increment_increment` or `auto_increment_offset` to a noninteger value gives rise to an error, and the actual value of the variable remains unchanged.

**Note**

`auto_increment_increment` is also supported for use with NDB tables.

These two variables affect AUTO_INCREMENT column behavior as follows:

- **auto_increment_increment** controls the interval between successive column values. For example:

```sql
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+---------------------------------+-------+
| Variable_name                   | Value |
+---------------------------------+-------+
| auto_increment_increment        | 1     |
| auto_increment_offset           | 1     |
+---------------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc1
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.04 sec)

mysql> SET @@auto_increment_increment=10;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+---------------------------------+-------+
| Variable_name                   | Value |
+---------------------------------+-------+
| auto_increment_increment        | 10    |
| auto_increment_offset           | 1     |
+---------------------------------+-------+
2 rows in set (0.00 sec)
```
Replication and Binary Logging Options and Variables

```sql
mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+--------------------------+-------+
<table>
<thead>
<tr>
<th>col</th>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>auto_increment_increment</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>auto_increment_offset</td>
<td>5</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
+-----+--------------------------+-------+
4 rows in set (0.00 sec)

mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>auto_increment_increment</td>
<td>10</td>
</tr>
<tr>
<td>auto_increment_offset</td>
<td>5</td>
</tr>
</tbody>
</table>
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+--------------------------+-------+
<table>
<thead>
<tr>
<th>col</th>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>auto_increment_increment</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>auto_increment_offset</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
+-----+--------------------------+-------+
4 rows in set (0.02 sec)
```

- `auto_increment_offset` determines the starting point for the `AUTO_INCREMENT` column value. Consider the following, assuming that these statements are executed during the same session as the example given in the description for `auto_increment_increment`:

```sql
mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>auto_increment_increment</td>
<td>10</td>
</tr>
<tr>
<td>auto_increment_offset</td>
<td>5</td>
</tr>
</tbody>
</table>
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+--------------------------+-------+
<table>
<thead>
<tr>
<th>col</th>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>auto_increment_increment</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>auto_increment_offset</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
+-----+--------------------------+-------+
4 rows in set (0.02 sec)
```

If the value of `auto_increment_offset` is greater than that of `auto_increment_increment`, the value of `auto_increment_offset` is ignored.

Should one or both of these variables be changed and then new rows inserted into a table containing an `AUTO_INCREMENT` column, the results may seem counterintuitive because the series of `AUTO_INCREMENT` values is calculated without regard to any values already present in the column, and
the next value inserted is the least value in the series that is greater than the maximum existing value in the `AUTO_INCREMENT` column. In other words, the series is calculated like so:

\[ \text{auto_increment_offset} + N \times \text{auto_increment_increment} \]

where \( N \) is a positive integer value in the series \([1, 2, 3, ...]\). For example:

```sql
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)
```

```sql
mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
| 1   |
| 11  |
| 21  |
| 31  |
+-----+
4 rows in set (0.00 sec)
```

```sql
mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0
```

```sql
mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
| 1   |
| 11  |
| 21  |
| 31  |
| 35  |
| 45  |
| 55  |
| 65  |
+-----+
8 rows in set (0.00 sec)
```

The values shown for `auto_increment_increment` and `auto_increment_offset` generate the series \( 5 + N \times 10 \), that is, \([5, 15, 25, 35, 45, ...]\). The greatest value present in the `col` column prior to the `INSERT` is 31, and the next available value in the `AUTO_INCREMENT` series is 35, so the inserted values for `col` begin at that point and the results are as shown for the `SELECT` query.

It is not possible to confine the effects of these two variables to a single table, and thus they do not take the place of the sequences offered by some other database management systems; these variables control the behavior of all `AUTO_INCREMENT` columns in all tables on the MySQL server. If the global value of either variable is set, its effects persist until the global value is changed or overridden by setting the session value, or until `mysqld` is restarted. If the local value is set, the new value affects `AUTO_INCREMENT` columns for all tables into which new rows are inserted by the current user for the duration of the session, unless the values are changed during that session.

The default value of `auto_increment_increment` is 1. See Section 17.4.1.1, “Replication and `AUTO_INCREMENT`”.
Replication and Binary Logging Options and Variables

- **auto_increment_offset**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--auto-increment-offset=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>auto_increment_offset</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

This variable has a default value of 1. For particulars, see the description for `auto_increment_increment`.

**Note**

`auto_increment_offset` is also supported for use with NDB tables.

17.1.3.3 Replication Slave Options and Variables

- **Startup Options for Replication Slaves**

- **System Variables Used on Replication Slaves**

This section describes the server options and system variables that apply to slave replication servers. You can specify the options either on the command line or in an option file. Many of the options can be set while the server is running by using the `CHANGE MASTER TO` statement. You can specify system variable values using `SET`.

**Server ID.** On the master and each slave, you must set the `server_id` system variable to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique” means that each ID must be different from every other ID in use by any other replication master or slave. Example `my.cnf` file:

```
[mysqld]
server-id=3
```

**Startup Options for Replication Slaves**

The following list describes startup options for controlling replication slave servers. Many of these options can be set while the server is running by using the `CHANGE MASTER TO` statement. Others, such as the `--replicate-*` options, can be set only when the slave server starts. Replication-related system variables are discussed later in this section.

- **--abort-slave-event-count**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--abort-slave-event-count=#</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>
When this option is set to some positive integer value other than 0 (the default) it affects replication behavior as follows: After the slave SQL thread has started, value log events are permitted to be executed; after that, the slave SQL thread does not receive any more events, just as if the network connection from the master were cut. The slave thread continues to run, and the output from SHOW SLAVE STATUS displays Yes in both the Slave_IO_Running and the Slave_SQL_Running columns, but no further events are read from the relay log.

This option is used internally by the MySQL test suite for replication testing and debugging. It is not intended for use in a production setting.

- **--disconnect-slave-event-count**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--disconnect-slave-event-count=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

This option is used internally by the MySQL test suite for replication testing and debugging.

- **--log-slow-slave-statements**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--log-slow-slave-statements[={OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When the slow query log is enabled, this option enables logging for queries that have taken more than long_query_time seconds to execute on the slave.

Note that all statements logged in row format in the master will not be logged in the slave's slow log, even if this option is enabled.

- **--log-warnings[=level]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log-warnings[=#]</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log_warnings</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>platforms)</td>
<td></td>
</tr>
</tbody>
</table>
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This option causes a server to print more messages to the error log about what it is doing. With respect to replication, the server generates warnings that it succeeded in reconnecting after a network/ connection failure, and informs you as to how each slave thread started. This option is enabled (1) by default; to disable it, use --log-warnings=0. If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.4.2.11, “Communication Errors and Aborted Connections”.

Note
The effects of this option are not limited to replication. It affects diagnostic messages across a spectrum of server activities.

- `--master-info-file=file_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--master-info-file=file_name</code></td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>master.info</code></td>
</tr>
</tbody>
</table>

The name to use for the file in which the slave records information about the master. The default name is `master.info` in the data directory. For information about the format of this file, see Section 17.2.2.2, “Slave Status Logs”.

- `--master-retry-count=count`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--master-retry-count=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>86400</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

The number of times that the slave tries to connect to the master before giving up. Reconnects are attempted at intervals set by the `MASTER_CONNECT_RETRY` option of the `CHANGE MASTER TO` statement (default 60). Reconnection attempts are triggered when the slave reaches its connection timeout (specified by the `slave_net_timeout` system variable) without receiving data from the master. The default value is 86400. A value of 0 means “infinite”; the slave attempts to connect forever.

- `--max-relay-log-size=size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-relay-log-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max Relay Log Size</code></td>
</tr>
</tbody>
</table>
The size at which the server rotates relay log files automatically. If this value is nonzero, the relay log is rotated automatically when its size exceeds this value. If this value is zero (the default), the size at which relay log rotation occurs is determined by the value of \texttt{max_binlog_size}. For more information, see Section 17.2.2.1, "The Slave Relay Log".

- \texttt{--relay-log-purge}={0|1}

Disable or enable automatic purging of relay logs as soon as they are no longer needed. The default value is 1 (enabled). This is a global variable that can be changed dynamically with \texttt{SET GLOBAL relay_log_purge = N}.

- \texttt{--relay-log-space-limit=size}

This option places an upper limit on the total size in bytes of all relay logs on the slave. A value of 0 means “no limit.” This is useful for a slave server host that has limited disk space. When the limit is reached, the I/O thread stops reading binary log events from the master server until the SQL thread has caught up and deleted some unused relay logs. Note that this limit is not absolute: There are cases...
Replication and Binary Logging Options and Variables

where the SQL thread needs more events before it can delete relay logs. In that case, the I/O thread exceeds the limit until it becomes possible for the SQL thread to delete some relay logs because not doing so would cause a deadlock. You should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0). In that case, there is a chance that the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, but the SQL thread has no relay log to purge and is unable to satisfy the I/O thread. This forces the I/O thread to ignore `--relay-log-space-limit` temporarily.

- `--replicate-do-db=db_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--replicate-do-db=name</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The effects of this option depend on whether statement-based or row-based replication is in use.

**Statement-based replication.** Tell the slave SQL thread to restrict replication to statements where the default database (that is, the one selected by `USE`) is `db_name`. To specify more than one database, use this option multiple times, once for each database; however, doing so does not replicate cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` while a different database (or no database) is selected.

**Warning**

To specify multiple databases you **must** use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

An example of what does not work as you might expect when using statement-based replication: If the slave is started with `--replicate-do-db=sales` and you issue the following statements on the master, the `UPDATE` statement is **not** replicated:

```sql
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “check just the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

**Row-based replication.** Tells the slave SQL thread to restrict replication to database `db_name`. Only tables belonging to `db_name` are changed; the current database has no effect on this. Suppose that the slave is started with `--replicate-do-db=sales` and row-based replication is in effect, and then the following statements are run on the master:

```sql
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The `february` table in the `sales` database on the slave is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, issuing the following statements on the master has no effect on the slave when using row-based replication and `--replicate-do-db=sales`:

```sql
USE prices;
```
UPDATE prices.march SET amount=amount-25;

Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement’s effects would still not be replicated.

Another important difference in how `--replicate-do-db` is handled in statement-based replication as opposed to row-based replication occurs with regard to statements that refer to multiple databases. Suppose that the slave is started with `--replicate-do-db=db1`, and the following statements are executed on the master:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based replication, then both tables are updated on the slave. However, when using row-based replication, only `table1` is affected on the slave; since `table2` is in a different database, `table2` on the slave is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement would have no effect on the slave when using statement-based replication. However, if you are using row-based replication, the `UPDATE` would change `table1` on the slave, but not `table2`—in other words, only tables in the database named by `--replicate-do-db` are changed, and the choice of default database has no effect on this behavior.

If you need cross-database updates to work, use `--replicate-wild-do-table=db_name.%` instead. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

**Note**

This option affects replication in the same manner that `--binlog-do-db` affects binary logging, and the effects of the replication format on how `--replicate-do-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-do-db`.

This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

- `--replicate-ignore-db=db_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--replicate-ignore-db=name</code></td>
</tr>
</tbody>
</table>
As with `--replicate-do-db`, the effects of this option depend on whether statement-based or row-based replication is in use.

**Statement-based replication.**  Tells the slave SQL thread not to replicate any statement where the default database (that is, the one selected by `USE`) is `db_name`.

**Row-based replication.**  Tells the slave SQL thread not to update any tables in the database `db_name`. The default database has no effect.

When using statement-based replication, the following example does not work as you might expect. Suppose that the slave is started with `--replicate-ignore-db=sales` and you issue the following statements on the master:

```sql
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement is replicated in such a case because `--replicate-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based replication, the `UPDATE` statement's effects are not propagated to the slave, and the slave's copy of the `sales.january` table is unchanged; in this instance, `--replicate-ignore-db=sales` causes all changes made to tables in the master's copy of the `sales` database to be ignored by the slave.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

You should not use this option if you are using cross-database updates and you do not want these updates to be replicated. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

If you need cross-database updates to work, use `--replicate-wild-ignore-table=db_name.%` instead. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

**Note**

This option affects replication in the same manner that `--binlog-ignore-db` affects binary logging, and the effects of the replication format on how `--replicate-ignore-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-ignore-db`.

This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

```sql
--replicate-do-table=db_name.tbl_name
```

Tells the slave SQL thread to restrict replication to the specified table. To specify more than one table, use this option multiple times, once for each table. This works for both cross-database updates and
default database updates, in contrast to \texttt{--replicate-do-db}. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the \texttt{--replicate-*-db} options.

- \texttt{--replicate-ignore-table=\texttt{db}_name.\\texttt{tbl}_name}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--replicate-ignore-table=\texttt{db}_name.\texttt{tbl}_name}</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

Tells the slave SQL thread not to replicate any statement that updates the specified table, even if any other tables might be updated by the same statement. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates, in contrast to \texttt{--replicate-ignore-db}. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the \texttt{--replicate-*-db} options.

- \texttt{--replicate-rewrite-db=\texttt{from}_name->\texttt{to}_name}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--replicate-rewrite-db=\texttt{old}_name-&gt;\texttt{new}_name}</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

Tells the slave to translate the default database (that is, the one selected by \texttt{USE}) to \texttt{to}_name if it was \texttt{from}_name on the master. Only statements involving tables are affected (not statements such as \texttt{CREATE DATABASE}, \texttt{DROP DATABASE}, and \texttt{ALTER DATABASE}), and only if \texttt{from}_name is the default database on the master. To specify multiple rewrites, use this option multiple times. The server uses the first one with a \texttt{from}_name value that matches. The database name translation is done \texttt{before} the \texttt{--replicate-*} rules are tested.

Statements in which table names are qualified with database names when using this option do not work with table-level replication filtering options such as \texttt{--replicate-do-table}. Suppose we have a database named \texttt{a} on the master, one named \texttt{b} on the slave, each containing a table \texttt{t}, and have started the master with \texttt{--replicate-rewrite-db=\texttt{a->b}}. At a later point in time, we execute \texttt{DELETE FROM a.t}. In this case, no relevant filtering rule works, for the reasons shown here:

1. \texttt{--replicate-do-table=a.t} does not work because the slave has table \texttt{t} in database \texttt{b}.
2. \texttt{--replicate-do-table=b.t} does not match the original statement and so is ignored.
3. \texttt{--replicate-do-table=*.t} is handled identically to \texttt{--replicate-do-table=a.t}, and thus does not work, either.

Similarly, the \texttt{--replication-rewrite-db} option does not work with cross-database updates.

If you use this option on the command line and the > character is special to your command interpreter, quote the option value. For example:

```
shell> mysqld --replicate-rewrite-db="olddb->newdb"
```
Replication and Binary Logging Options and Variables

• **--replicate-same-server-id**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--replicate-same-server-id=[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

To be used on slave servers. Usually you should use the default setting of 0, to prevent infinite loops caused by circular replication. If set to 1, the slave does not skip events having its own server ID. Normally, this is useful only in rare configurations. Cannot be set to 1 if log_slave_updates is enabled. By default, the slave I/O thread does not write binary log events to the relay log if they have the slave's server ID (this optimization helps save disk usage). If you want to use --replicate-same-server-id, be sure to start the slave with this option before you make the slave read its own events that you want the slave SQL thread to execute.

• **--replicate-wild-do-table=db_name.tbl_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--replicate-wild-do-table=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

Tells the slave thread to restrict replication to statements where any of the updated tables match the specified database and table name patterns. Patterns can contain the % and _ wildcard characters, which have the same meaning as for the LIKE pattern-matching operator. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

This option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the --replicate-*-db options.

Example: --replicate-wild-do-table=foo%.bar% replicates only updates that use a table where the database name starts with foo and the table name starts with bar.

If the table name pattern is %, it matches any table name and the option also applies to database-level statements (CREATE DATABASE, DROP DATABASE, and ALTER DATABASE). For example, if you use --replicate-wild-do-table=foo%.%, database-level statements are replicated if the database name matches the pattern foo%.

To include literal wildcard characters in the database or table name patterns, escape them with a backslash. For example, to replicate all tables of a database that is named my_own$db, but not replicate tables from the my1ownAABCdb database, you should escape the _ and % characters like this: --replicate-wild-do-table=my\_own\%db. If you use the option on the command line, you might need to double the backslashes or quote the option value, depending on your command interpreter. For example, with the bash shell, you would need to type --replicate-wild-do-table=my\\_own\\ %db.

• **--replicate-wild-ignore-table=db_name.tbl_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--replicate-wild-ignore-table=name</td>
</tr>
</tbody>
</table>
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

Tells the slave thread not to replicate a statement where any table matches the given wildcard pattern. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

Example: `--replicate-wild-ignore-table=foo%.bar%` does not replicate updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

For information about how matching works, see the description of the `--replicate-wild-do-table` option. The rules for including literal wildcard characters in the option value are the same as for `--replicate-wild-ignore-table` as well.

- `--skip-slave-start`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--skip-slave-start=[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Tells the slave server not to start the slave threads when the server starts. To start the threads later, use a `START SLAVE` statement.

- `--slave_compressed_protocol=(0|1)`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--slave-compressed-protocol=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_compressed_protocol</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If this option is set to 1, use compression for the slave/master protocol if both the slave and the master support it. The default is 0 (no compression).

- `--slave-skip-errors=[err_code1, err_code2, ...|all]`

(MySQL NDB Cluster 7.2.6 and higher) `--slave-skip-errors=[err_code1, err_code2, ...|all|ddl_exist_errors]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--slave-skip-errors=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_skip_errors</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid Values</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>[list of error codes]</td>
</tr>
<tr>
<td></td>
<td>all</td>
</tr>
<tr>
<td></td>
<td>ddl_exist_errors</td>
</tr>
</tbody>
</table>

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This option tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the option value.

Do not use this option unless you fully understand why you are getting errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, an error that stops replication should never occur. Indiscriminate use of this option results in slaves becoming hopelessly out of synchrony with the master, with you having no idea why this has occurred.

For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. Appendix B, Errors, Error Codes, and Common Problems, lists server error codes.

You can also (but should not) use the very nonrecommended value of `all` to cause the slave to ignore all error messages and keeps going regardless of what happens. Needless to say, if you use `all`, there are no guarantees regarding the integrity of your data. Please do not complain (or file bug reports) in this case if the slave’s data is not anywhere close to what it is on the master. You have been warned.

MySQL NDB Cluster 7.2.6 and higher support an additional shorthand value `ddl_exist_errors` for use with the enhanced failover mechanism which is implemented beginning with that version of NDB Cluster. This value is equivalent to the error code list `1007,1008,1050,1051,1054,1060,1061,1068,1094,1146`. This value is not supported by the `mysqld` binary included with the MySQL Server 5.5 distribution. (Bug #11762277, Bug #54854) For more information, see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
--slave-skip-errors=ddl_exist_errors
```

System Variables Used on Replication Slaves

The following list describes system variables for controlling replication slave servers. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used with replication slaves are listed earlier in this section.

- `init_slave`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--init-slave=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>init_slave</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
This variable is similar to `init_connect`, but is a string to be executed by a slave server each time the SQL thread starts. The format of the string is the same as for the `init_connect` variable.

**Note**

The SQL thread sends an acknowledgment to the client before it executes `init_slave`. Therefore, it is not guaranteed that `init_slave` has been executed when `START SLAVE` returns. See Section 13.4.2.5, “START SLAVE Statement”, for more information.

- relay_log

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--relay-log=file_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>relay_log</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The base name for the relay log. The default base name is `host_name-relay-bin`.

The server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. The server creates relay log files in sequence by adding a numeric suffix to the base name.

Due to the manner in which MySQL parses server options, if you specify this variable at server startup, you must supply a value; *the default base name is used only if the option is not actually specified*. If you specify the `relay_log` system variable at server startup without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.2, “Specifying Program Options”.

If you specify this variable, the value specified is also used as the base name for the relay log index file. You can override this behavior by specifying a different relay log index file base name using the `relay_log_index` system variable.

Starting with MySQL 5.5.20, when the server reads an entry from the index file, it checks whether the entry contains a relative path. If it does, the relative part of the path in replaced with the absolute path set using the `relay_log` system variable. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. Prior to MySQL 5.5.20, manual intervention was required whenever relocating the binary log or relay log files. ([Bug #11745230](https://bugs.mysql.com/bug.php?id=11745230), [Bug #12133](https://bugs.mysql.com/bug.php?id=12133))

You may find the `relay_log` system variable useful in performing the following tasks:

- Creating relay logs whose names are independent of host names.

- If you need to put the relay logs in some area other than the data directory because your relay logs tend to be very large and you do not want to decrease `max_relay_log_size`.

- To increase speed by using load-balancing between disks.
Replication and Binary Logging Options and Variables

• **relay_log_index**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--relay-log-index=file_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>relay_log_index</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td><em>host_name</em>-relay-bin.index</td>
</tr>
</tbody>
</table>

The name for the relay log index file. The default name is `host_name-relay-bin.index` in the data directory, where `host_name` is the name of the slave server.

Due to the manner in which MySQL parses server options, if you specify this variable at server startup, you must supply a value; *the default base name is used only if the option is not actually specified*. If you specify the `relay_log_index` system variable at server startup without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.2, “Specifying Program Options”.

• **relay_log_info_file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--relay-log-info-file=file_name</td>
</tr>
<tr>
<td>System Variable</td>
<td>relay_log_info_file</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td>relay-log.info</td>
</tr>
</tbody>
</table>

The name of the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory. For information about the format of this file, see Section 17.2.2.2, “Slave Status Logs”.

• **relay_log_recovery**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--relay-log-recovery={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>relay_log_recovery</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

If enabled, this variable enables automatic relay log recovery immediately following server startup, which means that the replication slave discards all unprocessed relay logs and retrieves them from the replication master. This should be used following a crash on the replication slave to ensure that no...
possibly corrupted relay logs are processed. The default value is 0 (disabled). This global variable can be changed dynamically at runtime, or set with the `--relay-log-recovery` option at slave startup.

- **report_host**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--report-host=host_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>report_host</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The host name or IP address of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server. Leave the value unset if you do not want the slave to register itself with the master.

**Note**

It is not sufficient for the master to simply read the IP address of the slave from the TCP/IP socket after the slave connects. Due to NAT and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

- **report_password**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--report-password=name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>report_password</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The account password of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the master was started with `--show-slave-auth-info`.

Although the name of this variable might imply otherwise, `report_password` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the password for the MySQL replication user account.

- **report_port**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--report-port=port_num</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>report_port</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value (&gt;= 5.5.23)</td>
<td>0</td>
</tr>
</tbody>
</table>
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value (&lt;= 5.5.22)</td>
<td>3306</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

The TCP/IP port number for connecting to the slave, to be reported to the master during slave registration. Set this only if the slave is listening on a nondefault port or if you have a special tunnel from the master or other clients to the slave. If you are not sure, do not use this option.

Prior to MySQL 5.5.23, the default value for this option was 3306. In MySQL 5.5.23 and higher, the value shown is the port number actually used by the slave (Bug #13333431). This change also affects the default value displayed by `SHOW SLAVE HOSTS`.

- **report_user**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--report-user=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>report_user</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

The account user name of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the master was started with `--show-slave-auth-info`.

Although the name of this variable might imply otherwise, `report_user` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the name of the MySQL replication user account.

- **rpl_recovery_rank**

This variable is unused, and is removed in MySQL 5.6.

- **slave_compressed_protocol**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--slave-compressed-protocol[==OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>slave_compressed_protocol</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether to use compression of the master/slave protocol if both master and slave support it. If this variable is disabled (the default), connections are uncompressed. See also Section 4.2.5, “Connection Compression Control”.
Replication and Binary Logging Options and Variables

• **slave_exec_mode**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--slave-exec-mode=mode</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_exec_mode</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>IDEMPOTENT (NDB)</td>
</tr>
<tr>
<td></td>
<td>STRICT (Other)</td>
</tr>
<tr>
<td>Valid Values</td>
<td>IDEMPOTENT</td>
</tr>
<tr>
<td></td>
<td>STRICT</td>
</tr>
</tbody>
</table>

Controls how a slave thread resolves conflicts and errors during replication. **IDEMPOTENT** mode causes suppression of duplicate-key and no-key-found errors; **STRICT** means no such suppression takes place.

**IDEMPOTENT** mode is intended for use in multi-master replication, circular replication, and some other special replication scenarios for NDB Cluster Replication. (See Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”, and Section 18.6.11, “NDB Cluster Replication Conflict Resolution”, for more information.) NDB Cluster ignores any value explicitly set for `slave_exec_mode`, and always treats it as **IDEMPOTENT**.

In MySQL Server 5.5, **STRICT** mode is the default value.

For storage engines other than NDB, **IDEMPOTENT** mode should be used only when you are absolutely sure that duplicate-key errors and key-not-found errors can safely be ignored. It is meant to be used in fail-over scenarios for NDB Cluster where multi-master replication or circular replication is employed, and is not recommended for use in other cases.

• **slave_load_tmpdir**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--slave-load-tmpdir=dir_name</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_load_tmpdir</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
<tr>
<td>Default Value</td>
<td>Value of <code>--tmpdir</code></td>
</tr>
</tbody>
</table>

The name of the directory where the slave creates temporary files. The variable value is by default equal to the value of the `tmpdir` system variable.

When the slave SQL thread replicates a `LOAD DATA` statement, it extracts the file to be loaded from the relay log into temporary files, and then loads these into the table. If the file loaded on the master is huge, the temporary files on the slave are huge, too. Therefore, it might be advisable to use this option to tell the slave to put temporary files in a directory located in some file system that has a lot of available...
space. In that case, the relay logs are huge as well, so you might also want to set the `relay_log` system variable to place the relay logs in that file system.

The directory specified by this option should be located in a disk-based file system (not a memory-based file system) so that the temporary files used to replicate `LOAD DATA` statements can survive machine restarts. The directory also should not be one that is cleared by the operating system during the system startup process.

- `slave_max_allowed_packet`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--slave-max-allowed-packet=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.26</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_max_allowed_packet</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1073741824</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1073741824</td>
</tr>
</tbody>
</table>

In MySQL 5.5.26 and higher, this variable sets the maximum packet size for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`.

This global variable always has a value that is a positive integer multiple of 1024; if you set it to some value that is not, the value is rounded down to the next highest multiple of 1024 for it is stored or used; setting `slave_max_allowed_packet` to 0 causes 1024 to be used. (A truncation warning is issued in all such cases.) The default and maximum value is 1073741824 (1 GB); the minimum is 1024.

- `slave_net_timeout`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--slave-net-timeout=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>slave_net_timeout</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>3600</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of seconds to wait for more data from the master before the slave considers the connection broken, aborts the read, and tries to reconnect. The first retry occurs immediately after the timeout. The interval between retries is controlled by the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement, and the number of reconnection attempts is limited by the `--master-retry-count` option. The default is 3600 seconds (one hour).
• **slave_skip_errors**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--slave-skip-errors=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>slave_skip_errors</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
<tr>
<td>Valid Values</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>[list of error codes]</td>
</tr>
<tr>
<td></td>
<td>all</td>
</tr>
<tr>
<td></td>
<td>ddl_exist_errors</td>
</tr>
</tbody>
</table>

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This variable tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the variable value.

• **slave_transaction_retries**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--slave-transaction-retries=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>slave_transaction_retries</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If a replication slave SQL thread fails to execute a transaction because of an InnoDB deadlock or because the transaction's execution time exceeded InnoDB's innodb_lock_wait_timeout or NDBCLUSTER's TransactionDeadlockDetectionTimeout or TransactionInactiveTimeout, it automatically retries slave_transaction_retries times before stopping with an error. The default value is 10.

• **slave_type_conversions**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--slave-type-conversions=set</td>
</tr>
<tr>
<td>System Variable</td>
<td>slave_type_conversions</td>
</tr>
</tbody>
</table>
### Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Set</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
<tr>
<td>Valid Values</td>
<td>ALL_LOSSY, ALL_NON_LOSSY</td>
</tr>
</tbody>
</table>

Controls the type conversion mode in effect on the slave when using row-based replication, including NDB Cluster Replication. Its value is a comma-delimited set of zero or more elements from the list: ALL_LOSSY, ALL_NON_LOSSY. Set this variable to an empty string to disallow type conversions between the master and the slave. Changes require a restart of the slave to take effect.

For additional information on type conversion modes applicable to attribute promotion and demotion in row-based replication, see [Row-based replication: attribute promotion and demotion](#).

- **sql_slave_skip_counter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>sql_slave_skip_counter</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>

The number of events from the master that a slave server should skip.

⚠️ **Important**

If skipping the number of events specified by setting this variable would cause the slave to begin in the middle of an event group, the slave continues to skip until it finds the beginning of the next event group and begins from that point. For more information, see [Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Statement”](#).

- **sync_master_info**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--sync-master-info=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>sync_master_info</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>

(64-bit platforms)
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If the value of this variable is greater than 0, a replication slave synchronizes its `master.info` file to disk (using `fdatasync()`) after every `sync_master_info` events. The default value is 0 (recommended in most situations), which does not force any synchronization to disk by the MySQL server; in this case, the server relies on the operating system to flush the `master.info` file's contents from time to time as for any other file.

- **sync_relay_log**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--sync-relay-log=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>sync_relay_log</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If the value of this variable is greater than 0, the MySQL server synchronizes its relay log to disk (using `fdatasync()`) after every `sync_relay_log` events are written to the relay log.

The default value of `sync_relay_log` is 0, which does no synchronizing to disk; in this case, the server relies on the operating system to flush the relay log's contents from time to time as for any other file.

A value of 1 is the safest choice because in the event of a crash you lose at most one event from the relay log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

- **sync_relay_log_info**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--sync-relay-log-info=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>sync_relay_log_info</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>
If the value of this variable is greater than 0, a replication slave synchronizes its `relay-log.info` file to disk (using `fdatasync()`) after every `sync_relay_log_info` transactions. A value of 1 is the generally the best choice. The default value of `sync_relay_log_info` is 0, which does not force any synchronization to disk by the MySQL server—in this case, the server relies on the operating system to flush the `relay-log.info` file’s contents from time to time as for any other file.

### 17.1.3.4 Binary Log Options and Variables

- **Startup Options Used with Binary Logging**
- **System Variables Used with Binary Logging**

You can use the `mysqld` options and system variables that are described in this section to affect the operation of the binary log as well as to control which statements are written to the binary log. For additional information about the binary log, see Section 5.4.4, “The Binary Log”. For additional information about using MySQL server options and system variables, see Section 5.1.6, “Server Command Options”, and Section 5.1.7, “Server System Variables”.

#### Startup Options Used with Binary Logging

The following list describes startup options for enabling and configuring the binary log. System variables used with binary logging are discussed later in this section.

- **--binlog-row-event-max-size=N**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--binlog-row-event-max-size=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1024</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>256</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Specify the maximum size of a row-based binary log event, in bytes. Rows are grouped into events smaller than this size if possible. The value should be a multiple of 256. The default is 1024. See Section 17.1.2, “Replication Formats”.

- **--log-bin [=base_name]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log-bin=file_name</code></td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

Enable binary logging. The server logs all statements that change data to the binary log, which is used for backup and replication. See Section 5.4.4, “The Binary Log”.
Replication and Binary Logging Options and Variables

The option value, if given, is the base name for the log sequence. The server creates binary log files in sequence by adding a numeric suffix to the base name. It is recommended that you specify a base name (see Section B.4.7, “Known Issues in MySQL”, for the reason). Otherwise, MySQL uses `host_name-bin` as the base name.

In MySQL 5.5.20 and higher, when the server reads an entry from the index file, it checks whether the entry contains a relative path, and if it does, the relative part of the path is replaced with the absolute path set using the `--log-bin` option. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. Previous to MySQL 5.5.20, manual intervention was required whenever relocating the binary log or relay log files. (Bug #11745230, Bug #12133)

Setting this option causes the `log_bin` system variable to be set to ON (or 1), and not to the base name. This is a known issue; see Bug #19614 for more information.

- `--log-bin-index=[file_name]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--log-bin-index=file_name</code></td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
</tbody>
</table>

The name for the binary log index file, which contains the names of the binary log files. By default, it has the same location and base name as the value specified for the binary log files using the `--log-bin` option, plus the extension `.index`. If you do not specify `--log-bin`, the default binary log index file name is `binlog.index`. If you omit the file name and do not specify one with `--log-bin`, the default binary log index file name is `host_name-bin.index`, using the name of the host machine.

For information on the format and management of the binary log, see Section 5.4.4, “The Binary Log”.

**Statement selection options.** The options in the following list affect which statements are written to the binary log, and thus sent by a replication master server to its slaves. There are also options for slave servers that control which statements received from the master should be executed or ignored. For details, see Section 17.1.3.3, “Replication Slave Options and Variables”.

- `--binlog-do-db=db_name`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--binlog-do-db=name</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

This option affects binary logging in a manner similar to the way that `--replicate-do-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-do-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-do-db` always apply in determining whether or not the statement is logged.

**Statement-based logging.** Only those statements are written to the binary log where the default database (that is, the one selected by `USE`) is `db_name`. To specify more than one database, use this
Replication and Binary Logging Options and Variables

option multiple times, once for each database; however, doing so does not cause cross-database statements such as UPDATE some_db.some_table SET foo='bar' to be logged while a different database (or no database) is selected.

Warning

To specify multiple databases you must use multiple instances of this option. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

An example of what does not work as you might expect when using statement-based logging: If the server is started with --binlog-do-db=sales and you issue the following statements, the UPDATE statement is not logged:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “just check the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table DELETE statements or multiple-table UPDATE statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Another case which may not be self-evident occurs when a given database is replicated even though it was not specified when setting the option. If the server is started with --binlog-do-db=sales, the following UPDATE statement is logged even though prices was not included when setting --binlog-do-db:

```
USE sales;
UPDATE prices.discounts SET percentage = percentage + 10;
```

Because sales is the default database when the UPDATE statement is issued, the UPDATE is logged.

Row-based logging. Logging is restricted to database db_name. Only changes to tables belonging to db_name are logged; the default database has no effect on this. Suppose that the server is started with --binlog-do-db=sales and row-based logging is in effect, and then the following statements are executed:

```
USE prices;
UPDATE sales.febuary SET amount=amount+100;
```

The changes to the february table in the sales database are logged in accordance with the UPDATE statement; this occurs whether or not the USE statement was issued. However, when using the row-based logging format and --binlog-do-db=sales, changes made by the following UPDATE are not logged:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the USE prices statement were changed to USE sales, the UPDATE statement’s effects would still not be written to the binary log.

Another important difference in --binlog-do-db handling for statement-based logging as opposed to the row-based logging occurs with regard to statements that refer to multiple databases. Suppose that the server is started with --binlog-do-db=db1, and the following statements are executed:

```
USE db1;
```

Warning
Replication and Binary Logging Options and Variables

UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;

If you are using statement-based logging, the updates to both tables are written to the binary log. However, when using the row-based format, only the changes to table1 are logged; table2 is in a different database, so it is not changed by the UPDATE. Now suppose that, instead of the USE db1 statement, a USE db4 statement had been used:

USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;

In this case, the UPDATE statement is not written to the binary log when using statement-based logging. However, when using row-based logging, the change to table1 is logged, but not that to table2—in other words, only changes to tables in the database named by --binlog-do-db are logged, and the choice of default database has no effect on this behavior.

- **--binlog-ignore-db=db_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--binlog-ignore-db=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

This option affects binary logging in a manner similar to the way that --replicate-ignore-db affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of --replicate-ignore-db depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of binlog_format. For example, DDL statements such as CREATE TABLE and ALTER TABLE are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for --binlog-ignore-db always apply in determining whether or not the statement is logged.

**Statement-based logging.** Tells the server to not log any statement where the default database (that is, the one selected by USE) is db_name.

Prior to MySQL 5.5.32, this option caused any statements containing fully qualified table names not to be logged if there was no default database specified (that is, when SELECT DATABASE() returned NULL). In MySQL 5.5.32 and higher, when there is no default database, no --binlog-ignore-db options are applied, and such statements are always logged. (Bug #11829838, Bug #60188)

**Row-based format.** Tells the server not to log updates to any tables in the database db_name. The current database has no effect.

When using statement-based logging, the following example does not work as you might expect. Suppose that the server is started with --binlog-ignore-db=sales and you issue the following statements:

USE prices;
UPDATE sales.january SET amount=amount+1000;

The UPDATE statement is logged in such a case because --binlog-ignore-db applies only to the default database (determined by the USE statement). Because the sales database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based logging, the UPDATE statement's effects are not written to the binary log, which means that no changes to the sales.january table are logged; in this instance, --binlog-ignore-db=sales causes all changes made to tables in the master's copy of the sales database to be ignored for purposes of binary logging.
To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

You should not use this option if you are using cross-database updates and you do not want these updates to be logged.

**Testing and debugging options.** The following binary log options are used in replication testing and debugging. They are not intended for use in normal operations.

- **--max-binlog-dump-events=N**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--max-binlog-dump-events=#</strong></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

This option is used internally by the MySQL test suite for replication testing and debugging.

- **--sporadic-binlog-dump-fail**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>**--sporadic-binlog-dump-fail[{OFF</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This option is used internally by the MySQL test suite for replication testing and debugging.

**System Variables Used with Binary Logging**

The following list describes system variables for controlling binary logging. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used to control binary logging are listed earlier in this section. For information about the `sql_log_bin` and `sql_log_off` variables, see Section 5.1.7, “Server System Variables”.

- **binlog_cache_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--binlog-cache-size=#</strong></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>binlog_cache_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32768</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value (64-bit platforms)</td>
<td><code>18446744073709551615</code></td>
</tr>
<tr>
<td>Maximum Value (32-bit platforms)</td>
<td><code>4294967295</code></td>
</tr>
</tbody>
</table>
The size of the cache to hold changes to the binary log during a transaction. A binary log cache is allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large transactions, you can increase this cache size to get better performance. The `Binlog_cache_use` and `Binlog_cache_disk_use` status variables can be useful for tuning the size of this variable. See Section 5.4.4, “The Binary Log”.

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets the size for both caches. This means that, in these MySQL versions, the total memory used for these caches is double the value set for `binlog_cache_size`.

Beginning with MySQL 5.5.9, `binlog_cache_size` sets the size for the transaction cache only, and the size of the statement cache is governed by the `binlog_stmt_cache_size` system variable.

- `binlog_direct_non_transactional_updates`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--binlog-direct-non-transactional-updates=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>binlog_direct_non_transactional_updates</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Due to concurrency issues, a slave can become inconsistent when a transaction contains updates to both transactional and nontransactional tables. MySQL tries to preserve causality among these statements by writing nontransactional statements to the transaction cache, which is flushed upon commit. However, problems arise when modifications done to nontransactional tables on behalf of a transaction become immediately visible to other connections because these changes may not be written immediately into the binary log.

Beginning with MySQL 5.5.2, the `binlog_direct_non_transactional_updates` variable offers one possible workaround to this issue. By default, this variable is disabled. Enabling `binlog_direct_non_transactional_updates` causes updates to nontransactional tables to be written directly to the binary log, rather than to the transaction cache.

`binlog_direct_non_transactional_updates` works only for statements that are replicated using the statement-based binary logging format; that is, it works only when the value of `binlog_format` is `STATEMENT`, or when `binlog_format` is `MIXED` and a given statement is being replicated using the statement-based format. This variable has no effect when the binary log format is `ROW`, or when `binlog_format` is set to `MIXED` and a given statement is replicated using the row-based format.

⚠️ Important

Before enabling this variable, you must make certain that there are no dependencies between transactional and nontransactional tables; an example of such a dependency would be the statement `INSERT INTO myisam_table SELECT * FROM innodb_table`. Otherwise, such statements are likely to cause the slave to diverge from the master.

Beginning with MySQL 5.5.5, this variable has no effect when the binary log format is `ROW` or `MIXED`. (Bug #51291)
• **binlog_format**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--binlog-format=format</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>binlog_format</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value (&gt;= 5.5.31-</td>
<td>MIXED</td>
</tr>
<tr>
<td>ndb-7.2.13)</td>
<td></td>
</tr>
<tr>
<td>Default Value (&gt;= 5.5.15-</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>ndb-7.2.1, &lt;= 5.5.30-</td>
<td></td>
</tr>
<tr>
<td>ndb-7.2.12)</td>
<td></td>
</tr>
<tr>
<td>Default Value</td>
<td>STATEMENT</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ROW</td>
</tr>
<tr>
<td></td>
<td>STATEMENT</td>
</tr>
<tr>
<td></td>
<td>MIXED</td>
</tr>
</tbody>
</table>

This variable sets the binary logging format, and can be any one of **STATEMENT**, **ROW**, or **MIXED**. See Section 17.1.2, “Replication Formats”. Setting the binary logging format without enabling binary logging sets the `binlog_format` global system variable and logs a warning.

**binlog_format** can be set at startup or at runtime, except that under some conditions, changing this variable at runtime is not possible or causes replication to fail. For more information, see Section 5.4.4.2, “Setting The Binary Log Format”.

**Note**

While you can change the logging format at runtime, it is **not** recommended that you change it while replication is ongoing. This is due in part to the fact that slaves do not honor the master's `binlog_format` setting; a given MySQL Server can change only its own logging format.

In MySQL 5.5, the default format is **STATEMENT**. This is also true for MySQL NDB Cluster 7.2.1 and higher. See Section 17.1.2, “Replication Formats”.

**Exception.** In MySQL NDB Cluster 7.2.1 through MySQL NDB Cluster 7.2.12, the default for this variable is **STATEMENT**. In MySQL NDB Cluster 7.2.13 and higher, when the NDB storage engine is enabled, the default is **MIXED**. (Bug #16417224) See also Section 18.6.6, “Starting NDB Cluster...”
Replication and Binary Logging Options and Variables

Replication (Single Replication Channel)”, and Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”.

Setting the session value of this system variable is a restricted operation. The session user must have privileges sufficient to set restricted session variables. See Section 5.1.8.1, “System Variable Privileges”.

The rules governing when changes to this variable take effect and how long the effect lasts are the same as for other MySQL server system variables. For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”.

When MIXED is specified, statement-based replication is used, except for cases where only row-based replication is guaranteed to lead to proper results. For example, this happens when statements contain user-defined functions (UDF) or the UUID() function.

For details of how stored programs (stored procedures and functions, triggers, and events) are handled when each binary logging format is set, see Section 20.7, “Stored Program Binary Logging”.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger.
- If the session is currently in row-based replication mode and has open temporary tables.
- Beginning with MySQL 5.5.3, within a transaction. (Bug #47863)

Trying to switch the format in those cases results in an error.

Note

Prior to MySQL NDB Cluster 7.2.1, it was also not possible to change the binary logging format at runtime when the NDBCLUSTER storage engine was enabled. In MySQL NDB Cluster 7.2.1 and higher, this restriction is removed.

The binary log format affects the behavior of the following server options:

- --replicate-do-db
- --replicate-ignore-db
- --binlog-do-db
- --binlog-ignore-db

These effects are discussed in detail in the descriptions of the individual options.

- binlog_stmt_cache_size

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--binlog-stmt-cache-size=#</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.9</td>
</tr>
<tr>
<td>System Variable</td>
<td>binlog_stmt_cache_size</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>
Beginning with MySQL 5.5.9, this variable determines the size of the cache for the binary log to hold nontransactional statements issued during a transaction. In MySQL 5.5.3 and higher, separate binary log transaction and statement caches are allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (\textit{--log-bin} option). If you often use large nontransactional statements during transactions, you can increase this cache size to get more performance. The \texttt{Binlog_stmt_cache_use} and \texttt{Binlog_stmt_cache_disk_use} status variables can be useful for tuning the size of this variable. See Section 5.4.4, “The Binary Log”. In MySQL 5.5.3 through 5.5.8, the size for both caches is set using \texttt{binlog_cache_size}. This means that, in these MySQL versions, the total memory used for these caches is double the value set for \texttt{binlog_cache_size}. Beginning with MySQL 5.5.9, \texttt{binlog_cache_size} sets the size for the transaction cache only.

- \texttt{log_bin}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>\texttt{log_bin}</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

Whether the binary log is enabled. If the \texttt{--log-bin} option is used, then the value of this variable is \texttt{ON}; otherwise it is \texttt{OFF}. This variable reports only on the status of binary logging (enabled or disabled); it does not actually report the value to which \texttt{--log-bin} is set.

See Section 5.4.4, “The Binary Log”.

- \texttt{log_bin_trust_functionCreators}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--log-bin-trust-function-creators}=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>\texttt{log_bin_trust_functionCreators}</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This variable applies when binary logging is enabled. It controls whether stored function creators can be trusted not to create stored functions that will cause unsafe events to be written to the binary log. If set to 0 (the default), users are not permitted to create or alter stored functions unless they have the \texttt{SUPER} privilege in addition to the \texttt{CREATE ROUTINE} or \texttt{ALTER ROUTINE} privilege. A setting of 0 also enforces...
the restriction that a function must be declared with the `DETERMINISTIC` characteristic, or with the
`READS SQL DATA` or `NO SQL` characteristic. If the variable is set to 1, MySQL does not enforce these
restrictions on stored function creation. This variable also applies to trigger creation. See Section 20.7,
“Stored Program Binary Logging”.

- `log_bin_use_v1_row_events`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--log-bin-use-v1-row-events=[{OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.15-ndb-7.2.1</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log_bin_use_v1_row_events</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether Version 2 binary logging is in use. If this variable is 0 (disabled, the default), Version 2 binary
log events are in use. If this variable is 1 (enabled), the server writes the binary log using Version 1
logging events (the only version of binary log events used in previous releases), and thus produces a
binary log that can be read by older slaves.

Version 2 binary log row events are used by default beginning with MySQL NDB Cluster
7.2.1; however, Version 2 events cannot be read by previous NDB Cluster releases. Enabling
`log_bin_use_v1_row_events` causes `mysqld` to write the binary log using Version 1 logging events.

This variable is read-only at runtime. To switch between Version 1 and Version 2 binary event binary
logging, it is necessary to set `log_bin_use_v1_row_events` at server startup.

Other than when performing upgrades of NDB Cluster Replication, `log_bin_use_v1_row_events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB $EPOCH_TRANS()` as the conflict detection function, which requires Version 2 binary log row events. Thus, this variable and `--ndb-log-transaction-id` are not compatible.

**Note**

Version 2 binary log row events are also available in MySQL NDB Cluster
7.0.27 and MySQL NDB Cluster 7.1.6 and later MySQL NDB Cluster 7.0 and
7.1 releases. However, prior to MySQL NDB Cluster 7.2.1, Version 1 events are
the default (and so the default value for this option is 1 in those versions). You
should keep this mind when planning upgrades for setups using NDB Cluster
Replication.

This variable is not supported in mainline MySQL Server 5.5.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `log_slave_updates`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--log-slave-updates=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>log_slave_updates</code></td>
</tr>
</tbody>
</table>
Whether updates received by a slave server from a master server should be logged to the slave's own binary log.

Normally, a slave does not log to its own binary log any updates that are received from a master server. Enabling this variable tells the slave to log the updates performed by its SQL thread to its own binary log. For this variable to have any effect, the slave must also be started with the `--log-bin` option to enable binary logging. See Section 17.1.3, “Replication and Binary Logging Options and Variables”. Prior to MySQL 5.5, the server would not start when enabling `log_slave_updates` without also starting the server with the `--log-bin` option, and would fail with an error; in MySQL 5.5, only a warning is generated. (Bug #44663)

`log_slave_updates` is enabled when you want to chain replication servers. For example, you might want to set up replication servers using this arrangement:

```
A -> B -> C
```

Here, A serves as the master for the slave B, and B serves as the master for the slave C. For this to work, B must be both a master and a slave. You must start both A and B with `--log-bin` to enable binary logging, and B with `log_slave_updates` enabled so that updates received from A are logged by B to its binary log.

- `max_binlog_cache_size`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--max-binlog-cache-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>max_binlog_cache_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>18446744073709551615</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>18446744073709551615</td>
</tr>
</tbody>
</table>

If a transaction requires more than this many bytes of memory, the server generates a Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage error. The minimum value is 4096. The maximum possible value is 16EB (exabytes).
maximum recommended value is 4GB; this is due to the fact that MySQL currently cannot work with binary log positions greater than 4GB.

Note
Prior to MySQL 5.5.28, 64-bit Windows platforms truncated the stored value for this variable to 4G, even when it was set to a greater value (Bug #13961678).

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets the upper limit for both caches. This means that, in these MySQL versions, the effective maximum for these caches is double the value set for \texttt{max_binlog_cache_size}.

Beginning with MySQL 5.5.9, \texttt{max_binlog_cache_size} sets the size for the transaction cache only, and the upper limit for the statement cache is governed by the \texttt{max_binlog_stmt_cache_size} system variable.

Also beginning with MySQL 5.5.9, the session visibility of the \texttt{max_binlog_cache_size} system variable matches that of the \texttt{binlog_cache_size} system variable: In MySQL 5.5.8 and earlier releases, a change in \texttt{max_binlog_cache_size} took immediate effect; in MySQL 5.5.9 and higher, a change in \texttt{max_binlog_cache_size} takes effect only for new sessions that started after the value is changed.

- \texttt{max_binlog_size}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--max-binlog-size=}#{\texttt{#}}</td>
</tr>
<tr>
<td>System Variable</td>
<td>\texttt{max_binlog_size}</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1073741824</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1073741824</td>
</tr>
</tbody>
</table>

If a write to the binary log causes the current log file size to exceed the value of this variable, the server rotates the binary logs (closes the current file and opens the next one). The minimum value is 4096 bytes. The maximum and default value is 1GB.

A transaction is written in one chunk to the binary log, so it is never split between several binary logs. Therefore, if you have big transactions, you might see binary log files larger than \texttt{max_binlog_size}.

If \texttt{max_relay_log_size} is 0, the value of \texttt{max_binlog_size} applies to relay logs as well.

- \texttt{max_binlog_stmt_cache_size}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--max-binlog-stmt-cache-size=}#{\texttt{#}}</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.9</td>
</tr>
<tr>
<td>System Variable</td>
<td>\texttt{max_binlog_stmt_cache_size}</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
Replication and Binary Logging Options and Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>18446744073709547520</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>18446744073709547520</td>
</tr>
</tbody>
</table>

If nontransactional statements require more than this many bytes of memory, the server generates an error. The minimum value is 4096. The maximum and default values are 4GB on 32-bit platforms and 16EB (exabytes) on 64-bit platforms.

Note
Prior to MySQL 5.5.28, 64-bit Windows platforms truncated the stored value for this variable to 4G, even when it was set to a greater value (Bug #13961678).

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets the upper limit for both caches. This means that, in these MySQL versions, the effective maximum for these caches is double the value set for `max_binlog_cache_size`.

Beginning with MySQL 5.5.9, `max_binlog_stmt_cache_size` sets the size for the statement cache only, and the upper limit for the transaction cache is governed exclusively by the `max_binlog_cache_size` system variable.

- `sync_binlog`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--sync-binlog=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>sync_binlog</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Controls how often the MySQL server synchronizes the binary log to disk.

- `sync_binlog=0`: Disables synchronization of the binary log to disk by the MySQL server. Instead, the MySQL server relies on the operating system to flush the binary log to disk from time to time as it does for any other file. This setting provides the best performance, but in the event of a power failure or operating system crash, it is possible that the server has committed transactions that have not been synchronized to the binary log.

- `sync_binlog=1`: Enables synchronization of the binary log to disk before transactions are committed. This is the safest setting but can have a negative impact on performance due to the increased number of disk writes. In the event of a power failure or operating system crash, you lose at most one statement or transaction from the binary log.
Common Replication Administration Tasks

- **sync_binlog=N**, where \( N \) is a value other than 0 or 1: The binary log is synchronized to disk after every \( N \) writes to the binary log. There is one write to the binary log per statement if autocommit is enabled, and one write per transaction otherwise. In the event of a power failure or operating system crash, it is possible that the server has committed transactions that have not been flushed to the binary log. This setting can have a negative impact on performance due to the increased number of disk writes. A higher value improves performance, but with an increased risk of data loss.

For the greatest possible durability and consistency in a replication setup that uses InnoDB with transactions, use these settings:

- **sync_binlog=1**.
- **innodb_flush_log_at_trx_commit=1**.

**Caution**

Many operating systems and some disk hardware fool the flush-to-disk operation. They may tell mysqld that the flush has taken place, even though it has not. In this case, the durability of transactions is not guaranteed even with the recommended settings, and in the worst case, a power outage can corrupt InnoDB data. Using a battery-backed disk cache in the SCSI disk controller or in the disk itself speeds up file flushes, and makes the operation safer. You can also try to disable the caching of disk writes in hardware caches.

17.1.4 Common Replication Administration Tasks

Once replication has been started it should execute without requiring much regular administration. Depending on your replication environment, you will want to check the replication status of each slave periodically, daily, or even more frequently.

17.1.4.1 Checking Replication Status

The most common task when managing a replication process is to ensure that replication is taking place and that there have been no errors between the slave and the master. The primary statement for this is `SHOW SLAVE STATUS`, which you must execute on each slave:

```
mysql> SHOW SLAVE STATUS\G
```

```
+-------------------------------+----------------------------------------------------------+
| Slave_IO_State: Waiting for master to send event | Master_Host: master1 |
| Master_User: root | Master_Port: 3306 |
| Connect_Retry: 60 | Master_Log_File: mysql-bin.000004 |
| Master_Log_Pos: 931 | Read_Master_Log_Pos: 931 |
| Read_Master_Log_Pos: 931 | Relay_Log_File: slave1-relay-bin.000056 |
| Relay_Log_Pos: 950 | Slave_IO_Running: Yes |
| Slave_SQL_Running: Yes | Slave_LOG_BIN: mysql-bin.000004 |
| Replicate_Do_DB: | Slave_IO_Running: Yes |
| Replicate_Ignore_DB: | Slave_SQL_Running: Yes |
| Replicate_Do_Table: | Replicate_Ignore_Table: |
| Replicate_Ignore_Server: | Replicate_Ignore_DB: |
| Replicate_Wild_Do_Table: | Replicate_Wild_Ignore_Table: |
| Replicate_Wild_Ignore_Server: | Replicate_Wild_Ignore_DB: |
+-------------------------------+----------------------------------------------------------+
```

2052
The key fields from the status report to examine are:

- **Slave_IO_State**: The current status of the slave. See Section 8.14.6, “Replication Slave I/O Thread States”, and Section 8.14.7, “Replication Slave SQL Thread States”, for more information.

- **Slave_IO_Running**: Whether the I/O thread for reading the master's binary log is running. Normally, you want this to be **Yes** unless you have not yet started replication or have explicitly stopped it with **STOP SLAVE**.

- **Slave_SQL_Running**: Whether the SQL thread for executing events in the relay log is running. As with the I/O thread, this should normally be **Yes**.

- **Last_IO_Error, Last_SQL_Error**: The last errors registered by the I/O and SQL threads when processing the relay log. Ideally these should be blank, indicating no errors.

- **Seconds_Behind_Master**: The number of seconds that the slave SQL thread is behind processing the master binary log. A high number (or an increasing one) can indicate that the slave is unable to handle events from the master in a timely fashion.

A value of 0 for **Seconds_Behind_Master** can usually be interpreted as meaning that the slave has caught up with the master, but there are some cases where this is not strictly true. For example, this can occur if the network connection between master and slave is broken but the slave I/O thread has not yet noticed this—that is, *slave_net_timeout* has not yet elapsed.

It is also possible that transient values for **Seconds_Behind_Master** may not reflect the situation accurately. When the slave SQL thread has caught up on I/O, **Seconds_Behind_Master** displays 0; but when the slave I/O thread is still queuing up a new event, **Seconds_Behind_Master** may show a large value until the SQL thread finishes executing the new event. This is especially likely when the events have old timestamps; in such cases, if you execute **SHOW SLAVE STATUS** several times in a relatively short period, you may see this value change back and forth repeatedly between 0 and a relatively large value.

Several pairs of fields provide information about the progress of the slave in reading events from the master binary log and processing them in the relay log:

- **(Master_Log_file, Read_Master_Log_Pos)**: Coordinates in the master binary log indicating how far the slave I/O thread has read events from that log.

- **(Relay_Master_Log_File, Exec_Master_Log_Pos)**: Coordinates in the master binary log indicating how far the slave SQL thread has executed events received from that log.
Common Replication Administration Tasks

• (Relay_Log_File, Relay_Log_Pos): Coordinates in the slave relay log indicating how far the slave SQL thread has executed the relay log. These correspond to the preceding coordinates, but are expressed in slave relay log coordinates rather than master binary log coordinates.

The SHOW STATUS statement also provides some information relating specifically to replication slaves. The replication heartbeat information displayed by SHOW STATUS lets you check that the replication connection is active even if the master has not sent events to the slave recently. The master sends a heartbeat signal to a slave if there are no updates to, and no unsent events in, the binary log for a longer period than the heartbeat interval. The MASTER_HEARTBEAT_PERIOD setting on the master (set by the CHANGE MASTER TO statement) specifies the frequency of the heartbeat, which defaults to half of the connection timeout interval for the slave (slave_net_timeout). The Slave_last_heartbeat variable for SHOW STATUS shows when the replication slave last received a heartbeat signal.

On the master, you can check the status of connected slaves using SHOW PROCESSLIST to examine the list of running processes. Slave connections have Binlog Dump in the Command field:

```
``` mysql> SHOW PROCESSLIST \G;
*************************** 4. row ***************************
    Id: 10
    User: root
    Host: slave1:58371
    db: NULL
    Command: Binlog Dump
    Time: 777
    State: Has sent all binlog to slave; waiting for binlog to be updated
    Info: NULL
```

Because it is the slave that drives the replication process, very little information is available in this report.

For slaves that were started with the --report-host option and are connected to the master, the SHOW SLAVE HOSTS statement on the master shows basic information about the slaves. The output includes the ID of the slave server, the value of the --report-host option, the connecting port, and master ID:

```
``` mysql> SHOW SLAVE HOSTS;
+-----------+--------+------+-------------------+-----------+
<table>
<thead>
<tr>
<th>Server_id</th>
<th>Host</th>
<th>Port</th>
<th>Rpl_recovery_rank</th>
<th>Master_id</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>slave1</td>
<td>3306</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
+-----------+--------+------+-------------------+-----------+
1 row in set (0.00 sec)
```

17.1.4.2 Pausing Replication on the Slave

You can stop and start the replication of statements on the slave using the STOP SLAVE and START SLAVE statements.

To stop processing of the binary log from the master, use STOP SLAVE:

```
``` mysql> STOP SLAVE;
```

When replication is stopped, the slave I/O thread stops reading events from the master binary log and writing them to the relay log, and the SQL thread stops reading events from the relay log and executing them. You can pause the I/O or SQL thread individually by specifying the thread type:

```
``` mysql> STOP SLAVE IO_THREAD;
mysql> STOP SLAVE SQL_THREAD;
```

To start execution again, use the START SLAVE statement:

```
``` mysql> START SLAVE;
```
To start a particular thread, specify the thread type:

```sql
mysql> START SLAVE IO_THREAD;
mysql> START SLAVE SQL_THREAD;
```

For a slave that performs updates only by processing events from the master, stopping only the SQL thread can be useful if you want to perform a backup or other task. The I/O thread will continue to read events from the master but they are not executed. This makes it easier for the slave to catch up when you restart the SQL thread.

Stopping only the I/O thread enables the events in the relay log to be executed by the SQL thread up to the point where the relay log ends. This can be useful when you want to pause execution to catch up with events already received from the master, when you want to perform administration on the slave but also ensure that it has processed all updates to a specific point. This method can also be used to pause event receipt on the slave while you conduct administration on the master. Stopping the I/O thread but permitting the SQL thread to run helps ensure that there is not a massive backlog of events to be executed when replication is started again.

### 17.2 Replication Implementation

Replication is based on the master server keeping track of all changes to its databases (updates, deletes, and so on) in its binary log. The binary log serves as a written record of all events that modify database structure or content (data) from the moment the server was started. Typically, `SELECT` statements are not recorded because they modify neither database structure nor content.

Each slave that connects to the master requests a copy of the binary log. That is, it pulls the data from the master, rather than the master pushing the data to the slave. The slave also executes the events from the binary log that it receives. This has the effect of repeating the original changes just as they were made on the master. Tables are created or their structure modified, and data is inserted, deleted, and updated according to the changes that were originally made on the master.

Because each slave is independent, the replaying of the changes from the master's binary log occurs independently on each slave that is connected to the master. In addition, because each slave receives a copy of the binary log only by requesting it from the master, the slave is able to read and update the copy of the database at its own pace and can start and stop the replication process at will without affecting the ability to update to the latest database status on either the master or slave side.

For more information on the specifics of the replication implementation, see Section 17.2.1, "Replication Implementation Details".

Masters and slaves report their status in respect of the replication process regularly so that you can monitor them. See Section 8.14, "Examining Thread Information", for descriptions of all replicated-related states.

The master binary log is written to a local relay log on the slave before it is processed. The slave also records information about the current position with the master's binary log and the local relay log. See Section 17.2.2, "Replication Relay and Status Logs".

Database changes are filtered on the slave according to a set of rules that are applied according to the various configuration options and variables that control event evaluation. For details on how these rules are applied, see Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

### 17.2.1 Replication Implementation Details

MySQL replication capabilities are implemented using three threads, one on the master server and two on the slave:
**Replication Implementation Details**

- **Binlog dump thread.** The master creates a thread to send the binary log contents to a slave when the slave connects. This thread can be identified in the output of `SHOW PROCESSLIST` on the master as the Binlog Dump thread.

  The binary log dump thread acquires a lock on the master's binary log for reading each event that is to be sent to the slave. As soon as the event has been read, the lock is released, even before the event is sent to the slave.

- **Slave I/O thread.** When a `START SLAVE` statement is issued on a slave server, the slave creates an I/O thread, which connects to the master and asks it to send the updates recorded in its binary logs.

  The slave I/O thread reads the updates that the master's Binlog Dump thread sends (see previous item) and copies them to local files that comprise the slave's relay log.

  The state of this thread is shown as `Slave_IO_running` in the output of `SHOW SLAVE STATUS` or as `Slave_running` in the output of `SHOW STATUS`.

- **Slave SQL thread.** The slave creates an SQL thread to read the relay log that is written by the slave I/O thread and execute the events contained therein.

  In the preceding description, there are three threads per master/slave connection. A master that has multiple slaves creates one binary log dump thread for each currently connected slave, and each slave has its own I/O and SQL threads.

  A slave uses two threads to separate reading updates from the master and executing them into independent tasks. Thus, the task of reading statements is not slowed down if statement execution is slow. For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binary log contents from the master when the slave starts, even if the SQL thread lags far behind. If the slave stops before the SQL thread has executed all the fetched statements, the I/O thread has at least fetched everything so that a safe copy of the statements is stored locally in the slave's relay logs, ready for execution the next time that the slave starts. This enables the master server to purge its binary logs sooner because it no longer needs to wait for the slave to fetch their contents.

  The `SHOW PROCESSLIST` statement provides information that tells you what is happening on the master and on the slave regarding replication. For information on master states, see Section 8.14.5, “Replication Master Thread States”. For slave states, see Section 8.14.6, “Replication Slave I/O Thread States”, and Section 8.14.7, “Replication Slave SQL Thread States”.

  The following example illustrates how the three threads show up in the output from `SHOW PROCESSLIST`.

  On the master server, the output from `SHOW PROCESSLIST` looks like this:

  ```
  mysql> SHOW PROCESSLIST\G
  *************************** 1. row ***************************
  Id: 2
  User: root
  Host: localhost:32931
  db: NULL
  Command: Binlog Dump
  Time: 94
  State: Has sent all binlog to slave; waiting for binlog to be updated
  Info: NULL
  ```

  Here, thread 2 is a Binlog Dump replication thread that services a connected slave. The State information indicates that all outstanding updates have been sent to the slave and that the master is waiting for more updates to occur. If you see no Binlog Dump threads on a master server, this means that replication is not running; that is, no slaves are currently connected.
On a slave server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
   Id: 10
   User: system user
   Host:  
   db: NULL
Command: Connect
   Time: 11
   State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
   Id: 11
   User: system user
   Host:  
   db: NULL
Command: Connect
   Time: 11
   State: Has read all relay log; waiting for the slave I/O
          thread to update it
   Info: NULL
```

The `State` information indicates that thread 10 is the I/O thread that is communicating with the master server, and thread 11 is the SQL thread that is processing the updates stored in the relay logs. At the time that `SHOW PROCESSLIST` was run, both threads were idle, waiting for further updates.

The value in the `Time` column can show how late the slave is compared to the master. See Section A.14, “MySQL 5.5 FAQ: Replication”. If sufficient time elapses on the master side without activity on the `Binlog Dump` thread, the master determines that the slave is no longer connected. As for any other client connection, the timeouts for this depend on the values of `net_write_timeout` and `net_retry_count`; for more information about these, see Section 5.1.7, “Server System Variables”.

The `SHOW SLAVE STATUS` statement provides additional information about replication processing on a slave server. See Section 17.1.4.1, “Checking Replication Status”.

### 17.2.2 Replication Relay and Status Logs

During replication, a slave server creates several logs that hold the binary log events relayed from the master to the slave, and to record information about the current status and location within the relay log. There are three types of logs used in the process, listed here:

- The **relay log** consists of the events read from the binary log of the master and written by the slave I/O thread. Events in the relay log are executed on the slave as part of the SQL thread.

- The **master info log** contains status and current configuration information for the slave's connection to the master. This log holds information on the master host name, login credentials, and coordinates indicating how far the slave has read from the master's binary log.

- The **relay log info log** holds status information about the execution point within the slave's relay log.

#### 17.2.2.1 The Slave Relay Log

The relay log, like the binary log, consists of a set of numbered files containing events that describe database changes, and an index file that contains the names of all used relay log files.

The term “relay log file” generally denotes an individual numbered file containing database events. The term “relay log” collectively denotes the set of numbered relay log files plus the index file.
Replication Relay and Status Logs

Relay log files have the same format as binary log files and can be read using `mysqlbinlog` (see Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files").

By default, relay log file names have the form `host_name-relay-bin.nnnnnn` in the data directory, where `host_name` is the name of the slave server host and `nnnnnn` is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with `000001`. The slave uses an index file to track the relay log files currently in use. The default relay log index file name is `host_name-relay-bin.index` in the data directory.

The default relay log file and relay log index file names can be overridden with, respectively, the `relay_log` and `relay_log_index` system variables (see Section 17.1.3, “Replication and Binary Logging Options and Variables”).

If a slave uses the default host-based relay log file names, changing a slave's host name after replication has been set up can cause replication to fail with the errors `Failed to open the relay log` and `Could not find target log during relay log initialization`. This is a known issue (see Bug #2122). If you anticipate that a slave's host name might change in the future (for example, if networking is set up on the slave such that its host name can be modified using DHCP), you can avoid this issue entirely by using the `relay_log` and `relay_log_index` system variables to specify relay log file names explicitly when you initially set up the slave. This will make the names independent of server host name changes.

If you encounter the issue after replication has already begun, one way to work around it is to stop the slave server, prepend the contents of the old relay log index file to the new one, and then restart the slave. On a Unix system, this can be done as shown here:

```
shell> cat new_relay_log_name.index >> old_relay_log_name.index
shell> mv old_relay_log_name.index new_relay_log_name.index
```

A slave server creates a new relay log file under the following conditions:

- Each time the I/O thread starts.
- When the logs are flushed (for example, with `FLUSH LOGS` or `mysqladmin flush-logs`).
- When the size of the current relay log file becomes “too large,” determined as follows:
  - If the value of `max_relay_log_size` is greater than 0, that is the maximum relay log file size.
  - If the value of `max_relay_log_size` is 0, `max_binlog_size` determines the maximum relay log file size.

The SQL thread automatically deletes each relay log file after it has executed all events in the file and no longer needs it. There is no explicit mechanism for deleting relay logs because the SQL thread takes care of doing so. However, `FLUSH LOGS` rotates relay logs, which influences when the SQL thread deletes them.

### 17.2.2.2 Slave Status Logs

A replication slave server creates two logs. By default, these logs are files named `master.info` and `relay-log.info` and created in the data directory. The names and locations of these files can be changed by using the `--master-info-file` option and the `relay_log_info_file` system variable, respectively. See Section 17.1.3, “Replication and Binary Logging Options and Variables”.

The two status logs contain information similar to that shown in the output of the `SHOW SLAVE STATUS` statement, which is discussed in Section 13.4.2, “SQL Statements for Controlling Slave Servers”. Because
the status logs are stored on disk, they survive a slave server’s shutdown. The next time the slave starts up, it reads the two logs to determine how far it has proceeded in reading binary logs from the master and in processing its own relay logs.

Access to the master info log should be restricted because it contains the password for connecting to the master. See Section 6.1.2.3, “Passwords and Logging”.

The slave I/O thread updates the master info log. The following table shows the correspondence between the lines in the `master.info` file and the columns displayed by `SHOW SLAVE STATUS`.

<table>
<thead>
<tr>
<th><code>master.info File Line</code></th>
<th><code>SHOW SLAVE STATUS Column</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><code>Number of lines in the file</code></td>
<td>Number of lines in the file</td>
</tr>
<tr>
<td>2</td>
<td><code>Master_Log_File</code></td>
<td>The name of the master binary log currently being read from the master</td>
</tr>
<tr>
<td>3</td>
<td><code>Read_Master_Log_Pos</code></td>
<td>The current position within the master binary log that have been read from the master</td>
</tr>
<tr>
<td>4</td>
<td><code>Master_Host</code></td>
<td>The host name of the master</td>
</tr>
<tr>
<td>5</td>
<td><code>Master_User</code></td>
<td>The user name used to connect to the master</td>
</tr>
<tr>
<td>6</td>
<td><code>Password (not shown by SHOW SLAVE STATUS)</code></td>
<td>The password used to connect to the master</td>
</tr>
<tr>
<td>7</td>
<td><code>Master_Port</code></td>
<td>The network port used to connect to the master</td>
</tr>
<tr>
<td>8</td>
<td><code>Connect_Retry</code></td>
<td>The period (in seconds) that the slave will wait before trying to reconnect to the master</td>
</tr>
<tr>
<td>9</td>
<td><code>Master_SSL_Allowed</code></td>
<td>Indicates whether the server supports SSL connections</td>
</tr>
<tr>
<td>10</td>
<td><code>Master_SSL_CA_File</code></td>
<td>The file used for the Certificate Authority (CA) certificate</td>
</tr>
<tr>
<td>11</td>
<td><code>Master_SSL_CA_Path</code></td>
<td>The path to the Certificate Authority (CA) certificates</td>
</tr>
<tr>
<td>12</td>
<td><code>Master_SSL_Cert</code></td>
<td>The name of the SSL certificate file</td>
</tr>
<tr>
<td>13</td>
<td><code>Master_SSL_Cipher</code></td>
<td>The list of possible ciphers used in the handshake for the SSL connection</td>
</tr>
<tr>
<td>14</td>
<td><code>Master_SSL_Key</code></td>
<td>The name of the SSL key file</td>
</tr>
<tr>
<td>15</td>
<td><code>Master_SSL_Verify_Server_Cert</code></td>
<td>Whether to verify the server certificate</td>
</tr>
<tr>
<td>16</td>
<td><code>Replicate_Ignore_Server_Ids</code></td>
<td>The number of server IDs to be ignored, followed by the actual server IDs</td>
</tr>
</tbody>
</table>

The slave SQL thread updates the relay log info log. The following table shows the correspondence between the lines in the `relay-log.info` file and the columns displayed by `SHOW SLAVE STATUS`.

<table>
<thead>
<tr>
<th><code>Line in relay-log.info</code></th>
<th><code>SHOW SLAVE STATUS Column</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><code>Relay_Log_File</code></td>
<td>The name of the current relay log file</td>
</tr>
</tbody>
</table>
How Servers Evaluate Replication Filtering Rules

### How Servers Evaluate Replication Filtering Rules

If a master server does not write a statement to its binary log, the statement is not replicated. If the server does log the statement, the statement is sent to all slaves and each slave determines whether to execute it or ignore it.

On the master, you can control which databases to log changes for by using the `--binlog-do-db` and `--binlog-ignore-db` options to control binary logging. For a description of the rules that servers use in evaluating these options, see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”. You should not use these options to control which databases and tables are replicated. Instead, use filtering on the slave to control the events that are executed on the slave.

On the slave side, decisions about whether to execute or ignore statements received from the master are made according to the `--replicate-*` options that the slave was started with. (See Section 17.1.3, “Replication and Binary Logging Options and Variables”.)

In the simplest case, when there are no `--replicate-*` options, the slave executes all statements that it receives from the master. Otherwise, the result depends on the particular options given.

Database-level options (`--replicate-do-db`, `--replicate-ignore-db`) are checked first; see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”, for a description of this process. If no database-level options are used, option checking proceeds to any table-level options that may be in use (see Section 17.2.3.2, “Evaluation of Table-Level Replication Options”, for a discussion of these). If one or more database-level options are used but none are matched, the statement is not replicated.

To make it easier to determine what effect an option set will have, it is recommended that you avoid mixing “do” and “ignore” options, or wildcard and nonwildcard options. An example of the latter that may have unintended effects is the use of `--replicate-do-db` and `--replicate-wild-do-table` together, where `--replicate-wild-do-table` uses a pattern for the database name that matches the name given for `--replicate-do-db`. Suppose a replication slave is started with `--replicate-do-db=dbx`.

<table>
<thead>
<tr>
<th>Line in <code>relay-log.info</code></th>
<th>SHOW SLAVE STATUS Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Relay_Log_Pos</td>
<td>The current position within the relay log file; events up to this position have been executed on the slave database</td>
</tr>
<tr>
<td>3</td>
<td>Relay_Master_Log_File</td>
<td>The name of the master binary log file from which the events in the relay log file were read</td>
</tr>
<tr>
<td>4</td>
<td>Exec_Master_Log_Pos</td>
<td>The equivalent position within the master's binary log file of events that have already been executed</td>
</tr>
</tbody>
</table>

The contents of the `relay-log.info` file and the states shown by the `SHOW SLAVE STATUS` statement might not match if the `relay-log.info` file has not been flushed to disk. Ideally, you should only view `relay-log.info` on a slave that is offline (that is, `mysqld` is not running). For a running system, `SHOW SLAVE STATUS` should be used.

When you back up the slave's data, you should back up these two status logs, along with the relay log files. The status logs are needed to resume replication after you restore the data from the slave. If you lose the relay logs but still have the relay log info log, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. Of course, this requires that the binary logs still exist on the master.
How Servers Evaluate Replication Filtering Rules

```
--replicate-wild-do-table=db%.t1. Then, suppose that on the master, you issue the statement CREATE DATABASE dbx. Although you might expect it, this statement is not replicated because it does not reference a table named t1.

If any --replicate-rewrite-db options were specified, they are applied before the --replicate-* filtering rules are tested.
```

Note

Database-level filtering options are case-sensitive on platforms supporting case sensitivity in filenames, whereas table-level filtering options are not (regardless of platform). This is true regardless of the value of the lower_case_table_names system variable.

17.2.3.1 Evaluation of Database-Level Replication and Binary Logging Options

When evaluating replication options, the slave begins by checking to see whether there are any --replicate-do-db or --replicate-ignore-db options that apply. When using --binlog-do-db or --binlog-ignore-db, the process is similar, but the options are checked on the master.

The database that is checked for a match depends on the binary log format of the statement that is being handled. If the statement has been logged using the row format, the database where data is to be changed is the database that is checked. If the statement has been logged using the statement format, the default database (specified with a USE statement) is the database that is checked.

Note

Only DML statements can be logged using the row format. DDL statements are always logged as statements, even when binlog_format=ROW. All DDL statements are therefore always filtered according to the rules for statement-based replication. This means that you must select the default database explicitly with a USE statement in order for a DDL statement to be applied.

For replication, the steps involved are listed here:

1. Which logging format is used?
   - **STATEMENT.** Test the default database.
   - **ROW.** Test the database affected by the changes.

2. Are there any --replicate-do-db options?
   - **Yes.** Does the database match any of them?
     - **Yes.** Continue to Step 4.
     - **No.** Ignore the update and exit.
   - **No.** Continue to step 3.

3. Are there any --replicate-ignore-db options?
   - **Yes.** Does the database match any of them?
     - **Yes.** Ignore the update and exit.
     - **No.** Continue to step 4.
4. Proceed to checking the table-level replication options, if there are any. For a description of how these options are checked, see Section 17.2.3.2, “Evaluation of Table-Level Replication Options”.

Important
A statement that is still permitted at this stage is not yet actually executed. The statement is not executed until all table-level options (if any) have also been checked, and the outcome of that process permits execution of the statement.

For binary logging, the steps involved are listed here:

1. Are there any --binlog-do-db or --binlog-ignore-db options?
   - Yes. Continue to step 2.
   - No. Log the statement and exit.

2. Is there a default database (has any database been selected by USE)?
   - Yes. Continue to step 3.
   - No. Ignore the statement and exit.

3. There is a default database. Are there any --binlog-do-db options?
   - Yes. Do any of them match the database?
     - Yes. Log the statement and exit.
     - No. Ignore the statement and exit.
   - No. Continue to step 4.

4. Do any of the --binlog-ignore-db options match the database?
   - Yes. Ignore the statement and exit.
   - No. Log the statement and exit.

Important
For statement-based logging, an exception is made in the rules just given for the CREATE DATABASE, ALTER DATABASE, and DROP DATABASE statements. In those cases, the database being created, altered, or dropped replaces the default database when determining whether to log or ignore updates.

--binlog-do-db can sometimes mean “ignore other databases”. For example, when using statement-based logging, a server running with only --binlog-do-db=sales does not write to the binary log statements for which the default database differs from sales. When using row-based logging with the same option, the server logs only those updates that change data in sales.

17.2.3.2 Evaluation of Table-Level Replication Options

The slave checks for and evaluates table options only if either of the following two conditions is true:

- No matching database options were found.
How Servers Evaluate Replication Filtering Rules

• One or more database options were found, and were evaluated to arrive at an “execute” condition according to the rules described in the previous section (see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”).

First, as a preliminary condition, the slave checks whether statement-based replication is enabled. If so, and the statement occurs within a stored function, the slave executes the statement and exits. If row-based replication is enabled, the slave does not know whether a statement occurred within a stored function on the master, so this condition does not apply.

Note

For statement-based replication, replication events represent statements (all changes making up a given event are associated with a single SQL statement); for row-based replication, each event represents a change in a single table row (thus a single statement such as UPDATE mytable SET mycol = 1 may yield many row-based events). When viewed in terms of events, the process of checking table options is the same for both row-based and statement-based replication.

Having reached this point, if there are no table options, the slave simply executes all events. If there are any --replicate-do-table or --replicate-wild-do-table options, the event must match one of these if it is to be executed; otherwise, it is ignored. If there are any --replicate-ignore-table or --replicate-wild-ignore-table options, all events are executed except those that match any of these options.

The following steps describe this evaluation in more detail. The starting point is the end of the evaluation of the database-level options, as described in Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”.

1. Are there any table replication options?
   • Yes. Continue to step 2.
   • No. Execute the update and exit.

2. Which logging format is used?
   • STATEMENT. Carry out the remaining steps for each statement that performs an update.
   • ROW. Carry out the remaining steps for each update of a table row.

3. Are there any --replicate-do-table options?
   • Yes. Does the table match any of them?
     • Yes. Execute the update and exit.
     • No. Continue to step 4.
   • No. Continue to step 4.

4. Are there any --replicate-ignore-table options?
   • Yes. Does the table match any of them?
     • Yes. Ignore the update and exit.
     • No. Continue to step 5.
How Servers Evaluate Replication Filtering Rules

5. Are there any `--replicate-wild-do-table` options?
   • Yes.  Does the table match any of them?
     • Yes.  Execute the update and exit.
     • No.  Continue to step 6.
   • No.  Continue to step 6.

6. Are there any `--replicate-wild-ignore-table` options?
   • Yes.  Does the table match any of them?
     • Yes.  Ignore the update and exit.
     • No.  Continue to step 7.
   • No.  Continue to step 7.

7. Is there another table to be tested?
   • Yes.  Go back to step 3.
   • No.  Continue to step 8.

8. Are there any `--replicate-do-table` or `--replicate-wild-do-table` options?
   • Yes.  Ignore the update and exit.
   • No.  Execute the update and exit.

Note
Statement-based replication stops if a single SQL statement operates on both a table that is included by a `--replicate-do-table` or `--replicate-wild-do-table` option, and another table that is ignored by a `--replicate-ignore-table` or `--replicate-wild-ignore-table` option. The slave must either execute or ignore the complete statement (which forms a replication event), and it cannot logically do this. This also applies to row-based replication for DDL statements, because DDL statements are always logged as statements, without regard to the logging format in effect. The only type of statement that can update both an included and an ignored table and still be replicated successfully is a DML statement that has been logged with `binlog_format=ROW`.

17.2.3.3 Replication Rule Application

This section provides additional explanation and examples of usage for different combinations of replication filtering options.

Some typical combinations of replication filter rule types are given in the following table:

<table>
<thead>
<tr>
<th>Condition (Types of Options)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>No <code>--replicate-*</code> options at all:</td>
<td>The slave executes all events that it receives from the master.</td>
</tr>
</tbody>
</table>
### Condition (Types of Options)

<table>
<thead>
<tr>
<th>Condition (Types of Options)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>--replicate-*-db options, but no table options:</td>
<td>The slave accepts or ignores events using the database options. It executes all events permitted by those options because there are no table restrictions.</td>
</tr>
<tr>
<td>--replicate-*-table options, but no database options:</td>
<td>All events are accepted at the database-checking stage because there are no database conditions. The slave executes or ignores events based solely on the table options.</td>
</tr>
<tr>
<td>A combination of database and table options:</td>
<td>The slave accepts or ignores events using the database options. Then it evaluates all events permitted by those options according to the table options. This can sometimes lead to results that seem counterintuitive, and that may be different depending on whether you are using statement-based or row-based replication; see the text for an example.</td>
</tr>
</tbody>
</table>

A more complex example follows, in which we examine the outcomes for both statement-based and row-based settings.

Suppose that we have two tables `mytbl1` in database `db1` and `mytbl2` in database `db2` on the master, and the slave is running with the following options (and no other replication filtering options):

- `replicate-ignore-db = db1`
- `replicate-do-table  = db2.tbl2`

Now we execute the following statements on the master:

```sql
USE db1;
INSERT INTO db2.tbl2 VALUES (1);
```

The results on the slave vary considerably depending on the binary log format, and may not match initial expectations in either case.

**Statement-based replication.** The `USE` statement causes `db1` to be the default database. Thus the `--replicate-ignore-db` option matches, and the `INSERT` statement is ignored. The table options are not checked.

**Row-based replication.** The default database has no effect on how the slave reads database options when using row-based replication. Thus, the `USE` statement makes no difference in how the `--replicate-ignore-db` option is handled: the database specified by this option does not match the database where the `INSERT` statement changes data, so the slave proceeds to check the table options. The table specified by `--replicate-do-table` matches the table to be updated, and the row is inserted.

### 17.3 Replication Solutions

Replication can be used in many different environments for a range of purposes. This section provides general notes and advice on using replication for specific solution types.

For information on using replication in a backup environment, including notes on the setup, backup procedure, and files to back up, see Section 17.3.1, “Using Replication for Backups”.

For advice and tips on using different storage engines on the master and slaves, see Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.

Using replication as a scale-out solution requires some changes in the logic and operation of applications that use the solution. See Section 17.3.3, “Using Replication for Scale-Out”.

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2065
For performance or data distribution reasons, you may want to replicate different databases to different replication slaves. See Section 17.3.4, “Replicating Different Databases to Different Slaves”.

As the number of replication slaves increases, the load on the master can increase and lead to reduced performance (because of the need to replicate the binary log to each slave). For tips on improving your replication performance, including using a single secondary server as a replication master, see Section 17.3.5, “Improving Replication Performance”.

For guidance on switching masters, or converting slaves into masters as part of an emergency failover solution, see Section 17.3.6, “Switching Masters During Failover”.

To secure your replication communication, you can encrypt the communication channel. For step-by-step instructions, see Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”.

### 17.3.1 Using Replication for Backups

To use replication as a backup solution, replicate data from the master to a slave, and then back up the data slave. The slave can be paused and shut down without affecting the running operation of the master, so you can produce an effective snapshot of “live” data that would otherwise require the master to be shut down.

How you back up a database depends on its size and whether you are backing up only the data, or the data and the replication slave state so that you can rebuild the slave in the event of failure. There are therefore two choices:

- If you are using replication as a solution to enable you to back up the data on the master, and the size of your database is not too large, the `mysqldump` tool may be suitable. See Section 17.3.1.1, “Backing Up a Slave Using mysqldump”.

- For larger databases, where `mysqldump` would be impractical or inefficient, you can back up the raw data files instead. Using the raw data files option also means that you can back up the binary and relay logs that will enable you to recreate the slave in the event of a slave failure. For more information, see Section 17.3.1.2, “Backing Up Raw Data from a Slave”.

Another backup strategy, which can be used for either master or slave servers, is to put the server in a read-only state. The backup is performed against the read-only server, which then is changed back to its usual read/write operational status. See Section 17.3.1.3, “Backing Up a Master or Slave by Making It Read Only”.

#### 17.3.1.1 Backing Up a Slave Using mysqldump

Using `mysqldump` to create a copy of a database enables you to capture all of the data in the database in a format that enables the information to be imported into another instance of MySQL Server (see Section 4.5.4, “mysqldump — A Database Backup Program”). Because the format of the information is SQL statements, the file can easily be distributed and applied to running servers in the event that you need access to the data in an emergency. However, if the size of your data set is very large, `mysqldump` may be impractical.

When using `mysqldump`, you should stop replication on the slave before starting the dump process to ensure that the dump contains a consistent set of data:

1. Stop the slave from processing requests. You can stop replication completely on the slave using `mysqladmin`:

   ```shell
   mysqladmin stop-slave
   ```

   Alternatively, you can stop only the slave SQL thread to pause event execution:
Using Replication for Backups

```
shell> mysql -e 'STOP SLAVE SQL_THREAD;'
```

This enables the slave to continue to receive data change events from the master's binary log and store them in the relay logs using the I/O thread, but prevents the slave from executing these events and changing its data. Within busy replication environments, permitting the I/O thread to run during backup may speed up the catch-up process when you restart the slave SQL thread.

2. Run `mysqldump` to dump your databases. You may either dump all databases or select databases to be dumped. For example, to dump all databases:

```
shell> mysqldump --all-databases > fulldb.dump
```

3. Once the dump has completed, start slave operations again:

```
shell> mysqladmin start-slave
```

In the preceding example, you may want to add login credentials (user name, password) to the commands, and bundle the process up into a script that you can run automatically each day.

If you use this approach, make sure you monitor the slave replication process to ensure that the time taken to run the backup does not affect the slave's ability to keep up with events from the master. See Section 17.1.4.1, “Checking Replication Status”. If the slave is unable to keep up, you may want to add another slave and distribute the backup process. For an example of how to configure this scenario, see Section 17.3.4, “Replicating Different Databases to Different Slaves”.

17.3.1.2 Backing Up Raw Data from a Slave

To guarantee the integrity of the files that are copied, backing up the raw data files on your MySQL replication slave should take place while your slave server is shut down. If the MySQL server is still running, background tasks may still be updating the database files, particularly those involving storage engines with background processes such as InnoDB. With InnoDB, these problems should be resolved during crash recovery, but since the slave server can be shut down during the backup process without affecting the execution of the master it makes sense to take advantage of this capability.

To shut down the server and back up the files:

1. Shut down the slave MySQL server:

```
shell> mysqladmin shutdown
```

2. Copy the data files. You can use any suitable copying or archive utility, including `cp`, `tar` or `WinZip`. For example, assuming that the data directory is located under the current directory, you can archive the entire directory as follows:

```
shell> tar cf /tmp/dbbackup.tar ./data
```

3. Start the MySQL server again. Under Unix:

```
shell> mysqld_safe &
```

Under Windows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"
```

Normally you should back up the entire data directory for the slave MySQL server. If you want to be able to restore the data and operate as a slave (for example, in the event of failure of the slave), then in addition to the slave's data, you should also back up the slave status files, `master.info` and `relay-log.info`,

2067
along with the relay log files. These files are needed to resume replication after you restore the slave’s data.

If you lose the relay logs but still have the *relay-log.info* file, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use **CHANGE MASTER TO** with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. This requires that the binary logs still exist on the master server.

If your slave is replicating `LOAD DATA` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA` operations. The location of this directory is the value of the `slave_load_tmpdir` system variable. If the server was not started with that variable set, the directory location is the value of the `tmpdir` system variable.

### 17.3.1.3 Backing Up a Master or Slave by Making It Read Only

It is possible to back up either master or slave servers in a replication setup by acquiring a global read lock and manipulating the `read_only` system variable to change the read-only state of the server to be backed up:

1. Make the server read-only, so that it processes only retrievals and blocks updates.
2. Perform the backup.
3. Change the server back to its normal read/write state.

**Note**

The instructions in this section place the server to be backed up in a state that is safe for backup methods that get the data from the server, such as `mysqldump` (see Section 4.5.4, “`mysqldump — A Database Backup Program`”). You should not attempt to use these instructions to make a binary backup by copying files directly because the server may still have modified data cached in memory and not flushed to disk.

The following instructions describe how to do this for a master server and for a slave server. For both scenarios discussed here, suppose that you have the following replication setup:

- A master server M1
- A slave server S1 that has M1 as its master
- A client C1 connected to M1
- A client C2 connected to S1

In either scenario, the statements to acquire the global read lock and manipulate the `read_only` variable are performed on the server to be backed up and do not propagate to any slaves of that server.

**Scenario 1: Backup with a Read-Only Master**

Put the master M1 in a read-only state by executing these statements on it:

```sql
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While M1 is in a read-only state, the following properties are true:
Using Replication with Different Master and Slave Storage Engines

- Requests for updates sent by C1 to M1 will block because the server is in read-only mode.
- Requests for query results sent by C1 to M1 will succeed.
- Making a backup on M1 is safe.
- Making a backup on S1 is not safe. This server is still running, and might be processing the binary log or update requests coming from client C2.

While M1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on M1 completes, restore M1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

Although performing the backup on M1 is safe (as far as the backup is concerned), it is not optimal for performance because clients of M1 are blocked from executing updates.

This strategy applies to backing up a master server in a replication setup, but can also be used for a single server in a nonreplication setting.

**Scenario 2: Backup with a Read-Only Slave**

Put the slave S1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While S1 is in a read-only state, the following properties are true:

- The master M1 will continue to operate, so making a backup on the master is not safe.
- The slave S1 is stopped, so making a backup on the slave S1 is safe.

These properties provide the basis for a popular backup scenario: Having one slave busy performing a backup for a while is not a problem because it does not affect the entire network, and the system is still running during the backup. In particular, clients can still perform updates on the master server, which remains unaffected by backup activity on the slave.

While S1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on S1 completes, restore S1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

After the slave is restored to normal operation, it again synchronizes to the master by catching up with any outstanding updates from the binary log of the master.

### 17.3.2 Using Replication with Different Master and Slave Storage Engines

It does not matter for the replication process whether the source table on the master and the replicated table on the slave use different engine types. In fact, the `default_storage_engine` and `storage_engine` system variables are not replicated.
This provides a number of benefits in the replication process in that you can take advantage of different engine types for different replication scenarios. For example, in a typical scale-out scenario (see Section 17.3.3, "Using Replication for Scale-Out"), you want to use InnoDB tables on the master to take advantage of the transactional functionality, but use MyISAM on the slaves where transaction support is not required because the data is only read. When using replication in a data-logging environment you may want to use the Archive storage engine on the slave.

Configuring different engines on the master and slave depends on how you set up the initial replication process:

- If you used mysqldump to create the database snapshot on your master, you could edit the dump file text to change the engine type used on each table.
  
  Another alternative for mysqldump is to disable engine types that you do not want to use on the slave before using the dump to build the data on the slave. For example, you can add the --skip-innodb option on your slave to disable the InnoDB engine. If a specific engine does not exist for a table to be created, MySQL will use the default engine type, usually MyISAM. (This requires that the NO_ENGINE_SUBSTITUTION SQL mode is not enabled.) If you want to disable additional engines in this way, you may want to consider building a special binary to be used on the slave that only supports the engines you want.

- If you are using raw data files (a binary backup) to set up the slave, you will be unable to change the initial table format. Instead, use ALTER TABLE to change the table types after the slave has been started.

- For new master/slave replication setups where there are currently no tables on the master, avoid specifying the engine type when creating new tables.

If you are already running a replication solution and want to convert your existing tables to another engine type, follow these steps:

1. Stop the slave from running replication updates:

   ```
   mysql> STOP SLAVE;
   ```

   This will enable you to change engine types without interruptions.

2. Execute an ALTER TABLE ... ENGINE='engine_type' for each table to be changed.

3. Start the slave replication process again:

   ```
   mysql> START SLAVE;
   ```

Although the default_storage_engine variable is not replicated, be aware that CREATE TABLE and ALTER TABLE statements that include the engine specification will be correctly replicated to the slave. For example, if you have a CSV table and you execute:

```
mysql> ALTER TABLE csvtable Engine='MyISAM';
```

The above statement will be replicated to the slave and the engine type on the slave will be converted to MyISAM, even if you have previously changed the table type on the slave to an engine other than CSV. If you want to retain engine differences on the master and slave, you should be careful to use the default_storage_engine variable on the master when creating a new table. For example, instead of:

```
mysql> CREATE TABLE tablea (columna int) Engine=MyISAM;
```

Use this format:

```
mysql> SET default_storage_engine=MyISAM;
```
17.3.3 Using Replication for Scale-Out

You can use replication as a scale-out solution; that is, where you want to split up the load of database queries across multiple database servers, within some reasonable limitations.

Because replication works from the distribution of one master to one or more slaves, using replication for scale-out works best in an environment where you have a high number of reads and low number of writes/updates. Most websites fit into this category, where users are browsing the website, reading articles, posts, or viewing products. Updates only occur during session management, or when making a purchase or adding a comment/message to a forum.

Replication in this situation enables you to distribute the reads over the replication slaves, while still enabling your web servers to communicate with the replication master when a write is required. You can see a sample replication layout for this scenario in Figure 17.1, "Using Replication to Improve Performance During Scale-Out".

Figure 17.1 Using Replication to Improve Performance During Scale-Out

If the part of your code that is responsible for database access has been properly abstracted/modularized, converting it to run with a replicated setup should be very smooth and easy. Change the implementation of your database access to send all writes to the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system gives you the opportunity and motivation to clean it up. Start by creating a wrapper library or module that implements the following functions:

- `safe_writer_connect()`
- `safe_reader_connect()`
- `safe_reader_statement()`
- `safe_writer_statement()`
safe_in each function name means that the function takes care of handling all error conditions. You can use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

Then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it pays off in the long run. All applications that use the approach just described are able to take advantage of a master/slave configuration, even one involving multiple slaves. The code is much easier to maintain, and adding troubleshooting options is trivial. You need modify only one or two functions (for example, to log how long each statement took, or which statement among those issued gave you an error).

If you have written a lot of code, you may want to automate the conversion task by using the replace utility that comes with standard MySQL distributions, or write your own conversion script. Ideally, your code uses consistent programming style conventions. If not, then you are probably better off rewriting it anyway, or at least going through and manually regularizing it to use a consistent style.

### 17.3.4 Replicating Different Databases to Different Slaves

There may be situations where you have a single master and want to replicate different databases to different slaves. For example, you may want to distribute different sales data to different departments to help spread the load during data analysis. A sample of this layout is shown in Figure 17.2, “Using Replication to Replicate Databases to Separate Replication Slaves”.

![Figure 17.2 Using Replication to Replicate Databases to Separate Replication Slaves](image)

You can achieve this separation by configuring the master and slaves as normal, and then limiting the binary log statements that each slave processes by using the `--replicate-wild-do-table` configuration option on each slave.

**Important**

You should not use `--replicate-do-db` for this purpose when using statement-based replication, since statement-based replication causes this option’s effects to vary according to the database that is currently selected. This applies to mixed-format replication as well, since this enables some updates to be replicated using the statement-based format.

However, it should be safe to use `--replicate-do-db` for this purpose if you are using row-based replication only, since in this case the currently selected database has no effect on the option’s operation.

For example, to support the separation as shown in Figure 17.2, “Using Replication to Replicate Databases to Separate Replication Slaves”, you should configure each replication slave as follows, before executing `START SLAVE`:

- Replication slave 1 should use `--replicate-wild-do-table=databaseA.%`.
- Replication slave 2 should use `--replicate-wild-do-table=databaseB.%`. 
• Replication slave 3 should use `--replicate-wild-do-table=databaseC.%`.

Each slave in this configuration receives the entire binary log from the master, but executes only those events from the binary log that apply to the databases and tables included by the `--replicate-wild-do-table` option in effect on that slave.

If you have data that must be synchronized to the slaves before replication starts, you have a number of choices:

• Synchronize all the data to each slave, and delete the databases, tables, or both that you do not want to keep.

• Use `mysqldump` to create a separate dump file for each database and load the appropriate dump file on each slave.

• Use a raw data file dump and include only the specific files and databases that you need for each slave.

**Note**

This does not work with InnoDB databases unless you use `innodb_file_per_table`.

### 17.3.5 Improving Replication Performance

As the number of slaves connecting to a master increases, the load, although minimal, also increases, as each slave uses a client connection to the master. Also, as each slave must receive a full copy of the master binary log, the network load on the master may also increase and create a bottleneck.

If you are using a large number of slaves connected to one master, and that master is also busy processing requests (for example, as part of a scale-out solution), then you may want to improve the performance of the replication process.

One way to improve the performance of the replication process is to create a deeper replication structure that enables the master to replicate to only one slave, and for the remaining slaves to connect to this primary slave for their individual replication requirements. A sample of this structure is shown in Figure 17.3, “Using an Additional Replication Host to Improve Performance”.

**Figure 17.3 Using an Additional Replication Host to Improve Performance**

For this to work, you must configure the MySQL instances as follows:

• Master 1 is the primary master where all changes and updates are written to the database. Binary logging should be enabled on this machine.

• Master 2 is the slave to the Master 1 that provides the replication functionality to the remainder of the slaves in the replication structure. Master 2 is the only machine permitted to connect to Master 1. Master 2 also has binary logging enabled, and the `log_slave_updates` system variable enabled so that
replication instructions from Master 1 are also written to Master 2's binary log so that they can then be replicated to the true slaves.

- Slave 1, Slave 2, and Slave 3 act as slaves to Master 2, and replicate the information from Master 2, which actually consists of the upgrades logged on Master 1.

The above solution reduces the client load and the network interface load on the primary master, which should improve the overall performance of the primary master when used as a direct database solution.

If your slaves are having trouble keeping up with the replication process on the master, there are a number of options available:

- If possible, put the relay logs and the data files on different physical drives. To do this, set the `relay_log` system variable to specify the location of the relay log.

- If the slaves are significantly slower than the master, you may want to divide up the responsibility for replicating different databases to different slaves. See Section 17.3.4, “Replicating Different Databases to Different Slaves”.

- If your master makes use of transactions and you are not concerned about transaction support on your slaves, use MyISAM or another nontransactional engine on the slaves. See Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.

- If your slaves are not acting as masters, and you have a potential solution in place to ensure that you can bring up a master in the event of failure, then you can disable the `log_slave_updates` system variable. This prevents "dumb" slaves from also logging events they have executed into their own binary log.

17.3.6 Switching Masters During Failover

There is in MySQL 5.5 no official solution for providing failover between master and slaves in the event of a failure. Instead, you must set up a master and one or more slaves; then, you need to write an application or script that monitors the master to check whether it is up, and instructs the slaves and applications to change master in case of failure. This section discusses some of the issues encountered when setting up failover in this fashion.

You can tell a slave to change to a new master using the `CHANGE MASTER TO` statement. The slave does not check whether the databases on the master are compatible with those on the slave; it simply begins reading and executing events from the specified coordinates in the new master's binary log. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the structure or integrity of the database, provided that you exercise care in making the change.

Slaves should be run with the `--log-bin` option and without enabling the `log_slave_updates` system variable. In this way, the slave is ready to become a master without restarting the slave `mysql`. Assume that you have the structure shown in Figure 17.4, “Redundancy Using Replication, Initial Structure”.

Remember that you can tell a slave to change its master at any time, using the `CHANGE MASTER TO` statement. The slave will not check whether the databases on the master are compatible with the slave; it will just start reading and executing events from the specified binary log coordinates on the new master. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the database structure or integrity providing you are careful.

Run your slaves with the `--log-bin` option and without enabling the `log_slave_updates` system variable. In this way, the slave is ready to become a master as soon as you issue `STOP SLAVE; RESET`
Switching Masters During Failover

MASTER, and CHANGE MASTER TO statement on the other slaves. For example, assume that you have the structure shown in Figure 17.4, “Redundancy Using Replication, Initial Structure”.

Figure 17.4 Redundancy Using Replication, Initial Structure

In this diagram, the MySQL Master holds the master database, the MySQL Slave hosts are replication slaves, and the Web Client machines are issuing database reads and writes. Web clients that issue only reads (and would normally be connected to the slaves) are not shown, as they do not need to switch to a new server in the event of failure. For a more detailed example of a read/write scale-out replication structure, see Section 17.3.3, “Using Replication for Scale-Out”.

Each MySQL Slave (Slave 1, Slave 2, and Slave 3) is a slave running with --log-bin and without enabling the log_slave_updates system variable. Because updates received by a slave from the master are not logged in the binary log unless log_slave_updates is enabled, the binary log on each slave is empty initially. If for some reason MySQL Master becomes unavailable, you can pick one of the slaves to become the new master. For example, if you pick Slave 1, all Web Clients should be redirected to Slave 1, which writes the updates to its binary log. Slave 2 and Slave 3 should then replicate from Slave 1.

The reason for running the slave without log_slave_updates enabled is to prevent slaves from receiving updates twice in case you cause one of the slaves to become the new master. If Slave 1 has log_slave_updates enabled, it writes any updates that it receives from Master in its own binary log. This means that, when Slave 2 changes from Master to Slave 1 as its master, it may receive updates from Slave 1 that it has already received from Master.

Make sure that all slaves have processed any statements in their relay log. On each slave, issue STOP SLAVE IO_THREAD, then check the output of SHOW PROCESSLIST until you see Has read all relay log. When this is true for all slaves, they can be reconfigured to the new setup. On the slave Slave 1 being promoted to become the master, issue STOP SLAVE and RESET MASTER.

On the other slaves Slave 2 and Slave 3, use STOP SLAVE and CHANGE MASTER TO MASTER_HOST='Slave1' (where 'Slave1' represents the real host name of Slave 1). To use CHANGE MASTER TO, add all information about how to connect to Slave 1 from Slave 2 or Slave 3 (user, password, port). When issuing the CHANGE MASTER TO statement in this, there is no need to specify the name of the Slave 1 binary log file or log position to read from, since the first binary log file and position 4, are the defaults. Finally, execute START SLAVE on Slave 2 and Slave 3.
Once the new replication setup is in place, you need to tell each Web Client to direct its statements to Slave 1. From that point on, all updates statements sent by Web Client to Slave 1 are written to the binary log of Slave 1, which then contains every update statement sent to Slave 1 since Master died.

The resulting server structure is shown in Figure 17.5, “Redundancy Using Replication, After Master Failure”.

**Figure 17.5 Redundancy Using Replication, After Master Failure**

When Master becomes available again, you should make it a slave of Slave 1. To do this, issue on Master the same CHANGE MASTER TO statement as that issued on Slave 2 and Slave 3 previously. Master then becomes a slave of Slave 1 and picks up the Web Client writes that it missed while it was offline.

To make Master a master again, use the preceding procedure as if Slave 1 was unavailable and Master was to be the new master. During this procedure, do not forget to run RESET MASTER on Master before making Slave 1, Slave 2, and Slave 3 slaves of Master. If you fail to do this, the slaves may pick up stale writes from the Web Client applications dating from before the point at which Master became unavailable.

You should be aware that there is no synchronization between slaves, even when they share the same master, and thus some slaves might be considerably ahead of others. This means that in some cases the procedure outlined in the previous example might not work as expected. In practice, however, relay logs on all slaves should be relatively close together.

One way to keep applications informed about the location of the master is to have a dynamic DNS entry for the master. With bind you can use nsupdate to update the DNS dynamically.

### 17.3.7 Setting Up Replication to Use Encrypted Connections

To use an encrypted connection for the transfer of the binary log required during replication, both the master and the slave servers must support encrypted network connections. If either server does not support encrypted connections (because it has not been compiled or configured for them), replication through an encrypted connection is not possible.
Setting up encrypted connections for replication is similar to doing so for client/server connections. You must obtain (or create) a suitable security certificate that you can use on the master, and a similar certificate (from the same certificate authority) on each slave. You must also obtain suitable key files.

For more information on setting up a server and client for encrypted connections, see Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”.

To enable encrypted connections on the master, you must create or obtain suitable certificate and key files, and then add the following configuration options to the master's configuration within the [mysqld] section of the master's my.cnf file, changing the file names as necessary:

```
[mysqld]
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

The paths to the files may be relative or absolute; we recommend that you always use complete paths for this purpose.

The options are as follows:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)
- `--ssl-cert`: The path name of the server public key certificate file. This certificate can be sent to the client and authenticated against the CA certificate that it has.
- `--ssl-key`: The path name of the server private key file.

On the slave, there are two ways to specify the information required for connecting using encryption to the master. You can either name the slave certificate and key files in the [client] section of the slave's my.cnf file, or you can explicitly specify that information using the CHANGE MASTER TO statement:

- To name the slave certificate and key files using an option file, add the following lines to the [client] section of the slave's my.cnf file, changing the file names as necessary:

  ```
  [client]
  ssl-ca=cacert.pem
  ssl-cert=client-cert.pem
  ssl-key=client-key.pem
  ```

  Restart the slave server, using the `--skip-slave-start` option to prevent the slave from connecting to the master. Use CHANGE MASTER TO to specify the master configuration, using the MASTER_SSL option to connect using encryption:

  ```
  mysql> CHANGE MASTER TO
        -> MASTER_HOST='master_hostname',
        -> MASTER_USER='replicate',
        -> MASTER_PASSWORD='password',
        -> MASTER_SSL=1;
  ```

- To specify the certificate and key names using the CHANGE MASTER TO statement, append the appropriate MASTER_SSL.xxx options:

  ```
  mysql> CHANGE MASTER TO
        -> MASTER_HOST='master_hostname',
        -> MASTER_USER='replicate',
        -> MASTER_PASSWORD='password',
        -> MASTER_SSL=1,
        -> MASTER_SSL_CA = 'ca_file_name',
        -> MASTER_SSL_CAPATH = 'ca_directory_name',
  ```
After the master information has been updated, start the slave replication process:

```sql
mysql> START SLAVE;
```

You can use the `SHOW SLAVE STATUS` statement to confirm that an encrypted connection was established successfully.

For more information on the `CHANGE MASTER TO` statement, see Section 13.4.2.1, "CHANGE MASTER TO Statement".

If you want to enforce the use of encrypted connections during replication, create a user with the `REPLICATION SLAVE` privilege and use the `REQUIRE SSL` option for that user. For example:

```sql
mysql> CREATE USER 'repl'@'%.example.com' IDENTIFIED BY 'password';
mysql> GRANT REPLICATION SLAVE ON *.* TO 'repl'@'%.example.com' REQUIRE SSL;
```

If the account already exists, you can add `REQUIRE SSL` to it with this statement:

```sql
mysql> GRANT USAGE ON *.* TO 'repl'@'%.example.com' REQUIRE SSL;
```

### 17.3.8 Semisynchronous Replication

In addition to the built-in asynchronous replication, MySQL 5.5 supports an interface to semisynchronous replication that is implemented by plugins. This section discusses what semisynchronous replication is and how it works. The following sections cover the administrative interface to semisynchronous replication and how to install, configure, and monitor it.

MySQL replication by default is asynchronous. The master writes events to its binary log but does not know whether or when a slave has retrieved and processed them. With asynchronous replication, if the master crashes, transactions that it has committed might not have been transmitted to any slave. Consequently, failover from master to slave in this case may result in failover to a server that is missing transactions relative to the master.

Semisynchronous replication can be used as an alternative to asynchronous replication:

- A slave indicates whether it is semisynchronous-capable when it connects to the master.
- If semisynchronous replication is enabled on the master side and there is at least one semisynchronous slave, a thread that performs a transaction commit on the master blocks after the commit is done and waits until at least one semisynchronous slave acknowledges that it has received all events for the transaction, or until a timeout occurs.
- The slave acknowledges receipt of a transaction’s events only after the events have been written to its relay log and flushed to disk.
- If a timeout occurs without any slave having acknowledged the transaction, the master reverts to asynchronous replication. When at least one semisynchronous slave catches up, the master returns to semisynchronous replication.
- Semisynchronous replication must be enabled on both the master and slave sides. If semisynchronous replication is disabled on the master, or enabled on the master but on no slaves, the master uses asynchronous replication.

While the master is blocking (waiting for acknowledgment from a slave after having performed a commit), it does not return to the session that performed the transaction. When the block ends, the master returns...
to the session, which then can proceed to execute other statements. At this point, the transaction has
committed on the master side, and receipt of its events has been acknowledged by at least one slave.

Blocking also occurs after rollbacks that are written to the binary log, which occurs when a transaction that
modifies nontransactional tables is rolled back. The rolled-back transaction is logged even though it has
no effect for transactional tables because the modifications to the nontransactional tables cannot be rolled
back and must be sent to slaves.

For statements that do not occur in transactional context (that is, when no transaction has been started
with \texttt{START TRANSACTION} or \texttt{SET autocommit = 0}), autocommit is enabled and each statement
commits implicitly. With semisynchronous replication, the master blocks after committing each such
statement, just as it does for explicit transaction commits.

To understand what the “semi” in “semisynchronous replication” means, compare it with asynchronous and
fully synchronous replication:

- With asynchronous replication, the master writes events to its binary log and slaves request them when
  they are ready. There is no guarantee that any event will ever reach any slave.

- With fully synchronous replication, when a master commits a transaction, all slaves also will have
  committed the transaction before the master returns to the session that performed the transaction. The
drawback of this is that there might be a lot of delay to complete a transaction.

- Semisynchronous replication falls between asynchronous and fully synchronous replication. The master
  waits after commit only until at least one slave has received and logged the events. It does not wait
  for all slaves to acknowledge receipt, and it requires only receipt, not that the events have been fully
  executed and committed on the slave side.

Compared to asynchronous replication, semisynchronous replication provides improved data integrity.
When a commit returns successfully, it is known that the data exists in at least two places (on the
master and at least one slave). If the master commits but a crash occurs while the master is waiting for
acknowledgment from a slave, it is possible that the transaction may not have reached any slave.

Semisynchronous replication also places a rate limit on busy sessions by constraining the speed at which
binary log events can be sent from master to slave. When one user is too busy, this will slow it down, which
is useful in some deployment situations.

Semisynchronous replication does have some performance impact because commits are slower due to the
need to wait for slaves. This is the tradeoff for increased data integrity. The amount of slowdown is at least
the TCP/IP roundtrip time to send the commit to the slave and wait for the acknowledgment of receipt by
the slave. This means that semisynchronous replication works best for close servers communicating over
fast networks, and worst for distant servers communicating over slow networks.

17.3.8.1 Semisynchronous Replication Administrative Interface

The administrative interface to semisynchronous replication has several components:

- Two plugins implement semisynchronous capability. There is one plugin for the master side and one for
  the slave side.

- System variables control plugin behavior. Some examples:

  - \texttt{rpl\_semi\_sync\_master\_enabled}
    
    Controls whether semisynchronous replication is enabled on the master. To enable or disable the
    plugin, set this variable to 1 or 0, respectively. The default is 0 (off).

  - \texttt{rpl\_semi\_sync\_master\_timeout}
A value in milliseconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10000 (10 seconds).

- **rpl_semi_sync_slave_enabled**
  Similar to **rpl_semi_sync_master_enabled**, but controls the slave plugin.

All **rpl_semi_sync_** system variables are described at Section 5.1.7, “Server System Variables”.

- Status variables enable semisynchronous replication monitoring. Some examples:
  - **Rpl_semi_sync_master_clients**
    The number of semisynchronous slaves.
  - **Rpl_semi_sync_master_status**
    Whether semisynchronous replication currently is operational on the master. The value is 1 if the plugin has been enabled and a commit acknowledgment has occurred. It is 0 if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.
  - **Rpl_semi_sync_master_no_tx**
    The number of commits that were not acknowledged successfully by a slave.
  - **Rpl_semi_sync_master_yes_tx**
    The number of commits that were acknowledged successfully by a slave.
  - **Rpl_semi_sync_slave_status**
    Whether semisynchronous replication currently is operational on the slave. This is 1 if the plugin has been enabled and the slave I/O thread is running, 0 otherwise.

All **Rpl_semi_sync_** status variables are described at Section 5.1.9, “Server Status Variables”.

The system and status variables are available only if the appropriate master or slave plugin has been installed with INSTALL PLUGIN.

### 17.3.8.2 Semisynchronous Replication Installation and Configuration

Semisynchronous replication is implemented using plugins, so the plugins must be installed into the server to make them available. After a plugin has been installed, you control it by means of the system variables associated with it. These system variables are unavailable until the associated plugin has been installed.

This section describes how to install the semisynchronous replication plugins. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To use semisynchronous replication, the following requirements must be satisfied:

- MySQL 5.5 or higher must be installed.
- The capability of installing plugins requires a MySQL server that supports dynamic loading. To verify this, check that the value of the **have_dynamic_loading** system variable is YES. Binary distributions should support dynamic loading.
Semisynchronous Replication

- Replication must already be working. For information on creating a master/slave relationship, see Section 17.1.1, “How to Set Up Replication”.

To set up semisynchronous replication, use the following instructions. The `INSTALL PLUGIN`, `SET GLOBAL`, `STOP SLAVE`, and `START SLAVE` statements mentioned here require the `SUPER` privilege.

MySQL distributions include semisynchronous replication plugin files for the master side and the slave side.

To be usable by a master or slave server, the appropriate plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, configure the plugin directory location by setting the value of `plugin_dir` at server startup.

The plugin library file base names are `semisync_master` and `semisync_slave`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

The master plugin library file must be present in the plugin directory of the master server. The slave plugin library file must be present in the plugin directory of each slave server.

To load the plugins, use the `INSTALL PLUGIN` statement on the master and on each slave that is to be semisynchronous (adjust the `.so` suffix for your platform as necessary).

On the master:

```
INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
```

On each slave:

```
INSTALL PLUGIN rpl_semi_sync_slave SONAME 'semisync_slave.so';
```

If an attempt to install a plugin results in an error on Linux similar to that shown here, you must install `libimf`:

```
mysql> INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
ERROR 1126 (HY000): Can't open shared library
'/usr/local/mysql/lib/plugin/semisync_master.so'
  (errno: 22 libimf.so: cannot open shared object file:
No such file or directory)
```

You can obtain `libimf` from https://dev.mysql.com/downloads/os-linux.html.

To see which plugins are installed, use the `SHOW PLUGINS` statement, or query the `INFORMATION_SCHEMA.PLUGINS` table.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
                  FROM INFORMATION_SCHEMA.PLUGINS
                 WHERE PLUGIN_NAME LIKE '%semi%';
+----------------------+---------------+
| PLUGIN_NAME          | PLUGIN_STATUS |
|----------------------|---------------+
| rpl_semi_sync_master | ACTIVE        |
+----------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

After a semisynchronous replication plugin has been installed, it is disabled by default. The plugins must be enabled both on the master side and the slave side to enable semisynchronous replication. If only one side is enabled, replication will be asynchronous.
To control whether an installed plugin is enabled, set the appropriate system variables. You can set these variables at runtime using SET GLOBAL, or at server startup on the command line or in an option file.

At runtime, these master-side system variables are available:

```
SET GLOBAL rpl_semi_sync_master_enabled = {0|1};
SET GLOBAL rpl_semi_sync_master_timeout = N;
```

On the slave side, this system variable is available:

```
SET GLOBAL rpl_semi_sync_slave_enabled = {0|1};
```

For `rpl_semi_sync_master_enabled` or `rpl_semi_sync_slave_enabled`, the value should be 1 to enable semisynchronous replication or 0 to disable it. By default, these variables are set to 0.

For `rpl_semi_sync_master_timeout`, the value `N` is given in milliseconds. The default value is 10000 (10 seconds).

If you enable semisynchronous replication on a slave at runtime, you must also start the slave I/O thread (stopping it first if it is already running) to cause the slave to connect to the master and register as a semisynchronous slave:

```
STOP SLAVE IO_THREAD;
START SLAVE IO_THREAD;
```

If the I/O thread is already running and you do not restart it, the slave continues to use asynchronous replication.

At server startup, the variables that control semisynchronous replication can be set as command-line options or in an option file. A setting listed in an option file takes effect each time the server starts. For example, you can set the variables in `my.cnf` files on the master and slave sides as follows.

On the master:

```
[mysqld]
rpl_semi_sync_master_enabled=1
rpl_semi_sync_master_timeout=1000 # 1 second
```

On each slave:

```
[mysqld]
rpl_semi_sync_slave_enabled=1
```

### 17.3.8.3 Semisynchronous Replication Monitoring

The plugins for the semisynchronous replication capability expose several system and status variables that you can examine to determine its configuration and operational state.

The system variable reflect how semisynchronous replication is configured. To check their values, use `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'rpl_semi_sync%';
```

The status variables enable you to monitor the operation of semisynchronous replication. To check their values, use `SHOW STATUS`:

```
mysql> SHOW STATUS LIKE 'Rpl_semi_sync%';
```

When the master switches between asynchronous or semisynchronous replication due to commit-blocking timeout or a slave catching up, it sets the value of the `Rpl_semi_sync_master_status` status variable
appropriately. Automatic fallback from semisynchronous to asynchronous replication on the master means that it is possible for the `rpl_semi_sync_master_enabled` system variable to have a value of 1 on the master side even when semisynchronous replication is in fact not operational at the moment. You can monitor the `rpl_semi_sync_master_status` status variable to determine whether the master currently is using asynchronous or semisynchronous replication.

To see how many semisynchronous slaves are connected, check `Rpl_semi_sync_master_clients`.

The number of commits that have been acknowledged successfully or unsuccessfully by slaves are indicated by the `Rpl_semi_sync_master_yes_tx` and `Rpl_semi_sync_master_no_tx` variables.

On the slave side, `Rpl_semi_sync_slave_status` indicates whether semisynchronous replication currently is operational.

## 17.4 Replication Notes and Tips

### 17.4.1 Replication Features and Issues

The following sections provide information about what is supported and what is not in MySQL replication, and about specific issues and situations that may occur when replicating certain statements.

Statement-based replication depends on compatibility at the SQL level between the master and slave. In others, successful SBR requires that any SQL features used be supported by both the master and the slave servers. For example, if you use a feature on the master server that is available only in MySQL 5.5 (or later), you cannot replicate to a slave that uses MySQL 5.1 (or earlier).

Such incompatibilities also can occur within a release series when using pre-production releases of MySQL. For example, the `SLEEP()` function is available beginning with MySQL 5.0.12. If you use this function on the master, you cannot replicate to a slave that uses MySQL 5.0.11 or earlier.

For this reason, use Generally Available (GA) releases of MySQL for statement-based replication in a production setting, since we do not introduce new SQL statements or change their behavior within a given release series once that series reaches GA release status.

If you are planning to use statement-based replication between MySQL 5.5 and a previous MySQL release series, it is also a good idea to consult the edition of the MySQL Reference Manual corresponding to the earlier release series for information regarding the replication characteristics of that series.

With MySQL's statement-based replication, there may be issues with replicating stored routines or triggers. You can avoid these issues by using MySQL's row-based replication instead. For a detailed list of issues, see Section 20.7, “Stored Program Binary Logging”. For more information about row-based logging and row-based replication, see Section 5.4.4.1, “Binary Logging Formats”, and Section 17.1.2, “Replication Formats”.

For additional information specific to replication and InnoDB, see Section 14.22, “InnoDB and MySQL Replication”. For information relating to replication with NDB Cluster, see Section 18.6, “NDB Cluster Replication”.

### 17.4.1.1 Replication and AUTO_INCREMENT

Statement-based replication of `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values is done correctly, subject to the following exceptions:

- When using statement-based replication prior to MySQL 5.5.30, `AUTO_INCREMENT` columns in tables on the slave must match the same columns on the master; that is, `AUTO_INCREMENT` columns must be replicated to `AUTO_INCREMENT` columns. (Bug #12669186)
Replication Features and Issues

- A statement invoking a trigger or function that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. In MySQL 5.5, such statements are marked as unsafe. (Bug #45677)

- An `INSERT` into a table that has a composite primary key that includes an `AUTO_INCREMENT` column that is not the first column of this composite key is not safe for statement-based logging or replication. Beginning with MySQL 5.5.25, such statements are marked as unsafe. (Bug #11754117, Bug #45670)

  This issue does not affect tables using the InnoDB storage engine, since an InnoDB table with an `AUTO_INCREMENT` column requires at least one key where the auto-increment column is the only or leftmost column.

- Adding an `AUTO_INCREMENT` column to a table with `ALTER TABLE` might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to a table `t1` that has columns `col1` and `col2`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

  ```sql
  CREATE TABLE t2 LIKE t1;
  ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
  INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
  ```

  **Important**
  To guarantee the same ordering on both master and slave, the `ORDER BY` clause must name all columns of `t1`.

  The instructions just given are subject to the limitations of `CREATE TABLE ... LIKE`: Foreign key definitions are ignored, as are the `DATA DIRECTORY` and `INDEX DIRECTORY` table options. If a table definition includes any of those characteristics, create `t2` using a `CREATE TABLE` statement that is identical to the one used to create `t1`, but with the addition of the `AUTO_INCREMENT` column.

  Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

  ```sql
  DROP t1;
  ALTER TABLE t2 RENAME t1;
  ```

  See also Section B.4.6.1, “Problems with ALTER TABLE”.

17.4.1.2 Replication and BLACKHOLE Tables

The `BLACKHOLE` storage engine accepts data but discards it and does not store it. When performing binary logging, all inserts to such tables are always logged, regardless of the logging format in use. Updates and deletes are handled differently depending on whether statement based or row based logging is in use.

With the statement based logging format, all statements affecting `BLACKHOLE` tables are logged, but their effects ignored. When using row-based logging, updates and deletes to such tables are simply skipped—they are not written to the binary log. In MySQL 5.5.32 and later, a warning is logged whenever this occurs (Bug #13004581)

For this reason we recommend when you replicate to tables using the `BLACKHOLE` storage engine that you have the `binlog_format` server variable set to `STATEMENT`, and not to either `ROW` or `MIXED`.

17.4.1.3 Replication and Character Sets

The following applies to replication between MySQL servers that use different character sets:
• If the master has databases with a character set different from the global `character_set_server` value, you should design your `CREATE TABLE` statements so that they do not implicitly rely on the database default character set. A good workaround is to state the character set and collation explicitly in `CREATE TABLE` statements.

**17.4.1.4 Replication and CHECKSUM TABLE**

`CHECKSUM TABLE` returns a checksum that is calculated row by row, using a method that depends on the table row storage format, which is not guaranteed to remain the same between MySQL release series. For example, the storage format for temporal types such as `TIME`, `DATETIME`, and `TIMESTAMP` changes in MySQL 5.6 prior to MySQL 5.6.5, so if a 5.5 table is upgraded to MySQL 5.6, the checksum value may change.

**17.4.1.5 Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER**

In MySQL 5.5, the statements `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` are not written to the binary log, regardless of the binary logging format that is in use.

**17.4.1.6 Replication of CREATE ... IF NOT EXISTS Statements**

MySQL applies these rules when various `CREATE ... IF NOT EXISTS` statements are replicated:

• Every `CREATE DATABASE IF NOT EXISTS` statement is replicated, whether or not the database already exists on the master.

• Similarly, every `CREATE TABLE IF NOT EXISTS` statement without a `SELECT` is replicated, whether or not the table already exists on the master. This includes `CREATE TABLE IF NOT EXISTS ... LIKE`. Replication of `CREATE TABLE IF NOT EXISTS ... SELECT` follows somewhat different rules; see Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”, for more information.

• `CREATE EVENT IF NOT EXISTS` is always replicated in MySQL 5.5, whether or not the event named in the statement already exists on the master.

See also Bug #45574.

**17.4.1.7 Replication of CREATE TABLE ... SELECT Statements**

This section discusses how MySQL replicates `CREATE TABLE ... SELECT` statements.

These behaviors are not dependent on MySQL version:

• `CREATE TABLE ... SELECT` always performs an implicit commit (Section 13.3.3, “Statements That Cause an Implicit Commit”).

• If destination table does not exist, logging occurs as follows. It does not matter whether `IF NOT EXISTS` is present.

  • `STATEMENT` or `MIXED` format: The statement is logged as written.
  
  • `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

• If the statement fails, nothing is logged. This includes the case that the destination table exists and `IF NOT EXISTS` is not given.

When the destination table exists and `IF NOT EXISTS` is given, MySQL handles the statement in a version-dependent way.
In MySQL 5.1 before 5.1.51 and in MySQL 5.5 before 5.5.6 (this is the original behavior):

- **STATEMENT** or **MIXED** format: The statement is logged as written.
- **ROW** format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.1 as of 5.1.51:

- **STATEMENT** or **MIXED** format: The statement is logged as the equivalent pair of `CREATE TABLE` and `INSERT INTO ... SELECT` statements.
- **ROW** format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.5 as of 5.5.6:

- Nothing is inserted or logged.

These version dependencies arise due to a change in MySQL 5.5.6 in handling of `CREATE TABLE ... SELECT` not to insert rows if the destination table already exists, and a change made in MySQL 5.1.51 to preserve forward compatibility in replication of such statements from a 5.1 master to a 5.5 slave. For details, see Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”.

When using statement-based replication between a MySQL 5.6 or later slave and a master running a previous version of MySQL, a `CREATE TABLE ... SELECT` statement causing changes in other tables on the master fails on the slave, causing replication to stop. This is due to the fact that MySQL 5.6 does not allow a `CREATE TABLE ... SELECT` statement to make any changes in tables other than the table that is created by the statement—a change in behavior from previous versions of MySQL, which permitted these statements to do so. To keep this from happening, you should use row-based replication, rewrite the offending statement before running it on the master, or upgrade the master to MySQL 5.6 (or later). (If you choose to upgrade the master, keep in mind that such a `CREATE TABLE ... SELECT` statement will fail there as well, following the upgrade, unless the statement is rewritten to remove any side effects on other tables.) This is not an issue when using row-based replication, because the statement is logged as a `CREATE TABLE` statement with any changes to table data logged as row-insert events (or possibly row-update events), rather than as the entire `CREATE TABLE ... SELECT` statement.

### 17.4.1.8 Replication of CURRENT_USER()

The following statements support use of the `CURRENT_USER()` function to take the place of the name of (and, possibly, the host for) an affected user or a definer; in such cases, `CURRENT_USER()` is expanded where and as needed:

- DROP USER
- RENAME USER
- GRANT
- REVOKE
- CREATE FUNCTION
- CREATE PROCEDURE
- CREATE TRIGGER
- CREATE EVENT
• CREATE VIEW
• ALTER EVENT
• ALTER VIEW
• SET PASSWORD

When CURRENT_USER() or CURRENT_USER is used as the definer in any of the statements CREATE FUNCTION, CREATE PROCEDURE, CREATE TRIGGER, CREATE EVENT, CREATE VIEW, or ALTER VIEW when binary logging is enabled, the function reference is expanded before it is written to the binary log, so that the statement refers to the same user on both the master and the slave when the statement is replicated. CURRENT_USER() or CURRENT_USER is also expanded prior to being written to the binary log when used in DROP USER, RENAME USER, GRANT, REVOKE, or ALTER EVENT.

17.4.1.9 Replication with Differing Table Definitions on Master and Slave

Source and target tables for replication do not have to be identical. A table on the master can have more or fewer columns than the slave's copy of the table. In addition, corresponding table columns on the master and the slave can use different data types, subject to certain conditions.

Note
Replication between tables which are partitioned differently from one another is not supported. See Section 17.4.1.23, “Replication and Partitioning”.

In all cases where the source and target tables do not have identical definitions, the database and table names must be the same on both the master and the slave. Additional conditions are discussed, with examples, in the following two sections.

Replication with More Columns on Master or Slave

You can replicate a table from the master to the slave such that the master and slave copies of the table have differing numbers of columns, subject to the following conditions:

• Columns common to both versions of the table must be defined in the same order on the master and the slave.

  (This is true even if both tables have the same number of columns.)

• Columns common to both versions of the table must be defined before any additional columns.

This means that executing an ALTER TABLE statement on the slave where a new column is inserted into the table within the range of columns common to both tables causes replication to fail, as shown in the following example:

Suppose that a table t, existing on the master and the slave, is defined by the following CREATE TABLE statement:

```sql
CREATE TABLE t (
    c1 INT,
    c2 INT,
    c3 INT
);
```

Suppose that the ALTER TABLE statement shown here is executed on the slave:

```sql
ALTER TABLE t ADD COLUMN cnew1 INT AFTER c3;
```
The previous `ALTER TABLE` is permitted on the slave because the columns `c1`, `c2`, and `c3` that are common to both versions of table `t` remain grouped together in both versions of the table, before any columns that differ.

However, the following `ALTER TABLE` statement cannot be executed on the slave without causing replication to break:

```
ALTER TABLE t ADD COLUMN cnew2 INT AFTER c2;
```

Replication fails after execution on the slave of the `ALTER TABLE` statement just shown, because the new column `cnew2` comes between columns common to both versions of `t`.

- Each “extra” column in the version of the table having more columns must have a default value.

**Note**

A column's default value is determined by a number of factors, including its type, whether it is defined with a `DEFAULT` option, whether it is declared as `NULL`, and the server SQL mode in effect at the time of its creation; for more information, see Section 11.5, “Data Type Default Values”).

In addition, when the slave’s copy of the table has more columns than the master’s copy, each column common to the tables must use the same data type in both tables.

**Examples.** The following examples illustrate some valid and invalid table definitions:

**More columns on the master.** The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave> CREATE TABLE t1 (c1 INT, c2 INT);
```

The following table definitions would raise an error because the definitions of the columns common to both versions of the table are in a different order on the slave than they are on the master:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave> CREATE TABLE t1 (c2 INT, c1 INT);
```

The following table definitions would also raise an error because the definition of the extra column on the master appears before the definitions of the columns common to both versions of the table:

```
master> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
slave> CREATE TABLE t1 (c1 INT, c2 INT);
```

**More columns on the slave.** The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

The following definitions raise an error because the columns common to both versions of the table are not defined in the same order on both the master and the slave:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave> CREATE TABLE t1 (c2 INT, c1 INT, c3 INT);
```

The following table definitions also raise an error because the definition for the extra column in the slave’s version of the table appears before the definitions for the columns which are common to both versions of the table:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
```
Replication Features and Issues

The following table definitions fail because the slave’s version of the table has additional columns compared to the master’s version, and the two versions of the table use different data types for the common column \( c2 \):

<table>
<thead>
<tr>
<th>master</th>
<th>slave</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREATE TABLE t1 (c1 INT, c2 BIGINT);</td>
<td>CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);</td>
</tr>
</tbody>
</table>

Replication of Columns Having Different Data Types

Corresponding columns on the master’s and the slave’s copies of the same table ideally should have the same data type. However, beginning with MySQL 5.1.21, this is not always strictly enforced, as long as certain conditions are met.

All other things being equal, it is always possible to replicate from a column of a given data type to another column of the same type and same size or width, where applicable, or larger. For example, you can replicate from a \( \text{CHAR}(10) \) column to another \( \text{CHAR}(10) \), or from a \( \text{CHAR}(10) \) column to a \( \text{CHAR}(25) \) column without any problems. In certain cases, it also possible to replicate from a column having one data type (on the master) to a column having a different data type (on the slave); when the data type of the master’s version of the column is promoted to a type that is the same size or larger on the slave, this is known as attribute promotion.

Attribute promotion can be used with both statement-based and row-based replication, and is not dependent on the storage engine used by either the master or the slave. However, the choice of logging format does have an effect on the type conversions that are permitted; the particulars are discussed later in this section.

Important

Whether you use statement-based or row-based replication, the slave’s copy of the table cannot contain more columns than the master’s copy if you wish to employ attribute promotion.

Statement-based replication. When using statement-based replication, a simple rule of thumb to follow is, “If the statement run on the master would also execute successfully on the slave, it should also replicate successfully”. In other words, if the statement uses a value that is compatible with the type of a given column on the slave, the statement can be replicated. For example, you can insert any value that fits in a \( \text{TINYINT} \) column into a \( \text{BIGINT} \) column as well; it follows that, even if you change the type of a \( \text{TINYINT} \) column in the slave’s copy of a table to \( \text{BIGINT} \), any insert into that column on the master that succeeds should also succeed on the slave, since it is impossible to have a legal \( \text{TINYINT} \) value that is large enough to exceed a \( \text{BIGINT} \) column.

Prior to MySQL 5.5.30, when using statement-based replication, \( \text{AUTO_INCREMENT} \) columns were required to be the same on both the master and the slave; otherwise, updates could be applied to the wrong table on the slave. (Bug #12669186)

Row-based replication: attribute promotion and demotion. Formerly, due to the fact that in row-based replication changes rather than statements are replicated, and that these changes are transmitted using formats that do not always map directly to MySQL server column data types, you could not replicate between different subtypes of the same general type (for example, from \( \text{TINYINT} \) to \( \text{BIGINT} \), both \( \text{INT} \) subtypes). However, beginning with MySQL 5.5.3, MySQL Replication supports attribute promotion and demotion between smaller data types and larger types. It is also possible to specify whether or not to permit lossy (truncated) or non-lossy conversions of demoted column values, as explained later in this section.

Lossy and non-lossy conversions. In the event that the target type cannot represent the value being inserted, a decision must be made on how to handle the conversion. If we permit the conversion but truncate (or otherwise modify) the source value to achieve a “fit” in the target column, we make what is
known as a *lossy conversion*. A conversion which does not require truncation or similar modifications to fit the source column value in the target column is a *non-lossy* conversion.

**Type conversion modes (slave_type_conversions variable).** The setting of the `slave_type_conversions` global server variable controls the type conversion mode used on the slave. This variable takes a set of values from the following table, which shows the effects of each mode on the slave’s type-conversion behavior:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL_LOSSY</td>
<td>In this mode, type conversions that would mean loss of information are permitted. This does not imply that non-lossy conversions are permitted, merely that only cases requiring either lossy conversions or no conversion at all are permitted; for example, enabling only this mode permits an INT column to be converted to TINYINT (a lossy conversion), but not a TINYINT column to an INT column (non-lossy). Attempting the latter conversion in this case would cause replication to stop with an error on the slave.</td>
</tr>
<tr>
<td>ALL_NON_LOSSY</td>
<td>This mode permits conversions that do not require truncation or other special handling of the source value; that is, it permits conversions where the target type has a wider range than the source type. Setting this mode has no bearing on whether lossy conversions are permitted; this is controlled with the ALL_LOSSY mode. If only ALL_NON_LOSSY is set, but not ALL_LOSSY, then attempting a conversion that would result in the loss of data (such as INT to TINYINT, or CHAR(25) to VARCHAR(20)) causes the slave to stop with an error.</td>
</tr>
<tr>
<td>ALL_LOSSY, ALL_NON_LOSSY</td>
<td>When this mode is set, all supported type conversions are permitted, whether or not they are lossy conversions.</td>
</tr>
<tr>
<td>[empty]</td>
<td>When <code>slave_type_conversions</code> is not set, no attribute promotion or demotion is permitted; this means that all columns in the source and target tables must be of the same types. This mode is the default.</td>
</tr>
</tbody>
</table>

Changing the type conversion mode requires restarting the slave with the new `slave_type_conversions` setting.

**Supported conversions.** Supported conversions between different but similar data types are shown in the following list:

- Between any of the integer types `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`.
  
  This includes conversions between the signed and unsigned versions of these types.

  Lossy conversions are made by truncating the source value to the maximum (or minimum) permitted by the target column. For insuring non-lossy conversions when going from unsigned to signed types, the target column must be large enough to accommodate the range of values in the source column. For example, you can demote `TINYINT UNSIGNED` non-lossily to `SMALLINT`, but not to `TINYINT`.

- Between any of the decimal types `DECIMAL`, `FLOAT`, `DOUBLE`, and `NUMERIC`.

2090
**Replication Features and Issues**

**FLOAT to DOUBLE** is a non-lossy conversion; **DOUBLE to FLOAT** can only be handled lossily. A conversion from **DECIMAL(M, D)** to **DECIMAL(M', D')** where \( D' \geq D \) and \( (M'-D') \geq (M-D) \) are non-lossy; for any case where \( M' < M \), \( D' < D \), or both, only a lossy conversion can be made.

For any of the decimal types, if a value to be stored cannot be fit in the target type, the value is rounded down according to the rounding rules defined for the server elsewhere in the documentation. See **Section 12.19.4, “Rounding Behavior”**, for information about how this is done for decimal types.

- **Between any of the string types CHAR, VARCHAR, and TEXT**, including conversions between different widths.

Conversion of a CHAR, VARCHAR, or TEXT to a CHAR, VARCHAR, or TEXT column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first \( N \) characters of the string on the slave, where \( N \) is the width of the target column.

⚠️ **Important**

Replication between columns using different character sets is not supported.

- **Between any of the binary data types BINARY, VARBINARY, and BLOB**, including conversions between different widths.

Conversion of a BINARY, VARBINARY, or BLOB to a BINARY, VARBINARY, or BLOB column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first \( N \) bytes of the string on the slave, where \( N \) is the width of the target column.

- **Between any 2 BIT columns of any 2 sizes**.

When inserting a value from a BIT(\( M \)) column into a BIT(\( M' \)) column, where \( M' > M \), the most significant bits of the BIT(\( M' \)) columns are cleared (set to zero) and the \( M \) bits of the BIT(\( M \)) value are set as the least significant bits of the BIT(\( M' \)) column.

When inserting a value from a source BIT(\( M \)) column into a target BIT(\( M' \)) column, where \( M' < M \), the maximum possible value for the BIT(\( M' \)) column is assigned; in other words, an “all-set” value is assigned to the target column.

Conversions between types not in the previous list are not permitted.

**Replication type conversions in MySQL 5.5.3 and earlier.** Prior to MySQL 5.5.3, with row-based binary logging, you could not replicate between different INT subtypes, such as from **TINYINT** to **BIGINT**, because changes to columns of these types were represented differently from one another in the binary log when using row-based logging. (However, you could replicate from BLOB to TEXT using row-based replication because changes to BLOB and TEXT columns were represented using the same format in the binary log.)

Supported conversions for attribute promotion when using row-based replication prior to MySQL 5.5.3 are shown in the following table:

<table>
<thead>
<tr>
<th>From (Master)</th>
<th>To (Slave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BINARY</td>
<td>CHAR</td>
</tr>
<tr>
<td>BLOB</td>
<td>TEXT</td>
</tr>
<tr>
<td>CHAR</td>
<td>BINARY</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>NUMERIC</td>
</tr>
</tbody>
</table>
### Replication and DIRECTORY Table Options

If a `DATA DIRECTORY` or `INDEX DIRECTORY` table option is used in a `CREATE TABLE` statement on the master server, the table option is also used on the slave. This can cause problems if no corresponding directory exists in the slave host file system or if it exists but is not accessible to the slave server. This can be overridden by using the `NO_DIR_IN_CREATE` server SQL mode on the slave, which causes the slave to ignore the `DATA DIRECTORY` and `INDEX DIRECTORY` table options when replicating `CREATE TABLE` statements. The result is that MyISAM data and index files are created in the table's database directory.

For more information, see Section 5.1.10, “Server SQL Modes”.

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### Note

In all cases, the size or width of the column on the slave must be equal to or greater than that of the column on the master. For example, you could replicate from a `CHAR(10)` column on the master to a column that used `BINARY(10)` or `BINARY(25)` on the slave, but you could not replicate from a `CHAR(10)` column on the master to `BINARY(5)` column on the slave.

Any unique index (including primary keys) having a prefix must use a prefix of the same length on both master and slave; in such cases, differing prefix lengths are disallowed. It is possible to use a nonunique index whose prefix length differs between master and slave, but this can cause serious performance issues, particularly when the prefix used on the master is longer. This is due to the fact that 2 unique prefixes of a given length may no longer be unique at a shorter length; for example, the words `catalogue` and `catamount` have the 5-character prefixes `catal` and `catam`, respectively, but share the same 4-character prefix (`cata`). This can lead to queries that use such indexes executing less efficiently on the slave, when a shorter prefix is employed in the slave's definition of the same index than on the master.

For `DECIMAL` and `NUMERIC` columns, both the mantissa \((M)\) and the number of decimals \((D)\) must be the same size or larger on the slave as compared with the master. For example, replication from a `NUMERIC(5,4)` to a `DECIMAL(6,4)` worked, but not from a `NUMERIC(5,4)` to a `DECIMAL(5,3)`.

Prior to MySQL 5.5.3, MySQL replication did not support attribute promotion of any of the following data types to or from any other data type when using row-based replication:

- **INT** (including `TINYINT`, `SMALLINT`, `MEDIUMINT`, `BIGINT`).
  
  Promotion between `INT` subtypes—for example, from `SMALLINT` to `BIGINT`—was also not supported prior to MySQL 5.5.3.

- **SET** or **ENUM**.

- **FLOAT** or **DOUBLE**.

- All of the data types relating to dates, times, or both: `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, and `YEAR`.

---

<table>
<thead>
<tr>
<th>From (Master)</th>
<th>To (Slave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMERIC</td>
<td>DECIMAL</td>
</tr>
<tr>
<td>TEXT</td>
<td>BLOB</td>
</tr>
<tr>
<td>VARBINARY</td>
<td>VARCHAR</td>
</tr>
<tr>
<td>VARCHAR</td>
<td>VARBINARY</td>
</tr>
</tbody>
</table>
17.4.11 Replication of DROP ... IF EXISTS Statements

The `DROP DATABASE IF EXISTS`, `DROP TABLE IF EXISTS`, and `DROP VIEW IF EXISTS` statements are always replicated, even if the database, table, or view to be dropped does not exist on the master. This is to ensure that the object to be dropped no longer exists on either the master or the slave, once the slave has caught up with the master.

`DROP ... IF EXISTS` statements for stored programs (stored procedures and functions, triggers, and events) are also replicated, even if the stored program to be dropped does not exist on the master.

17.4.12 Replication and Floating-Point Values

With statement-based replication, values are converted from decimal to binary. Because conversions between decimal and binary representations of them may be approximate, comparisons involving floating-point values are inexact. This is true for operations that use floating-point values explicitly, or that use values that are converted to floating-point implicitly. Comparisons of floating-point values might yield different results on master and slave servers due to differences in computer architecture, the compiler used to build MySQL, and so forth. See Section 12.2, “Type Conversion in Expression Evaluation”, and Section B.4.4.8, “Problems with Floating-Point Values”.

17.4.13 Replication and FLUSH

Some forms of the `FLUSH` statement are not logged because they could cause problems if replicated to a slave: `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK`. For a syntax example, see Section 13.7.6.3, “FLUSH Statement”. The `FLUSH TABLES`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements are written to the binary log and thus replicated to slaves. This is not normally a problem because these statements do not modify table data.

However, this behavior can cause difficulties under certain circumstances. If you replicate the privilege tables in the `mysql` database and update those tables directly without using `GRANT`, you must issue a `FLUSH PRIVILEGES` on the slaves to put the new privileges into effect. In addition, if you use `FLUSH TABLES` when renaming a `MyISAM` table that is part of a `MERGE` table, you must issue `FLUSH TABLES` manually on the slaves. These statements are written to the binary log unless you specify `NO_WRITE_TO_BINLOG` or its alias `LOCAL`.

17.4.14 Replication and System Functions

Certain functions do not replicate well under some conditions:

- The `USER()`, `CURRENT_USER()` (or `CURRENT_USER`), `UUID()`, `VERSION()`, and `LOAD_FILE()` functions are replicated without change and thus do not work reliably on the slave unless row-based replication is enabled. (See Section 17.1.2, “Replication Formats”.)

  `USER()` and `CURRENT_USER()` are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #28086) (See also Section 17.4.1.8, “Replication of `CURRENT_USER()`”.) This is also true for `VERSION()` and `RAND()`.

- For `NOW()`, the binary log includes the timestamp. This means that the value `as returned by the call to this function on the master` is replicated to the slave. This can lead to a possibly unexpected result when replicating between MySQL servers in different time zones. Suppose that the master is located in New York, the slave is located in Stockholm, and both servers are using local time. Suppose further that, on the master, you create a table `mytable`, perform an `INSERT` statement on this table, and then select from the table, as shown here:

```
mysql> CREATE TABLE mytable (mycol TEXT);
```
Replication Features and Issues

```
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO mytable VALUES ( NOW() );
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM mytable;
+---------------------+
<table>
<thead>
<tr>
<th>mycol</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-09-01 12:00:00</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
</tbody>
</table>
| 1 row in set (0.00 sec)
```

Local time in Stockholm is 6 hours later than in New York; so, if you issue `SELECT NOW()` on the slave at that exact same instant, the value 2009-09-01 18:00:00 is returned. For this reason, if you select from the slave’s copy of `mytable` after the `CREATE TABLE` and `INSERT` statements just shown have been replicated, you might expect `mycol` to contain the value 2009-09-01 18:00:00. However, this is not the case; when you select from the slave’s copy of `mytable`, you obtain exactly the same result as on the master:

```
mysql> SELECT * FROM mytable;
+---------------------+
<table>
<thead>
<tr>
<th>mycol</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-09-01 12:00:00</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
</tbody>
</table>
| 1 row in set (0.00 sec)
```

Unlike `NOW()`, the `SYSDATE()` function is not replication-safe because it is not affected by `SET TIMESTAMP` statements in the binary log and is nondeterministic if statement-based logging is used. This is not a problem if row-based logging is used.

An alternative is to use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This must be done on the master and the slave to work correctly. In such cases, a warning is still issued by this function, but can safely be ignored as long as `--sysdate-is-now` is used on both the master and the slave.

Beginning with MySQL 5.5.1, `SYSDATE()` is automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode. (Bug #47995)

See also Section 17.4.1.33, “Replication and Time Zones”.

- The following restriction applies to statement-based replication only, not to row-based replication. The `GET_LOCK()`, `RELEASE_LOCK()`, `IS_FREE_LOCK()`, and `IS_USED_LOCK()` functions that handle user-level locks are replicated without the slave knowing the concurrency context on the master. Therefore, these functions should not be used to insert into a master table because the content on the slave would differ. For example, do not issue a statement such as `INSERT INTO mytable VALUES(GET_LOCK(...))`.

Beginning with MySQL 5.5.1, these functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #47995)

As a workaround for the preceding limitations when statement-based replication is in effect, you can use the strategy of saving the problematic function result in a user variable and referring to the variable in a later statement. For example, the following single-row `INSERT` is problematic due to the reference to the `UUID()` function:

```
INSERT INTO t VALUES(UUID());
```

To work around the problem, do this instead:
SET @my_uuid = UUID();
INSERT INTO t VALUES(@my_uuid);

That sequence of statements replicates because the value of @my_uuid is stored in the binary log as a
user-variable event prior to the INSERT statement and is available for use in the INSERT.

The same idea applies to multiple-row inserts, but is more cumbersome to use. For a two-row insert, you
can do this:

SET @my_uuid1 = UUID(); @my_uuid2 = UUID();
INSERT INTO t VALUES(@my_uuid1),(@my_uuid2);

However, if the number of rows is large or unknown, the workaround is difficult or impracticable. For
example, you cannot convert the following statement to one in which a given individual user variable is
associated with each row:

INSERT INTO t2 SELECT UUID(), * FROM t1;

Within a stored function, RAND() replicates correctly as long as it is invoked only once during the execution
of the function. (You can consider the function execution timestamp and random number seed as implicit
inputs that are identical on the master and slave.)

The FOUND_ROWS() and ROW_COUNT() functions are not replicated reliably using statement-based
replication. A workaround is to store the result of the function call in a user variable, and then use that in
the INSERT statement. For example, if you wish to store the result in a table named mytable, you might
normally do so like this:

SELECT SQL_CALC_FOUND_ROWS FROM mytable LIMIT 1;
INSERT INTO mytable VALUES( FOUND_ROWS() );

However, if you are replicating mytable, you should use SELECT ... INTO, and then store the variable
in the table, like this:

SELECT SQL_CALC_FOUND_ROWS INTO @found_rows FROM mytable LIMIT 1;
INSERT INTO mytable VALUES(@found_rows);

In this way, the user variable is replicated as part of the context, and applied on the slave correctly.

These functions are automatically replicated using row-based replication when using MIXED mode, and
generate a warning in STATEMENT mode. (Bug #12092, Bug #30244)

Prior to MySQL 5.5.35, the value of LAST_INSERT_ID() was not replicated correctly if any filtering
options such as --replicate-ignore-db and --replicate-do-table were enabled on the slave.
(Bug #17234370, BUG# 69861)

17.4.1.15 Replication of Invoked Features

Replication of invoked features such as user-defined functions (UDFs) and stored programs (stored
procedures and functions, triggers, and events) provides the following characteristics:

• The effects of the feature are always replicated.

• The following statements are replicated using statement-based replication:

  • CREATE EVENT

  • ALTER EVENT

  • DROP EVENT
Replication Features and Issues

- CREATE PROCEDURE
- DROP PROCEDURE
- CREATE FUNCTION
- DROP FUNCTION
- CREATE TRIGGER
- DROP TRIGGER

However, the effects of features created, modified, or dropped using these statements are replicated using row-based replication.

**Note**

Attempting to replicate invoked features using statement-based replication produces the warning `Statement is not safe to log in statement format`. For example, trying to replicate a UDF with statement-based replication generates this warning because it currently cannot be determined by the MySQL server whether the UDF is deterministic. If you are absolutely certain that the invoked feature's effects are deterministic, you can safely disregard such warnings.

- In the case of CREATE EVENT and ALTER EVENT:
  - The status of the event is set to **SLAVESIDE_DISABLED** on the slave regardless of the state specified (this does not apply to DROP EVENT).
  - The master on which the event was created is identified on the slave by its server ID. The `ORIGINATOR` column in `INFORMATION_SCHEMA.EVENTS` and the `originator` column in `mysql.event` store this information. See Section 21.8, "The INFORMATION_SCHEMA EVENTS Table", and Section 13.7.5.19, "SHOW EVENTS Statement", for more information.
  - The feature implementation resides on the slave in a renewable state so that if the master fails, the slave can be used as the master without loss of event processing.

To determine whether there are any scheduled events on a MySQL server that were created on a different server (that was acting as a replication master), query the `INFORMATION_SCHEMA.EVENTS` table in a manner similar to what is shown here:

```sql
SELECT EVENT_SCHEMA, EVENT_NAME
FROM INFORMATION_SCHEMA.EVENTS
WHERE STATUS = 'SLAVESIDE_DISABLED';
```

Alternatively, you can use the `SHOW EVENTS` statement, like this:

```sql
SHOW EVENTS
WHERE STATUS = 'SLAVESIDE_DISABLED';
```

When promoting a replication slave having such events to a replication master, you must enable each event using `ALTER EVENT event_name ENABLE`, where `event_name` is the name of the event.

If more than one master was involved in creating events on this slave, and you wish to identify events that were created only on a given master having the server ID `master_id`, modify the previous query on the `EVENTS` table to include the `ORIGINATOR` column, as shown here:
You can employ `ORIGINATOR` with the `SHOW EVENTS` statement in a similar fashion:

```sql
SHOW EVENTS
WHERE STATUS = 'SLAVESIDE_DISABLED'
AND ORIGINATOR = 'master_id'
```

Before enabling events that were replicated from the master, you should disable the MySQL Event Scheduler on the slave (using a statement such as `SET GLOBAL event_scheduler = OFF;`), run any necessary `ALTER EVENT` statements, restart the server, then re-enable the Event Scheduler on the slave afterward (using a statement such as `SET GLOBAL event_scheduler = ON;`).

If you later demote the new master back to being a replication slave, you must disable manually all events enabled by the `ALTER EVENT` statements. You can do this by storing in a separate table the event names from the `SELECT` statement shown previously, or using `ALTER EVENT` statements to rename the events with a common prefix such as `replicated_` to identify them.

If you rename the events, then when demoting this server back to being a replication slave, you can identify the events by querying the `EVENTS` table, as shown here:

```sql
SELECT CONCAT(EVENT_SCHEMA, '.', EVENT_NAME) AS 'Db.Event'
FROM INFORMATION_SCHEMA.EVENTS
WHERE INSTR(EVENT_NAME, 'replicated_') = 1;
```

17.4.1.16 Replication and LIMIT

Statement-based replication of `LIMIT` clauses in `DELETE`, `UPDATE`, and `INSERT ... SELECT` statements is unsafe since the order of the rows affected is not defined. (Such statements can be replicated correctly with statement-based replication only if they also contain an `ORDER BY` clause.) When such a statement is encountered:

- When using `STATEMENT` mode, a warning that the statement is not safe for statement-based replication is now issued.

  When using `STATEMENT` mode, warnings are issued for DML statements containing `LIMIT` even when they also have an `ORDER BY` clause (and so are made deterministic). This is a known issue. (Bug #42851)

- When using `MIXED` mode, the statement is now automatically replicated using row-based mode.

17.4.1.17 Replication and LOAD DATA

In MySQL 5.5.6 and later, `LOAD DATA` is considered unsafe for statement-based logging (see Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”). When `binlog_format=MIXED` is set, the statement is logged in row-based format. When `binlog_format=STATEMENT` is set, note that `LOAD DATA` does not generate a warning, unlike other unsafe statements.

When `mysqlbinlog` reads log events for `LOAD DATA` statements logged in statement-based format, a generated local file is created in a temporary directory. These temporary files are not automatically removed by `mysqlbinlog` or any other MySQL program. If you do use `LOAD DATA` statements with statement-based binary logging, you should delete the temporary files yourself after you no longer need the statement log. For more information, see Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files".
17.4.1.18 Replication and the Slow Query Log

In older versions of MySQL, replication slaves did not write replicated queries to the slow query log, even if the same queries were written to the slow query log on the master. This is no longer an issue in MySQL 5.5. (Bug #23300)

17.4.1.19 Replication and max_allowed_packet

max_allowed_packet sets an upper limit on the size of any single message between the MySQL server and clients, including replication slaves. If you are replicating large column values (such as might be found in TEXT or BLOB columns) and max_allowed_packet is too small on the master, the master fails with an error, and the slave shuts down the I/O thread. If max_allowed_packet is too small on the slave, this also causes the slave to stop the I/O thread.

Row-based replication currently sends all columns and column values for updated rows from the master to the slave, including values of columns that were not actually changed by the update. This means that, when you are replicating large column values using row-based replication, you must take care to set max_allowed_packet large enough to accommodate the largest row in any table to be replicated, even if you are replicating updates only, or you are inserting only relatively small values.

17.4.1.20 Replication and MEMORY Tables

When a master server shuts down and restarts, its MEMORY tables become empty. To replicate this effect to slaves, the first time that the master uses a given MEMORY table after startup, it logs an event that notifies slaves that the table must be emptied by writing a DELETE statement for that table to the binary log.

When a slave server shuts down and restarts, its MEMORY tables become empty. This causes the slave to be out of synchrony with the master and may lead to other failures or cause the slave to stop:

- Row-format updates and deletes received from the master may fail with Can't find record in 'memory_table'.
- Statements such as INSERT INTO ... SELECT FROM memory_table may insert a different set of rows on the master and slave.

The safe way to restart a slave that is replicating MEMORY tables is to first drop or delete all rows from the MEMORY tables on the master and wait until those changes have replicated to the slave. Then it is safe to restart the slave.

An alternative restart method may apply in some cases. When binlog_format=ROW, you can prevent the slave from stopping if you set slave_exec_mode=IDEMPOTENT before you start the slave again. This allows the slave to continue to replicate, but its MEMORY tables will still be different from those on the master. This can be okay if the application logic is such that the contents of MEMORY tables can be safely lost (for example, if the MEMORY tables are used for caching). slave_exec_mode=IDEMPOTENT applies globally to all tables, so it may hide other replication errors in non-MEMORY tables.

(The method just described is not applicable in NDB Cluster, where slave_exec_mode is always IDEMPOTENT, and cannot be changed.)

The size of MEMORY tables is limited by the value of the max_heap_table_size system variable, which is not replicated (see Section 17.4.1.37, “Replication and Variables”). A change in max_heap_table_size takes effect for MEMORY tables that are created or updated using ALTER TABLE ... ENGINE = MEMORY or TRUNCATE TABLE following the change, or for all MEMORY tables following a server restart. If you increase the value of this variable on the master without doing so on the slave, it becomes possible for a table on the master to grow larger than its counterpart on the slave, leading to inserts that succeed on the...
master but fail on the slave with Table is full errors. This is a known issue (Bug #48666). In such cases, you must set the global value of max_heap_table_size on the slave as well as on the master, then restart replication. It is also recommended that you restart both the master and slave MySQL servers, to insure that the new value takes complete (global) effect on each of them.

See Section 15.4, “The MEMORY Storage Engine”, for more information about MEMORY tables.

17.4.1.21 Replication of the mysql System Database

Data modification statements made to tables in the mysql database are replicated according to the value of binlog_format; if this value is MIXED, these statements are replicated using row-based format. However, statements that would normally update this information indirectly—such as GRANT, REVOKE, and statements manipulating triggers, stored routines, and views—are replicated to slaves using statement-based replication.

17.4.1.22 Replication and the Query Optimizer

It is possible for the data on the master and slave to become different if a statement is written in such a way that the data modification is nondeterministic; that is, left up the query optimizer. (In general, this is not a good practice, even outside of replication.) Examples of nondeterministic statements include DELETE or UPDATE statements that use LIMIT with no ORDER BY clause; see Section 17.4.1.16, “Replication and LIMIT”, for a detailed discussion of these.

17.4.1.23 Replication and Partitioning

Replication is supported between partitioned tables as long as they use the same partitioning scheme and otherwise have the same structure except where an exception is specifically allowed (see Section 17.4.1.9, “Replication with Differing Table Definitions on Master and Slave”).

Replication between tables having different partitioning is generally not supported. This because statements (such as ALTER TABLE ... DROP PARTITION) acting directly on partitions in such cases may produce different results on master and slave. In the case where a table is partitioned on the master but not on the slave, any statements operating on partitions on the master's copy of the slave fail on the slave. When the slave's copy of the table is partitioned but the master's copy is not, statements acting on partitions cannot be run on the master without causing errors there.

Due to these dangers of causing replication to fail entirely (on account of failed statements) and of inconsistencies (when the result of a partition-level SQL statement produces different results on master and slave), we recommend that insure that the partitioning of any tables to be replicated from the master is matched by the slave's versions of these tables.

17.4.1.24 Replication and REPAIR TABLE

When used on a corrupted or otherwise damaged table, it is possible for the REPAIR TABLE statement to delete rows that cannot be recovered. However, any such modifications of table data performed by this statement are not replicated, which can cause master and slave to lose synchronization. For this reason, in the event that a table on the master becomes damaged and you use REPAIR TABLE to repair it, you should first stop replication (if it is still running) before using REPAIR TABLE, then afterward compare the master's and slave's copies of the table and be prepared to correct any discrepancies manually, before restarting replication.

17.4.1.25 Replication and Reserved Words

You can encounter problems when you attempt to replicate from an older master to a newer slave and you make use of identifiers on the master that are reserved words in the newer MySQL version running on the
slave. An example of this is using a table column named range on a 5.0 master that is replicating to a 5.1 or higher slave because RANGE is a reserved word beginning in MySQL 5.1. Replication can fail in such cases with Error 1064 You have an error in your SQL syntax..., even if a database or table named using the reserved word or a table having a column named using the reserved word is excluded from replication. This is due to the fact that each SQL event must be parsed by the slave prior to execution, so that the slave knows which database object or objects would be affected; only after the event is parsed can the slave apply any filtering rules defined by --replicate-do-db, --replicate-do-table, --replicate-ignore-db, and --replicate-ignore-table.

To work around the problem of database, table, or column names on the master which would be regarded as reserved words by the slave, do one of the following:

- Use one or more ALTER TABLE statements on the master to change the names of any database objects where these names would be considered reserved words on the slave, and change any SQL statements that use the old names to use the new names instead.

- In any SQL statements using these database object names, write the names as quoted identifiers using backtick characters (`).

For listings of reserved words by MySQL version, see Reserved Words, in the MySQL Server Version Reference. For identifier quoting rules, see Section 9.2, “Schema Object Names”.

17.4.1.26 SET PASSWORD and Row-Based Replication

Row-based replication of SET PASSWORD statements from a MySQL 5.1 master to a MySQL 5.5 slave did not work correctly prior to MySQL 5.1.53 on the master and MySQL 5.5.7 on the slave (see Bug #57098, Bug #57357).

17.4.1.27 Replication and Master or Slave Shutdowns

It is safe to shut down a master server and restart it later. When a slave loses its connection to the master, the slave tries to reconnect immediately and retries periodically if that fails. The default is to retry every 60 seconds. This may be changed with the CHANGE MASTER TO statement. A slave also is able to deal with network connectivity outages. However, the slave notices the network outage only after receiving no data from the master for slave_net_timeout seconds. If your outages are short, you may want to decrease slave_net_timeout. See Section 5.1.7, “Server System Variables”.

An unclean shutdown (for example, a crash) on the master side can result in the master binary log having a final position less than the most recent position read by the slave, due to the master binary log file not being flushed. This can cause the slave not to be able to replicate when the master comes back up. Setting sync_binlog=1 in the master my.cnf file helps to minimize this problem because it causes the master to flush its binary log more frequently.

Shutting down a slave cleanly is safe because it keeps track of where it left off. However, be careful that the slave does not have temporary tables open; see Section 17.4.1.30, “Replication and Temporary Tables”. Unclean shutdowns might produce problems, especially if the disk cache was not flushed to disk before the problem occurred:

- For transactions, the slave commits and then updates relay-log.info. If a crash occurs between these two operations, relay log processing will have proceeded further than the information file indicates and the slave will re-execute the events from the last transaction in the relay log after it has been restarted.

- A similar problem can occur if the slave updates relay-log.info but the server host crashes before the write has been flushed to disk. To minimize the chance of this occurring, set sync_relay_log_info=1 in the slave my.cnf file. The default value of sync_relay_log_info is
0, which does not cause writes to be forced to disk; the server relies on the operating system to flush the file from time to time.

The fault tolerance of your system for these types of problems is greatly increased if you have a good uninterruptible power supply.

17.4.1.28 Slave Errors During Replication

If a statement produces the same error (identical error code) on both the master and the slave, the error is logged, but replication continues.

If a statement produces different errors on the master and the slave, the slave SQL thread terminates, and the slave writes a message to its error log and waits for the database administrator to decide what to do about the error. This includes the case that a statement produces an error on the master or the slave, but not both. To address the issue, connect to the slave manually and determine the cause of the problem. `SHOW SLAVE STATUS` is useful for this. Then fix the problem and run `START SLAVE`. For example, you might need to create a nonexistent table before you can start the slave again.

**Note**

If a temporary error is recorded in the slave's error log, you do not necessarily have to take any action suggested in the quoted error message. Temporary errors should be handled by the client retrying the transaction. For example, if the slave SQL thread records a temporary error relating to a deadlock, you do not need to restart the transaction manually on the slave, unless the slave SQL thread subsequently terminates with a nontemporary error message.

If this error code validation behavior is not desirable, some or all errors can be masked out (ignored) with the `--slave-skip-errors` option.

For nontransactional storage engines such as MyISAM, it is possible to have a statement that only partially updates a table and returns an error code. This can happen, for example, on a multiple-row insert that has one row violating a key constraint, or if a long update statement is killed after updating some of the rows. If that happens on the master, the slave expects execution of the statement to result in the same error code. If it does not, the slave SQL thread stops as described previously.

If you are replicating between tables that use different storage engines on the master and slave, keep in mind that the same statement might produce a different error when run against one version of the table, but not the other, or might cause an error for one version of the table, but not the other. For example, since MyISAM ignores foreign key constraints, an `INSERT` or `UPDATE` statement accessing an InnoDB table on the master might cause a foreign key violation but the same statement performed on a MyISAM version of the same table on the slave would produce no such error, causing replication to stop.

17.4.1.29 Replication and Server SQL Mode

Using different server SQL mode settings on the master and the slave may cause the same `INSERT` statements to be handled differently on the master and the slave, leading the master and slave to diverge. For best results, you should always use the same server SQL mode on the master and on the slave. This advice applies whether you are using statement-based or row-based replication.

If you are replicating partitioned tables, using different SQL modes on the master and the slave is likely to cause issues. At a minimum, this is likely to cause the distribution of data among partitions to be different in the master's and slave's copies of a given table. It may also cause inserts into partitioned tables that succeed on the master to fail on the slave.

For more information, see Section 5.1.10, “Server SQL Modes”. 
17.4.1.30 Replication and Temporary Tables

The discussion in the following paragraphs does not apply when binlog_format=ROW because, in that case, temporary tables are not replicated; this means that there are never any temporary tables on the slave to be lost in the event of an unplanned shutdown by the slave. The remainder of this section applies only when using statement-based or mixed-format replication. Loss of replicated temporary tables on the slave can be an issue, whenever binlog_format is STATEMENT or MIXED, for statements involving temporary tables that can be logged safely using statement-based format. For more information about row-based replication and temporary tables, see RBL, RBR, and temporary tables.

Safe slave shutdown when using temporary tables. Temporary tables are replicated except in the case where you stop the slave server (not just the slave threads) and you have replicated temporary tables that are open for use in updates that have not yet been executed on the slave. If you stop the slave server, the temporary tables needed by those updates are no longer available when the slave is restarted. To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use the following procedure:

1. Issue a STOP SLAVE SQL_THREAD statement.
2. Use SHOW STATUS to check the value of the Slave_open_temp_tables variable.
3. If the value is not 0, restart the slave SQL thread with START SLAVE SQL_THREAD and repeat the procedure later.
4. When the value is 0, issue a mysqladmin shutdown command to stop the slave.

Temporary tables and replication options. By default, all temporary tables are replicated; this happens whether or not there are any matching --replicate-do-db, --replicate-do-table, or --replicate-wild-do-table options in effect. However, the --replicate-ignore-table and --replicate-wild-ignore-table options are honored for temporary tables.

A recommended practice when using statement-based or mixed-format replication is to designate a prefix for exclusive use in naming temporary tables that you do not want replicated, then employ a --replicate-wild-ignore-table option to match that prefix. For example, you might give all such tables names beginning with norep (such as norepmytable, norepyourtable, and so on), then use --replicate-wild-ignore-table=norep% to prevent them from being replicated.

17.4.1.31 Replication Retries and Timeouts

The global system variable slave_transaction_retries affects replication as follows: If the slave SQL thread fails to execute a transaction because of an InnoDB deadlock or because it exceeded the InnoDB innodb_lock_wait_timeout value, or the NDBCLUSTER TransactionDeadlockDetectionTimeout or TransactionInactiveTimeout value, the slave automatically retries the transaction slave_transaction_retries times before stopping with an error. The default value is 10. The total retry count can be seen in the output of SHOW STATUS; see Section 5.1.9, “Server Status Variables”.

17.4.1.32 Replication and TIMESTAMP

Older versions of MySQL (prior to 4.1) differed significantly in several ways in their handling of the TIMESTAMP data type from what is supported in MySQL versions 5.5 and newer; these include syntax extensions which are deprecated in MySQL 5.1, and that no longer supported in MySQL 5.5. This can cause problems (including replication failures) when replicating between MySQL Server versions, if you are using columns that are defined using the old TIMESTAMP (N) syntax. See Section 2.11.3, “Changes in MySQL 5.5”, for more information about the differences, how they can impact MySQL replication, and what you can do if you encounter such problems.
17.4.1.33 Replication and Time Zones

The same system time zone should be set for both master and slave. Otherwise, statements depending on the local time on the master are not replicated properly, such as statements that use the NOW() or FROM_UNIXTIME() functions. You can set the time zone in which MySQL server runs by using the --timezone=timezone_name option of the mysqld_safe script or by setting the TZ environment variable. See also Section 17.4.1.14, “Replication and System Functions”.

17.4.1.34 Replication and Transactions

Mixing transactional and nontransactional statements within the same transaction. In general, you should avoid transactions that update both transactional and nontransactional tables in a replication environment. You should also avoid using any statement that accesses both transactional (or temporary) and nontransactional tables and writes to any of them.

As of MySQL 5.5.2, the server uses these rules for binary logging:

- If the initial statements in a transaction are nontransactional, they are written to the binary log immediately. The remaining statements in the transaction are cached and not written to the binary log until the transaction is committed. (If the transaction is rolled back, the cached statements are written to the binary log only if they make nontransactional changes that cannot be rolled back. Otherwise, they are discarded.)

- For statement-based logging, logging of nontransactional statements is affected by the binlog_direct_non_transactional_updates system variable. When this variable is OFF (the default), logging is as just described. When this variable is ON, logging occurs immediately for nontransactional statements occurring anywhere in the transaction (not just initial nontransactional statements). Other statements are kept in the transaction cache and logged when the transaction commits. binlog_direct_non_transactional_updates has no effect for row-format or mixed-format binary logging.

Transactional, nontransactional, and mixed statements.
To apply those rules, the server considers a statement nontransactional if it changes only nontransactional tables, and transactional if it changes only transactional tables. Prior to MySQL 5.5.6, a statement that changed both nontransactional and transactional tables was considered “mixed”. Beginning with MySQL 5.5.6, a statement that references both nontransactional and transactional tables and updates any of the tables involved, is considered a mixed statement. Mixed statements, like transactional statements, are cached and logged when the transaction commits.

Beginning with MySQL 5.5.6, a mixed statement that updates a transactional table is considered unsafe if the statement also performs either of the following actions:

- Updates or reads a temporary table
- Reads a nontransactional table and the transaction isolation level is less than REPEATABLE_READ

Also beginning with MySQL 5.5.6, any mixed statement following the update of a transactional table within a transaction is considered unsafe if it performs either of the following actions:

- Updates any table and reads from any temporary table
- Updates a nontransactional table and binlog_direct_non_transactional_updates is OFF

For more information, see Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”.
Replication Features and Issues

Note
A mixed statement is unrelated to mixed binary logging format.

Before MySQL 5.5.2, the rules for binary logging are similar to those just described, except that there is no `binlog_direct_non_transactional_updates` system variable to affect logging of transactional statements. Thus, the server immediately logs only the initial nontransactional statements in a transaction and caches the rest until commit time.

In situations where transactions mix updates to transactional and nontransactional tables, the order of statements in the binary log is correct, and all needed statements are written to the binary log even in case of a `ROLLBACK`. However, when a second connection updates the nontransactional table before the first connection transaction is complete, statements can be logged out of order because the second connection update is written immediately after it is performed, regardless of the state of the transaction being performed by the first connection.

Using different storage engines on master and slave. It is possible to replicate transactional tables on the master using nontransactional tables on the slave. For example, you can replicate an `InnoDB` master table as a `MyISAM` slave table. However, if you do this, there are problems if the slave is stopped in the middle of a `BEGIN ... COMMIT` block because the slave restarts at the beginning of the `BEGIN` block.

Beginning with MySQL 5.5.0, it is also safe to replicate transactions from `MyISAM` tables on the master to transactional tables—such as tables that use the `InnoDB` storage engine—on the slave. In such cases (beginning with MySQL 5.5.0), an `AUTOCOMMIT=1` statement issued on the master is replicated, thus enforcing `AUTOCOMMIT` mode on the slave.

When the storage engine type of the slave is nontransactional, transactions on the master that mix updates of transactional and nontransactional tables should be avoided because they can cause inconsistency of the data between the master transactional table and the slave nontransactional table. That is, such transactions can lead to master storage engine-specific behavior with the possible effect of replication going out of synchrony. MySQL does not issue a warning about this currently, so extra care should be taken when replicating transactional tables from the master to nontransactional tables on the slaves.

Changing the binary logging format within transactions. Beginning with MySQL 5.5.3, the `binlog_format` system variable is read-only as long as a transaction is in progress. (Bug #47863)

Every transaction (including `autocommit` transactions) is recorded in the binary log as though it starts with a `BEGIN` statement, and ends with either a `COMMIT` or a `ROLLBACK` statement. In MySQL 5.5, this is even for statements affecting tables that use a nontransactional storage engine (such as `MyISAM`).

17.4.1.35 Replication and Triggers

With statement-based replication, triggers executed on the master also execute on the slave. With row-based replication, triggers executed on the master do not execute on the slave. Instead, the row changes on the master resulting from trigger execution are replicated and applied on the slave.

This behavior is by design. If under row-based replication the slave applied the triggers as well as the row changes caused by them, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

If you want triggers to execute on both the master and the slave—perhaps because you have different triggers on the master and slave—you must use statement-based replication. However, to enable slave-side triggers, it is not necessary to use statement-based replication exclusively. It is sufficient to switch to statement-based replication only for those statements where you want this effect, and to use row-based replication the rest of the time.
Replication Features and Issues

A statement invoking a trigger (or function) that causes an update to an AUTO_INCREMENT column is not replicated correctly using statement-based replication. MySQL 5.5 marks such statements as unsafe. (Bug #45677)

17.4.1.36 Replication and TRUNCATE TABLE

TRUNCATE TABLE is normally regarded as a DML statement, and so would be expected to be logged and replicated using row-based format when the binary logging mode is ROW or MIXED. However this caused issues when logging or replicating, in STATEMENT or MIXED mode, tables that used transactional storage engines such as InnoDB when the transaction isolation level was READ COMMITTED or READ UNCOMMITTED, which precludes statement-based logging.

TRUNCATE TABLE is treated for purposes of logging and replication as DDL rather than DML so that it can be logged and replicated as a statement. However, the effects of the statement as applicable to InnoDB and other transactional tables on replication slaves still follow the rules described in Section 13.1.33, “TRUNCATE TABLE Statement” governing such tables. (Bug #36763)

17.4.1.37 Replication and Variables

System variables are not replicated correctly when using STATEMENT mode, except for the following variables when they are used with session scope:

- auto_increment_increment
- auto_increment_offset
- character_set_client
- character_set_connection
- character_set_database
- character_set_server
- collation_connection
- collation_database
- collation_server
- foreign_key_checks
- identity
- last_insert_id
- lc_time_names
- pseudo_thread_id
- sql_auto_is_null
- time_zone
- timestamp
- unique_checks

When MIXED mode is used, the variables in the preceding list, when used with session scope, cause a switch from statement-based to row-based logging. See Section 5.4.4.3, “Mixed Binary Logging Format”.
**sql_mode** is also replicated except for the **NO_DIR_IN_CREATE** mode; the slave always preserves its own value for **NO_DIR_IN_CREATE**, regardless of changes to it on the master. This is true for all replication formats.

However, when **mysqlbinlog** parses a `SET @sql_mode = mode` statement, the full `mode` value, including **NO_DIR_IN_CREATE**, is passed to the receiving server. For this reason, replication of such a statement may not be safe when **STATEMENT** mode is in use.

The **default_storage_engine** and **storage_engine** system variables are not replicated, regardless of the logging mode; this is intended to facilitate replication between different storage engines.

The **read_only** system variable is not replicated. In addition, the enabling this variable has different effects with regard to temporary tables, table locking, and the **SET PASSWORD** statement in different MySQL versions.

The **max_heap_table_size** system variable is not replicated. Increasing the value of this variable on the master without doing so on the slave can lead eventually to **Table is full** errors on the slave when trying to execute **INSERT** statements on a **MEMORY** table on the master that is thus permitted to grow larger than its counterpart on the slave. For more information, see Section 17.4.1.20, “Replication and MEMORY Tables”.

In statement-based replication, session variables are not replicated properly when used in statements that update tables. For example, the following sequence of statements will not insert the same data on the master and the slave:

```sql
SET max_join_size=1000;
INSERT INTO mytable VALUES(@@max_join_size);
```

This does not apply to the common sequence:

```sql
SET time_zone=...;
INSERT INTO mytable VALUES(CONVERT_TZ(..., ..., @@time_zone));
```

Replication of session variables is not a problem when row-based replication is being used, in which case, session variables are always replicated safely. See Section 17.1.2, “Replication Formats”.

In MySQL 5.5, the following session variables are written to the binary log and honored by the replication slave when parsing the binary log, regardless of the logging format:

- **sql_mode**
- **foreign_key_checks**
- **unique_checks**
- **character_set_client**
- **collation_connection**
- **collation_database**
- **collation_server**
- **sql_auto_is_null**

**Important**

Even though session variables relating to character sets and collations are written to the binary log, replication between different character sets is not supported.
It is strongly recommended that you always use the same setting for the `lower_case_table_names` system variable on both master and slave. In particular, when a case-sensitive file system is used, setting this variable to 1 on the slave, but to a different value on the master, can cause two types of problems: Names of databases are not converted to lowercase; in addition, when using row-based replication names of tables are also not converted. Either of these problems can cause replication to fail. This is a known issue, which is fixed in MySQL 5.6.

### 17.4.1.38 Replication and Views

Views are always replicated to slaves. Views are filtered by their own name, not by the tables they refer to. This means that a view can be replicated to the slave even if the view contains a table that would normally be filtered out by `replication-ignore-table` rules. Care should therefore be taken to ensure that views do not replicate table data that would normally be filtered for security reasons.

Replication from a table to a samed-named view is supported using statement-based logging, but not when using row-based logging. In MySQL 5.5.31 and later, trying to do so when row-based logging is in effect causes an error. (Bug #11752707, Bug #43975)

### 17.4.2 Replication Compatibility Between MySQL Versions

MySQL supports replication from one release series to the next higher release series. For example, you can replicate from a master running MySQL 5.1 to a slave running MySQL 5.5, from a master running MySQL 5.5 to a slave running MySQL 5.6, and so on.

However, one may encounter difficulties when replicating from an older master to a newer slave if the master uses statements or relies on behavior no longer supported in the version of MySQL used on the slave. For example, in MySQL 5.5, `CREATE TABLE ... SELECT` statements are permitted to change tables other than the one being created, but are no longer allowed to do so in MySQL 5.6 (see Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”).

The use of more than two MySQL Server versions is not supported in replication setups involving multiple masters, regardless of the number of master or slave MySQL servers. This restriction applies not only to release series, but to version numbers within the same release series as well. For example, if you are using a chained or circular replication setup, you cannot use MySQL 5.5.1, MySQL 5.5.2, and MySQL 5.5.4 concurrently, although you could use any two of these releases together.

---

**Important**

It is strongly recommended to use the most recent release available within a given MySQL release series because replication (and other) capabilities are continually being improved. It is also recommended to upgrade masters and slaves that use early releases of a release series of MySQL to GA (production) releases when the latter become available for that release series.

Replication from newer masters to older slaves may be possible, but is generally not supported. This is due to a number of factors:

- **Binary log format changes.** The binary log format can change between major releases. While we attempt to maintain backward compatibility, this is not always possible. For example, the binary log format implemented in MySQL 5.0 changed considerably from that used in previous versions, especially with regard to handling of character sets, `LOAD DATA`, and time zones. This means that replication from a MySQL 5.0 (or later) master to a MySQL 4.1 (or earlier) slave is generally not supported.

This also has significant implications for upgrading replication servers; see Section 17.4.3, “Upgrading a Replication Setup”, for more information.
Upgrading a Replication Setup

- **Use of row-based replication.** Row-based replication was implemented in MySQL 5.1.5, so you cannot replicate using row-based replication from any MySQL 5.5 or later master to a slave older than MySQL 5.1.5.

  For more information about row-based replication, see Section 17.1.2, “Replication Formats”.

- **SQL incompatibilities.** You cannot replicate from a newer master to an older slave using statement-based replication if the statements to be replicated use SQL features available on the master but not on the slave.

  However, if both the master and the slave support row-based replication, and there are no data definition statements to be replicated that depend on SQL features found on the master but not on the slave, you can use row-based replication to replicate the effects of data modification statements even if the DDL run on the master is not supported on the slave.

  For more information on potential replication issues, see Section 17.4.1, “Replication Features and Issues”.

### 17.4.3 Upgrading a Replication Setup

When you upgrade servers that participate in a replication setup, the procedure for upgrading depends on the current server versions and the version to which you are upgrading. This section provides information about how upgrading affects replication. For general information about upgrading MySQL, see Section 2.11, “Upgrading MySQL”.

When you upgrade a master to 5.5 from an earlier MySQL release series, you should first ensure that all the slaves of this master are using the same 5.5.x release. If this is not the case, you should first upgrade the slaves. To upgrade each slave, shut it down, upgrade it to the appropriate 5.5.x version, restart it, and restart replication. The 5.5 slave is able to read the old relay logs written prior to the upgrade and to execute the statements they contain. Relay logs created by the slave after the upgrade are in 5.5 format.

After the slaves have been upgraded, shut down the master, upgrade it to the same 5.5.x release as the slaves, and restart it. The 5.5 master is able to read the old binary logs written prior to the upgrade and to send them to the 5.5 slaves. The slaves recognize the old format and handle it properly. Binary logs created by the master subsequent to the upgrade are in 5.5 format. These too are recognized by the 5.5 slaves.

In other words, when upgrading to MySQL 5.5, the slaves must be MySQL 5.5 before you can upgrade the master to 5.5. Note that downgrading from 5.5 to older versions does not work so simply: You must ensure that any 5.5 binary log or relay log has been fully processed, so that you can remove it before proceeding with the downgrade.

Some upgrades may require that you drop and re-create database objects when you move from one MySQL series to the next. For example, collation changes might require that table indexes be rebuilt. Such operations, if necessary, are detailed at Section 2.11.3, “Changes in MySQL 5.5”. It is safest to perform these operations separately on the slaves and the master, and to disable replication of these operations from the master to the slave. To achieve this, use the following procedure:

1. Stop all the slaves and upgrade them. Restart them with the `--skip-slave-start` option so that they do not connect to the master. Perform any table repair or rebuilding operations needed to re-create database objects, such as use of `REPAIR TABLE` or `ALTER TABLE`, or dumping and reloading tables or triggers.

2. Disable the binary log on the master. To do this without restarting the master, execute a `SET sql_log_bin = OFF` statement. Alternatively, stop the master and restart it without the `--log-bin` option. If you restart the master, you might also want to disallow client connections. For example, if all
Troubleshooting Replication

clients connect using TCP/IP, enable the `skip_networking` system variable when you restart the master.

3. With the binary log disabled, perform any table repair or rebuilding operations needed to re-create database objects. The binary log must be disabled during this step to prevent these operations from being logged and sent to the slaves later.

4. Re-enable the binary log on the master. If you set `sql_log_bin` to `OFF` earlier, execute a `SET sql_log_bin = ON` statement. If you restarted the master to disable the binary log, restart it with `--log-bin`, and without enabling the `skip_networking` system variable so that clients and slaves can connect.

5. Restart the slaves, this time without the `--skip-slave-start` option.

17.4.4 Troubleshooting Replication

If you have followed the instructions but your replication setup is not working, the first thing to do is check the error log for messages. Many users have lost time by not doing this soon enough after encountering problems.

If you cannot tell from the error log what the problem was, try the following techniques:

- Verify that the master has binary logging enabled by issuing a `SHOW MASTER STATUS` statement. If logging is enabled, `Position` is nonzero. If binary logging is not enabled, verify that you are running the master with the `--log-bin` option.

- Verify that the `server_id` system variable was set at startup on both the master and slave and that the ID value is unique on each server.

- Verify that the slave is running. Use `SHOW SLAVE STATUS` to check whether the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify the options that were used when starting the slave server. For example, `--skip-slave-start` prevents the slave threads from starting until you issue a `START SLAVE` statement.

- If the slave is running, check whether it established a connection to the master. Use `SHOW PROCESSLIST`, find the I/O and SQL threads and check their `State` column to see what they display. See Section 17.2.1, “Replication Implementation Details”. If the I/O thread state says `Connecting to master`, check the following:

  - Verify the privileges for the user being used for replication on the master.

  - Check that the host name of the master is correct and that you are using the correct port to connect to the master. The port used for replication is the same as used for client network communication (the default is `3306`). For the host name, ensure that the name resolves to the correct IP address.

  - Check the configuration file to see whether the `skip_networking` system variable has been enabled on the master or slave to disable networking. If so, comment the setting or remove it.

  - If the master has a firewall or IP filtering configuration, ensure that the network port being used for MySQL is not being filtered.

  - Check that you can reach the master by using `ping` or `traceroute/tracert` to reach the host.

  - If the slave was running previously but has stopped, the reason usually is that some statement that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modified the data on the slave outside of the slave thread. If the slave stops unexpectedly, it is a bug or you have encountered one of the known replication limitations
described in Section 17.4.1, “Replication Features and Issues”. If it is a bug, see Section 17.4.5, “How to Report Replication Bugs or Problems”, for instructions on how to report it.

• If a statement that succeeded on the master refuses to run on the slave, try the following procedure if it is not feasible to do a full database resynchronization by deleting the slave’s databases and copying a new snapshot from the master:

1. Determine whether the affected table on the slave is different from the master table. Try to understand how this happened. Then make the slave’s table identical to the master’s and run START SLAVE.

2. If the preceding step does not work or does not apply, try to understand whether it would be safe to make the update manually (if needed) and then ignore the next statement from the master.

3. If you decide that the slave can skip the next statement from the master, issue the following statements:

   mysql> SET GLOBAL sql_slave_skip_counter = N;
   mysql> START SLAVE;

   The value of \( N \) should be 1 if the next statement from the master does not use AUTO_INCREMENT or LAST_INSERT_ID(). Otherwise, the value should be 2. The reason for using a value of 2 for statements that use AUTO_INCREMENT or LAST_INSERT_ID() is that they take two events in the binary log of the master.

   See also Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Statement”.

4. If you are sure that the slave started out perfectly synchronized with the master, and that no one has updated the tables involved outside of the slave thread, then presumably the discrepancy is the result of a bug. If you are running the most recent version of MySQL, please report the problem. If you are running an older version, try upgrading to the latest production release to determine whether the problem persists.

### 17.4.5 How to Report Replication Bugs or Problems

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to obtain as much information as possible from you to be able to track down the bug. Please spend some time and effort in preparing a good bug report.

If you have a repeatable test case that demonstrates the bug, please enter it into our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If you have a “phantom” problem (one that you cannot duplicate at will), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data goes out of synchrony, and you can have unique key violations on updates. In this case, the slave thread stops and waits for you to clean up the tables manually to bring them into synchrony. This is not a replication problem. It is a problem of outside interference causing replication to fail.

2. Run the slave with the \(--log-slave-updates\) and \(--log-bin\) options. These options cause the slave to log the updates that it receives from the master into its own binary logs.

3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it becomes difficult or impossible for us to track down the problem. The evidence you should collect is:

   • All binary log files from the master
• All binary log files from the slave
• The output of `SHOW MASTER STATUS` from the master at the time you discovered the problem
• The output of `SHOW SLAVE STATUS` from the slave at the time you discovered the problem
• Error logs from the master and the slave

4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the problem statement. `log_file` and `log_pos` are the `Master_Log_File` and `Read_Master_Log_Pos` values from `SHOW SLAVE STATUS`.

```
shell> mysqlbinlog --start-position=log_pos log_file | head
```

After you have collected the evidence for the problem, try to isolate it as a separate test case first. Then enter the problem with as much information as possible into our bugs database using the instructions at Section 1.6, “How to Report Bugs or Problems”.
# Chapter 18 MySQL NDB Cluster 7.2

## Table of Contents

18.1 NDB Cluster Overview ................................................................. 2116
  18.1.1 NDB Cluster Core Concepts .................................................. 2118
  18.1.2 NDB Cluster Nodes, Node Groups, Replicas, and Partitions .......... 2121
  18.1.3 NDB Cluster Hardware, Software, and Networking Requirements .... 2123
  18.1.4 What is New in MySQL NDB Cluster 7.2 .............................. 2125
  18.1.5 Options, Variables, and Parameters Added, Deprecated or Removed in NDB 7.2 2128
  18.1.6 MySQL Server Using InnoDB Compared with NDB Cluster .......... 2131
  18.1.7 Known Limitations of NDB Cluster ...................................... 2134

18.2 NDB Cluster Installation ........................................................... 2146
  18.2.1 Installing NDB Cluster on Linux ........................................ 2148
  18.2.2 Installing NDB Cluster on Windows .................................... 2155
  18.2.3 Initial Configuration of NDB Cluster .................................... 2163
  18.2.4 Initial Startup of NDB Cluster .......................................... 2165
  18.2.5 NDB Cluster Example with Tables and Data .......................... 2166
  18.2.6 Safe Shutdown and Restart of NDB Cluster ............................ 2170
  18.2.7 Upgrading and Downgrading NDB Cluster ............................... 2171

18.3 Configuration of NDB Cluster .................................................... 2173
  18.3.1 Quick Test Setup of NDB Cluster ....................................... 2173
  18.3.2 Overview of NDB Cluster Configuration Parameters, Options, and Variables 2176
  18.3.3 NDB Cluster Configuration Files ....................................... 2192
  18.3.4 Using High-Speed Interconnects with NDB Cluster .................. 2348

18.4 NDB Cluster Programs ............................................................... 2349
  18.4.1 ndbd — The NDB Cluster Data Node Daemon .......................... 2349
  18.4.2 ndbinfo_select_all — Select From ndbinfo Tables ................ 2357
  18.4.3 ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded) ...... 2358
  18.4.4 ndb — The NDB Cluster Management Server Daemon ................ 2359
  18.4.5 ndb — The NDB Cluster Management Client ............................ 2368
  18.4.6 ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables 2370
  18.4.7 ndb_config — Extract NDB Cluster Configuration Information .... 2372
  18.4.8 ndb_cpcd — Automate Testing for NDB Development ................. 2381
  18.4.9 ndb_delete_all — Delete All Rows from an NDB Table ............... 2381
  18.4.10 ndb_desc — Describe NDB Tables ..................................... 2382
  18.4.11 ndb_drop_index — Drop Index from an NDB Table .................. 2387
  18.4.12 ndb_drop_table — Drop an NDB Table ................................. 2388
  18.4.13 ndb_error_reporter — NDB Error-Reporting Utility ................ 2388
  18.4.14 ndb_index_stat — NDB Index Statistics Utility .................... 2390
  18.4.15 ndb_move_data — NDB Data Copy Utility ............................. 2396
  18.4.16 ndb_print_backup_file — Print NDB Backup File Contents ........ 2398
  18.4.17 ndb_print_file — Print NDB Disk Data File Contents ............. 2399
  18.4.18 ndb_print_schema_file — Print NDB Schema File Contents .......... 2399
  18.4.19 ndb_print_sys_file — Print NDB System File Contents ............. 2400
  18.4.20 ndb_redo_log_reader — Check and Print Content of Cluster Redo Log 2400
  18.4.21 ndb_recover — Restore an NDB Cluster Backup ....................... 2404
  18.4.22 ndb_select_all — Print Rows from an NDB Table ................... 2426
  18.4.23 ndb_select_count — Print Row Counts for NDB Tables ............... 2429
  18.4.24 ndb_show_tables — Display List of NDB Tables ..................... 2430
  18.4.25 ndb_size.pl — NDBCLUSTER Size Requirement Estimator ............ 2431
  18.4.26 ndb_waiter — Wait for NDB Cluster to Reach a Given Status ...... 2434
MySQL NDB Cluster is a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. The most recent NDB Cluster release series uses version 8 of the NDB storage engine (also known as NDBCLUSTER) to enable running several computers with MySQL servers and other software in a cluster. NDB Cluster 8.0, now available as a General Availability (GA) release beginning with version 8.0.19, incorporates version 8.0 of the NDB storage engine. NDB Cluster 7.6 and NDB Cluster 7.5, still available as GA releases, use versions 7.6 and 7.5 of NDB, respectively. Previous GA releases still available for use in production, NDB Cluster 7.4 and NDB Cluster 7.3, incorporate NDB versions 7.4 and 7.3, respectively. NDB Cluster 7.2, which uses version 7.2 of the NDB storage engine, is a past GA release that is no longer supported for new deployments; NDB 7.2 users are encouraged to upgrade to NDB 7.6 or NDB 8.0. NDB 7.1 and older release series are no longer supported or maintained.

Support for the NDBCLUSTER storage engine is not included in standard MySQL Server 5.5 binaries built by Oracle. Instead, users of NDB Cluster binaries from Oracle should upgrade to the most recent binary release of NDB Cluster for supported platforms—these include RPMs that should work with most Linux distributions. NDB Cluster users who build from source should use the sources provided for NDB Cluster. (Locations where the sources can be obtained are listed later in this section.)

This chapter contains information about NDB Cluster 7.2 releases through 5.5.65-ndb-7.2.39. NDB Cluster 8.0 is now available as a General Availability release, and recommended for new deployments; for information about NDB Cluster 8.0, see What is New in NDB Cluster. NDB Cluster 7.6, 7.5, 7.4, and 7.3 are previous GA releases still supported in production. For similar information about NDB Cluster 7.6 and
7.5, see What is New in NDB Cluster; for information about NDB CLuster 7.4 and 7.3, see What is New in MySQL NDB Cluster. NDB Cluster 7.2 is a past GA release series which is no longer supported for new deployments; we recommend that new deployments for production use NDB Cluster 8.0.

Supported Platforms. NDB Cluster is currently available and supported on a number of platforms. For exact levels of support available for on specific combinations of operating system versions, operating system distributions, and hardware platforms, please refer to https://www.mysql.com/support/supportedplatforms/cluster.html.

Availability. NDB Cluster binary and source packages are available for supported platforms from https://dev.mysql.com/downloads/cluster/.

NDB Cluster release numbers. NDB Cluster follows a somewhat different release pattern from the mainline MySQL Server 5.5 series of releases. In this Manual and other MySQL documentation, we identify these and later NDB Cluster releases employing a version number that begins with “NDB”. This version number is that of the NDBCLUSTER storage engine used in the release, and not of the MySQL server version on which the NDB Cluster release is based.

Version strings used in NDB Cluster software. The version string displayed by NDB Cluster programs uses this format:

```
mysql-mysql_server_version-ndb-ndb_engine_version
```

`mysql_server_version` represents the version of the MySQL Server on which the NDB Cluster release is based. For all NDB Cluster 6.x and 7.x releases, this is “5.1”. `ndb_engine_version` is the version of the NDB storage engine used by this release of the NDB Cluster software. You can see this format used in the mysql client, as shown here:

```
shell> mysql
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.5.65-ndb-7.2.39 Source distribution
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT VERSION()\G
*************************** 1. row ***************************
VERSION(): 5.5.65-ndb-7.2.39
1 row in set (0.00 sec)
```

This version string is also displayed in the output of the SHOW command in the ndb_mgm client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
------------------------
[ndbd(NDB)] 2 node(s)
id=1 @10.0.10.6 (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=2 @10.0.10.8 (5.5.65-ndb-7.2.39, Nodegroup: 0)

[ndb_mgm(MGM)] 1 node(s)
id=3 @10.0.10.2 (5.5.65-ndb-7.2.39)
```

The version string identifies the mainline MySQL version from which the NDB Cluster release was branched and the version of the NDBCLUSTER storage engine used. For example, the full version string for NDB 7.2.4 (the first NDB Cluster production release based on MySQL Server 5.5) is `mysql-5.5.19-ndb-7.2.4`. From this we can determine the following:
• Since the portion of the version string preceding `-ndb-` is the base MySQL Server version, this means that NDB 7.2.4 derives from the MySQL 5.5.19, and contains all feature enhancements and bugfixes from MySQL 5.5 up to and including MySQL 5.5.19.

• Since the portion of the version string following `-ndb-` represents the version number of the NDB (or NDBCLUSTER) storage engine, NDB 7.2.4 uses version 7.2.4 of the NDBCLUSTER storage engine.

New NDB Cluster releases are numbered according to updates in the NDB storage engine, and do not necessarily correspond in a one-to-one fashion with mainline MySQL Server releases. For example, NDB 7.2.4 (as previously noted) is based on MySQL 5.5.19, while NDB 7.2.0 was based on MySQL 5.1.51 (version string: `mysql-5.1.51-ndb-7.2.0`).

Compatibility with standard MySQL 5.5 releases. While many standard MySQL schemas and applications can work using NDB Cluster, it is also true that unmodified applications and database schemas may be slightly incompatible or have suboptimal performance when run using NDB Cluster (see Section 18.1.7, “Known Limitations of NDB Cluster”). Most of these issues can be overcome, but this also means that you are very unlikely to be able to switch an existing application datastore—that currently uses, for example, MyISAM or InnoDB—to use the NDB storage engine without allowing for the possibility of changes in schemas, queries, and applications. In addition, the MySQL Server and NDB Cluster codebases diverge considerably, so that the standard `mysqld` cannot function as a drop-in replacement for the version of `mysqld` supplied with NDB Cluster.

NDB Cluster development source trees. NDB Cluster development trees can also be accessed from https://github.com/mysql/mysql-server.

The NDB Cluster development sources maintained at https://github.com/mysql/mysql-server are licensed under the GPL. For information about obtaining MySQL sources using Git and building them yourself, see Section 2.9.5, “Installing MySQL Using a Development Source Tree”.

Note
As with MySQL Server 5.5, NDB Cluster 7.2 is built using CMake.

NDB Cluster 8.0 is available beginning with NDB 8.0.19 as a General Availability release, and is recommended for new deployments; see What is New in NDB Cluster, for more information. NDB Cluster 7.6 and 7.5 are previous GA releases still supported in production; for information about NDB Cluster 7.6, see What is New in NDB Cluster 7.6. For similar information about NDB Cluster 7.5, see What is New in NDB Cluster 7.5. NDB Cluster 7.4 and 7.3 are previous GA releases still supported in production, although we recommend that new deployments for production use NDB Cluster 8.0; see MySQL NDB Cluster 7.3 and NDB Cluster 7.4. NDB Cluster 7.2 is a past GA release series which no longer supported for new deployments; users of NDB 7.2 should upgrade to a later version.

This chapter represents a work in progress, and its contents are subject to revision as NDB Cluster continues to evolve. Additional information regarding NDB Cluster can be found on the MySQL website at http://www.mysql.com/products/cluster/.

Additional Resources. More information about NDB Cluster can be found in the following places:

• For answers to some commonly asked questions about NDB Cluster, see Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”.


• Many NDB Cluster users and developers blog about their experiences with NDB Cluster, and make feeds of these available through PlanetMySQL.

18.1 NDB Cluster Overview
**NDB Cluster** is a technology that enables clustering of in-memory databases in a shared-nothing system. The shared-nothing architecture enables the system to work with very inexpensive hardware, and with a minimum of specific requirements for hardware or software.

NDB Cluster is designed not to have any single point of failure. In a shared-nothing system, each component is expected to have its own memory and disk, and the use of shared storage mechanisms such as network shares, network file systems, and SANs is not recommended or supported.

NDB Cluster integrates the standard MySQL server with an in-memory clustered storage engine called **NDB** (which stands for “Network DataBase”). In our documentation, the term **NDB** refers to the part of the setup that is specific to the storage engine, whereas “MySQL NDB Cluster” refers to the combination of one or more MySQL servers with the NDB storage engine.

An NDB Cluster consists of a set of computers, known as **hosts**, each running one or more processes. These processes, known as **nodes**, may include MySQL servers (for access to NDB data), data nodes (for storage of the data), one or more management servers, and possibly other specialized data access programs. The relationship of these components in an NDB Cluster is shown here:

**Figure 18.1 NDB Cluster Components**

All these programs work together to form an NDB Cluster (see Section 18.4, “NDB Cluster Programs”). When data is stored by the NDB storage engine, the tables (and table data) are stored in the data nodes. Such tables are directly accessible from all other MySQL servers (SQL nodes) in the cluster. Thus, in a payroll application storing data in a cluster, if one application updates the salary of an employee, all other MySQL servers that query this data can see this change immediately.

Although an NDB Cluster SQL node uses the **mysqld** server daemon, it differs in a number of critical respects from the **mysqld** binary supplied with the MySQL 5.5 distributions, and the two versions of **mysqld** are not interchangeable.

In addition, a MySQL server that is not connected to an NDB Cluster cannot use the NDB storage engine and cannot access any NDB Cluster data.

The data stored in the data nodes for NDB Cluster can be mirrored; the cluster can handle failures of individual data nodes with no other impact than that a small number of transactions are aborted due to losing the transaction state. Because transactional applications are expected to handle transaction failure, this should not be a source of problems.
Individual nodes can be stopped and restarted, and can then rejoin the system (cluster). Rolling restarts (in which all nodes are restarted in turn) are used in making configuration changes and software upgrades (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”). Rolling restarts are also used as part of the process of adding new data nodes online (see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”). For more information about data nodes, how they are organized in an NDB Cluster, and how they handle and store NDB Cluster data, see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”.

Backing up and restoring NDB Cluster databases can be done using the NDB-native functionality found in the NDB Cluster management client and the ndb_restore program included in the NDB Cluster distribution. For more information, see Section 18.5.3, “Online Backup of NDB Cluster”, and Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”. You can also use the standard MySQL functionality provided for this purpose in mysql and the MySQL server. See Section 4.5.4, “mysqldump — A Database Backup Program”, for more information.

NDB Cluster nodes can employ different transport mechanisms for inter-node communications; TCP/IP over standard 100 Mbps or faster Ethernet hardware is used in most real-world deployments.

### 18.1.1 NDB Cluster Core Concepts

NDBCLUSTER (also known as NDB) is an in-memory storage engine offering high-availability and data-persistence features.

The NDBCLUSTER storage engine can be configured with a range of failover and load-balancing options, but it is easiest to start with the storage engine at the cluster level. NDB Cluster's NDB storage engine contains a complete set of data, dependent only on other data within the cluster itself.

The “Cluster” portion of NDB Cluster is configured independently of the MySQL servers. In an NDB Cluster, each part of the cluster is considered to be a node.

**Note**

In many contexts, the term “node” is used to indicate a computer, but when discussing NDB Cluster it means a process. It is possible to run multiple nodes on a single computer; for a computer on which one or more cluster nodes are being run we use the term cluster host.

There are three types of cluster nodes, and in a minimal NDB Cluster configuration, there will be at least three nodes, one of each of these types:

- **Management node**: The role of this type of node is to manage the other nodes within the NDB Cluster, performing such functions as providing configuration data, starting and stopping nodes, and running backups. Because this node type manages the configuration of the other nodes, a node of this type should be started first, before any other node. An MGM node is started with the command ndb_mgmd.

- **Data node**: This type of node stores cluster data. There are as many data nodes as there are replicas, times the number of fragments (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”). For example, with two replicas, each having two fragments, you need four data nodes. One replica is sufficient for data storage, but provides no redundancy; therefore, it is recommended to have 2 (or more) replicas to provide redundancy, and thus high availability. A data node is started with the command ndbd (see Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”) or ndbmtc (see Section 18.4.3, “ndbmtc — The NDB Cluster Data Node Daemon (Multi-Threaded)”).

NDB Cluster tables are normally stored completely in memory rather than on disk (this is why we refer to NDB Cluster as an in-memory database). However, some NDB Cluster data can be stored on disk; see Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.
NDB Cluster Core Concepts

- **SQL node**: This is a node that accesses the cluster data. In the case of NDB Cluster, an SQL node is a traditional MySQL server that uses the NDBCLUSTER storage engine. An SQL node is a `mysqld` process started with the `--ndbcluster` and `--ndb-connectstring` options, which are explained elsewhere in this chapter, possibly with additional MySQL server options as well.

An SQL node is actually just a specialized type of **API node**, which designates any application which accesses NDB Cluster data. Another example of an API node is the `ndb_restore` utility that is used to restore a cluster backup. It is possible to write such applications using the NDB API. For basic information about the NDB API, see *Getting Started with the NDB API*.

**Important**

It is not realistic to expect to employ a three-node setup in a production environment. Such a configuration provides no redundancy; to benefit from NDB Cluster's high-availability features, you must use multiple data and SQL nodes. The use of multiple management nodes is also highly recommended.

For a brief introduction to the relationships between nodes, node groups, replicas, and partitions in NDB Cluster, see *Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”*. Configuration of a cluster involves configuring each individual node in the cluster and setting up individual communication links between nodes. NDB Cluster is currently designed with the intention that data nodes are homogeneous in terms of processor power, memory space, and bandwidth. In addition, to provide a single point of configuration, all configuration data for the cluster as a whole is located in one configuration file.

The management server manages the cluster configuration file and the cluster log. Each node in the cluster retrieves the configuration data from the management server, and so requires a way to determine where the management server resides. When interesting events occur in the data nodes, the nodes transfer information about these events to the management server, which then writes the information to the cluster log.

In addition, there can be any number of cluster client processes or applications. These include standard MySQL clients, NDB-specific API programs, and management clients. These are described in the next few paragraphs.

**Standard MySQL clients.** NDB Cluster can be used with existing MySQL applications written in PHP, Perl, C, C++, Java, Python, Ruby, and so on. Such client applications send SQL statements to and receive responses from MySQL servers acting as NDB Cluster SQL nodes in much the same way that they interact with standalone MySQL servers.

MySQL clients using an NDB Cluster as a data source can be modified to take advantage of the ability to connect with multiple MySQL servers to achieve load balancing and failover. For example, Java clients using Connector/J 5.0.6 and later can use `jdbc:mysql:loadbalance://` URLs (improved in Connector/J 5.1.7) to achieve load balancing transparently; for more information about using Connector/J with NDB Cluster, see *Using Connector/J with NDB Cluster*.

**NDB client programs.** Client programs can be written that access NDB Cluster data directly from the NDBCLUSTER storage engine, bypassing any MySQL Servers that may be connected to the cluster, using the **NDB API**, a high-level C++ API. Such applications may be useful for specialized purposes where an SQL interface to the data is not needed. For more information, see *The NDB API*.

**NDB**-specific Java applications can also be written for NDB Cluster using the **NDB Cluster Connector for Java**. This NDB Cluster Connector includes **ClusterJ**, a high-level database API similar to object-relational mapping persistence frameworks such as Hibernate and JPA that connect directly to NDBCLUSTER, and so does not require access to a MySQL Server. Support is also provided in NDB Cluster for **ClusterJPA**, an OpenJPA implementation for NDB Cluster that leverages the strengths of ClusterJ and JDBC; ID
lookups and other fast operations are performed using ClusterJ (bypassing the MySQL Server), while more complex queries that can benefit from MySQL’s query optimizer are sent through the MySQL Server, using JDBC. See Java and NDB Cluster, and The ClusterJ API and Data Object Model, for more information.

The Memcache API for NDB Cluster, implemented as the loadable ndbmemcache storage engine for memcached version 1.6 and later, is available beginning with NDB 7.2.2. This API can be used to provide a persistent NDB Cluster data store, accessed using the memcache protocol.

The standard memcached caching engine is included in the NDB Cluster 7.2 distribution (7.2.2 and later). Each memcached server has direct access to data stored in NDB Cluster, but is also able to cache data locally and to serve (some) requests from this local cache.

For more information, see ndbmemcache—Memcache API for NDB Cluster.

Management clients. These clients connect to the management server and provide commands for starting and stopping nodes gracefully, starting and stopping message tracing (debug versions only), showing node versions and status, starting and stopping backups, and so on. An example of this type of program is the ndb_mgm management client supplied with NDB Cluster (see Section 18.4.5, “ndb_mgm — The NDB Cluster Management Client”). Such applications can be written using the MGM API, a C-language API that communicates directly with one or more NDB Cluster management servers. For more information, see The MGM API.

Oracle also makes available MySQL Cluster Manager, which provides an advanced command-line interface simplifying many complex NDB Cluster management tasks, such as restarting an NDB Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as mysqld server options and variables relating to NDB Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

Event logs. NDB Cluster logs events by category (startup, shutdown, errors, checkpoints, and so on), priority, and severity. A complete listing of all reportable events may be found in Section 18.5.6, “Event Reports Generated in NDB Cluster”. Event logs are of the two types listed here:

- **Cluster log**: Keeps a record of all desired reportable events for the cluster as a whole.
- **Node log**: A separate log which is also kept for each individual node.

**Note**
Under normal circumstances, it is necessary and sufficient to keep and examine only the cluster log. The node logs need be consulted only for application development and debugging purposes.

Checkpoint. Generally speaking, when data is saved to disk, it is said that a checkpoint has been reached. More specific to NDB Cluster, a checkpoint is a point in time where all committed transactions are stored on disk. With regard to the NDB storage engine, there are two types of checkpoints which work together to ensure that a consistent view of the cluster’s data is maintained. These are shown in the following list:

- **Local Checkpoint (LCP)**: This is a checkpoint that is specific to a single node; however, LCPs take place for all nodes in the cluster more or less concurrently. An LCP involves saving all of a node’s data to disk, and so usually occurs every few minutes. The precise interval varies, and depends upon the amount of data stored by the node, the level of cluster activity, and other factors.

- **Global Checkpoint (GCP)**: A GCP occurs every few seconds, when transactions for all nodes are synchronized and the redo-log is flushed to disk.

For more information about the files and directories created by local checkpoints and global checkpoints, see NDB Cluster Data Node File System Directory Files.
18.1.2 NDB Cluster Nodes, Node Groups, Replicas, and Partitions

This section discusses the manner in which NDB Cluster divides and duplicates data for storage.

A number of concepts central to an understanding of this topic are discussed in the next few paragraphs.

**Data node.** An `ndbd` or `ndbmtd` process, which stores one or more replicas—that is, copies of the partitions (discussed later in this section) assigned to the node group of which the node is a member.

Each data node should be located on a separate computer. While it is also possible to host multiple data node processes on a single computer, such a configuration is not usually recommended.

It is common for the terms “node” and “data node” to be used interchangeably when referring to an `ndbd` or `ndbmtd` process; where mentioned, management nodes (`ndb_mgmd` processes) and SQL nodes (`mysqld` processes) are specified as such in this discussion.

**Node group.** A node group consists of one or more nodes, and stores partitions, or sets of replicas (see next item).

The number of node groups in an NDB Cluster is not directly configurable; it is a function of the number of data nodes and of the number of replicas (`NoOfReplicas` configuration parameter), as shown here:

```
[# of node groups] = [# of data nodes] / NoOfReplicas
```

Thus, an NDB Cluster with 4 data nodes has 4 node groups if `NoOfReplicas` is set to 1 in the `config.ini` file, 2 node groups if `NoOfReplicas` is set to 2, and 1 node group if `NoOfReplicas` is set to 4. Replicas are discussed later in this section; for more information about `NoOfReplicas`, see Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.

⚠️ **Note**

All node groups in an NDB Cluster must have the same number of data nodes.

You can add new node groups (and thus new data nodes) online, to a running NDB Cluster; see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”, for more information.

**Partition.** This is a portion of the data stored by the cluster. Each node is responsible for keeping at least one copy of any partitions assigned to it (that is, at least one replica) available to the cluster.

The number of partitions used by default by NDB Cluster depends on the number of data nodes and the number of LDM threads in use by the data nodes, as shown here:

```
[# of partitions] = [# of data nodes] * [# of LDM threads]
```

When using data nodes running `ndbmtd`, the number of LDM threads is controlled by the setting for `MaxNoOfExecutionThreads`. When using `ndbd` there is a single LDM thread, which means that there are as many cluster partitions as nodes participating in the cluster. This is also the case when using `ndbmtd` with `MaxNoOfExecutionThreads` set to 3 or less. (You should be aware that the number of LDM threads increases with the value of this parameter, but not in a strictly linear fashion, and that there are additional constraints on setting it; see the description of `MaxNoOfExecutionThreads` for more information.)

**NDB and user-defined partitioning.** NDB Cluster normally partitions `NDBCLUSTER` tables automatically. However, it is also possible to employ user-defined partitioning with `NDBCLUSTER` tables. This is subject to the following limitations:

1. Only the `KEY` and `LINEAR KEY` partitioning schemes are supported in production with `NDB` tables.
2. The maximum number of partitions that may be defined explicitly for any NDB table is \(8 \times \text{number of LDM threads} \times \text{number of node groups}\), the number of node groups in an NDB Cluster being determined as discussed previously in this section. When running \texttt{ndbd}\ for data node processes, setting the number of LDM threads has no effect (since \texttt{ThreadConfig} applies only to \texttt{ndbmtd}); in such cases, this value can be treated as though it were equal to 1 for purposes of performing this calculation.

See Section 18.4.3, “\texttt{ndbmtd} — The NDB Cluster Data Node Daemon (Multi-Threaded)”, for more information.

For more information relating to NDB Cluster and user-defined partitioning, see Section 18.1.7, “Known Limitations of NDB Cluster”, and Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”.

**Replica.** This is a copy of a cluster partition. Each node in a node group stores a replica. Also sometimes known as a partition replica. The number of replicas is equal to the number of nodes per node group.

A replica belongs entirely to a single node; a node can (and usually does) store several replicas.

The following diagram illustrates an NDB Cluster with four data nodes running \texttt{ndbd}, arranged in two node groups of two nodes each; nodes 1 and 2 belong to node group 0, and nodes 3 and 4 belong to node group 1.

\[
\text{Note}
\]

Only data nodes are shown here; although a working NDB Cluster requires an \texttt{ndb_mgmd} process for cluster management and at least one SQL node to access the data stored by the cluster, these have been omitted from the figure for clarity.

**Figure 18.2 NDB Cluster with Two Node Groups**
The data stored by the cluster is divided into four partitions, numbered 0, 1, 2, and 3. Each partition is stored—in multiple copies—on the same node group. Partitions are stored on alternate node groups as follows:

- Partition 0 is stored on node group 0; a primary replica (primary copy) is stored on node 1, and a backup replica (backup copy of the partition) is stored on node 2.

- Partition 1 is stored on the other node group (node group 1); this partition's primary replica is on node 3, and its backup replica is on node 4.

- Partition 2 is stored on node group 0. However, the placing of its two replicas is reversed from that of Partition 0; for Partition 2, the primary replica is stored on node 2, and the backup on node 1.

- Partition 3 is stored on node group 1, and the placement of its two replicas are reversed from those of partition 1. That is, its primary replica is located on node 4, with the backup on node 3.

What this means regarding the continued operation of an NDB Cluster is this: so long as each node group participating in the cluster has at least one node operating, the cluster has a complete copy of all data and remains viable. This is illustrated in the next diagram.

**Figure 18.3 Nodes Required for a 2x2 NDB Cluster**

In this example, the cluster consists of two node groups each consisting of two data nodes. Each data node is running an instance of `ndbd`. Any combination of at least one node from node group 0 and at least one node from node group 1 is sufficient to keep the cluster “alive”. However, if both nodes from a single node group fail, the combination consisting of the remaining two nodes in the other node group is not sufficient. In this situation, the cluster has lost an entire partition and so can no longer provide access to a complete set of all NDB Cluster data.

### 18.1.3 NDB Cluster Hardware, Software, and Networking Requirements

One of the strengths of NDB Cluster is that it can be run on commodity hardware and has no unusual requirements in this regard, other than for large amounts of RAM, due to the fact that all live data storage is done in memory. (It is possible to reduce this requirement using Disk Data tables—see Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information about these.) Naturally, multiple and faster CPUs can enhance performance. Memory requirements for other NDB Cluster processes are relatively small.
The software requirements for NDB Cluster are also modest. Host operating systems do not require any unusual modules, services, applications, or configuration to support NDB Cluster. For supported operating systems, a standard installation should be sufficient. The MySQL software requirements are simple: all that is needed is a production release of NDB Cluster. It is not strictly necessary to compile MySQL yourself merely to be able to use NDB Cluster. We assume that you are using the binaries appropriate to your platform, available from the NDB Cluster software downloads page at https://dev.mysql.com/downloads/cluster/.

For communication between nodes, NDB Cluster supports TCP/IP networking in any standard topology, and the minimum expected for each host is a standard 100 Mbps Ethernet card, plus a switch, hub, or router to provide network connectivity for the cluster as a whole. We strongly recommend that an NDB Cluster be run on its own subnet which is not shared with machines not forming part of the cluster for the following reasons:

- **Security.** Communications between NDB Cluster nodes are not encrypted or shielded in any way. The only means of protecting transmissions within an NDB Cluster is to run your NDB Cluster on a protected network. If you intend to use NDB Cluster for Web applications, the cluster should definitely reside behind your firewall and not in your network's De-Militarized Zone (DMZ) or elsewhere. See Section 18.5.11.1, “NDB Cluster Security and Networking Issues”, for more information.

- **Efficiency.** Setting up an NDB Cluster on a private or protected network enables the cluster to make exclusive use of bandwidth between cluster hosts. Using a separate switch for your NDB Cluster not only helps protect against unauthorized access to NDB Cluster data, it also ensures that NDB Cluster nodes are shielded from interference caused by transmissions between other computers on the network. For enhanced reliability, you can use dual switches and dual cards to remove the network as a single point of failure; many device drivers support failover for such communication links.

**Network communication and latency.** NDB Cluster requires communication between data nodes and API nodes (including SQL nodes), as well as between data nodes and other data nodes, to execute queries and updates. Communication latency between these processes can directly affect the observed performance and latency of user queries. In addition, to maintain consistency and service despite the silent failure of nodes, NDB Cluster uses heartbeating and timeout mechanisms which treat an extended loss of communication from a node as node failure. This can lead to reduced redundancy. Recall that, to maintain data consistency, an NDB Cluster shuts down when the last node in a node group fails. Thus, to avoid increasing the risk of a forced shutdown, breaks in communication between nodes should be avoided wherever possible.

The failure of a data or API node results in the abort of all uncommitted transactions involving the failed node. Data node recovery requires synchronization of the failed node’s data from a surviving data node, and re-establishment of disk-based redo and checkpoint logs, before the data node returns to service. This recovery can take some time, during which the Cluster operates with reduced redundancy.

Heartbeating relies on timely generation of heartbeat signals by all nodes. This may not be possible if the node is overloaded, has insufficient machine CPU due to sharing with other programs, or is experiencing delays due to swapping. If heartbeat generation is sufficiently delayed, other nodes treat the node that is slow to respond as failed.

This treatment of a slow node as a failed one may or may not be desirable in some circumstances, depending on the impact of the node's slowed operation on the rest of the cluster. When setting timeout values such as `HeartbeatIntervalDbDb` and `HeartbeatIntervalDbApi` for NDB Cluster, care must be taken to achieve quick detection, failover, and return to service, while avoiding potentially expensive false positives.

Where communication latencies between data nodes are expected to be higher than would be expected in a LAN environment (on the order of 100 µs), timeout parameters must be increased to ensure that any
allowed periods of latency periods are well within configured timeouts. Increasing timeouts in this way has a corresponding effect on the worst-case time to detect failure and therefore time to service recovery.

LAN environments can typically be configured with stable low latency, and such that they can provide redundancy with fast failover. Individual link failures can be recovered from with minimal and controlled latency visible at the TCP level (where NDB Cluster normally operates). WAN environments may offer a range of latencies, as well as redundancy with slower failover times. Individual link failures may require route changes to propagate before end-to-end connectivity is restored. At the TCP level this can appear as large latencies on individual channels. The worst-case observed TCP latency in these scenarios is related to the worst-case time for the IP layer to reroute around the failures.

SCI (Scalable Coherent Interface). It may also be possible to use the high-speed Scalable Coherent Interface (SCI) with NDB Cluster, but this is no longer officially supported. See Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”, for more information.

18.1.4 What is New in MySQL NDB Cluster 7.2

In this section, we discuss changes in the implementation of NDB Cluster in MySQL NDB Cluster 7.2, as compared to NDB Cluster 7.1 and earlier releases. Changes and features most likely to be of interest are shown in the following list:

• NDB Cluster 7.2 is based on MySQL 5.5. For more information about new features in MySQL Server 5.5, see Section 1.4, “What Is New in MySQL 5.5”.

• Version 2 binary log row events, to provide support for improvements in NDB Cluster Replication conflict detection (see next item). A given mysqld can be made to use Version 1 or Version 2 binary logging row events by setting the log_bin_use_v1_row_events system variable.

• Two new “primary wins” conflict detection and resolution functions NDB$EPOCH() and NDB$EPOCH_TRANS() for use in replication setups with 2 NDB Clusters. For more information, see Section 18.6, “NDB Cluster Replication”.

• Distribution of MySQL users and privileges across NDB Cluster SQL nodes is now supported—see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”.

• Improved support for distributed pushed-down joins, which greatly improve performance for many joins that can be executed in parallel on the data nodes.

• Default values for a number of data node configuration parameters such as HeartbeatIntervalDbDb and ArbitrationTimeout have been improved.

• Support for the Memcache API using the loadable ndbmemcache storage engine. See ndbmemcache—Memcache API for NDB Cluster.

This section contains information about NDB Cluster 7.2 releases through 5.5.65-ndb-7.2.39, a past General Availability (GA) release which is no longer supported for new deployments. (NDB 7.1 and earlier releases series are no longer maintained or supported in production.) We recommend that new deployments use NDB Cluster 8.0, which is the most recent General Availability release; see What is New in NDB Cluster, for more information about new features and other changes in NDB 8.0. NDB Cluster 7.6 and NDB Cluster 7.5 are a previous GA release still supported in production; see MySQL NDB Cluster 7.5 and NDB Cluster 7.6, for more information. NDB 7.4 and 7.3 are older GA releases also still supported in production; see MySQL NDB Cluster 7.3 and NDB Cluster 7.4.

The following improvements to NDB Cluster have been made in NDB Cluster 7.2:

• Based on MySQL Server 5.5. Previous NDB Cluster release series, including NDB Cluster 7.1, used MySQL 5.1 as a base. Beginning with NDB 7.2.1, NDB Cluster 7.2 is based on MySQL Server 5.5, so that NDB Cluster users can benefit from MySQL 5.5’s improvements in scalability and performance.
monitoring. As with MySQL 5.5, NDB 7.2.1 and later use CMake for configuring and building from source in place of GNU Autotools (used in MySQL 5.1 and NDB Cluster releases based on MySQL 5.1). For more information about changes and improvements in MySQL 5.5, see Section 1.4, “What Is New in MySQL 5.5”.

**Conflict detection using GCI Reflection.**  NDB Cluster Replication implements a new “primary wins” conflict detection and resolution mechanism. *GCI Reflection* applies in two-cluster circulation “active-active” replication setups, tracking the order in which changes are applied on the NDB Cluster designated as primary relative to changes originating on the other NDB Cluster (referred to as the secondary). This relative ordering is used to determine whether changes originating on the slave are concurrent with any changes that originate locally, and are therefore potentially in conflict. Two new conflict detection functions are added: When using `NDB$EPOCH()`, rows that are out of sync on the secondary are realigned with those on the primary; with `NDB$EPOCH_TRANS()`, this realignment is applied to transactions. For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

**Version 2 binary log row events.**  A new format for binary log row events, known as Version 2 binary log row events, provides support for improvements in NDB Cluster Replication conflict detection (see previous item) and is intended to facilitate further improvements in MySQL Replication. You can cause a given `mysqld` use Version 1 or Version 2 binary logging row events by setting the `log_bin_use_v1_row_events` system variable. For backward compatibility, Version 2 binary log row events are also available in NDB Cluster 7.0 (7.0.27 and later) and NDB Cluster 7.1 (7.1.16 and later). However, NDB Cluster 7.0 and NDB Cluster 7.1 continue to use Version 1 binary log row events as the default, whereas the default in NDB 7.2.1 and later is use Version 2 row events for binary logging.

**Distribution of MySQL users and privileges.**  Automatic distribution of MySQL users and privileges across all SQL nodes in a given NDB Cluster is now supported. To enable this support, you must first import an SQL script `share/mysql/ndb_dist_priv.sql` that is included with the NDB Cluster 7.2 distribution. This script creates several stored procedures which you can use to enable privilege distribution and perform related tasks.

When a new MySQL Server joins an NDB Cluster where privilege distribution is in effect, it also participates in the privilege distribution automatically.

Once privilege distribution is enabled, all changes to the grant tables made on any `mysqld` attached to the cluster are immediately available on any other attached MySQL Servers. This is true whether the changes are made using `CREATE USER`, `GRANT`, or any of the other statements described elsewhere in this Manual (see Section 13.7.1, “Account Management Statements”). This includes privileges relating to stored routines and views; however, automatic distribution of the views or stored routines themselves is not currently supported.

For more information, see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”.

**Distributed pushed-down joins.**  Many joins can now be pushed down to the NDB kernel for processing on NDB Cluster data nodes. Previously, a join was handled in NDB Cluster by means of repeated accesses of NDB by the SQL node; however, when pushed-down joins are enabled, a pushable join is sent in its entirety to the data nodes, where it can be distributed among the data nodes and executed in parallel on multiple copies of the data, with a single, merged result being returned to `mysqld`. This can reduce greatly the number of round trips between an SQL node and the data nodes required to handle such a join, leading to greatly improved performance of join processing.

It is possible to determine when joins can be pushed down to the data nodes by examining the join with `EXPLAIN`. A number of new system status variables (`Ndb_pushed_queries_defined`, `Ndb_pushed_queries_dropped`, `Ndb_pushed_queries_executed`, and `Ndb_pushed_reads`) and additions to the `counters` table (in the `ndbinfo` information database) can also be helpful in determining when and how well joins are being pushed down.
More information and examples are available in the description of the `ndb_join_pushdown` server system variable. See also the description of the status variables referenced in the previous paragraph, as well as Section 18.5.10.7, “The `ndbinfo` counters Table”.

- **Improved default values for data node configuration parameters.** In order to provide more resiliency to environmental issues and better handling of some potential failure scenarios, and to perform more reliably with increases in memory and other resource requirements brought about by recent improvements in join handling by NDB, the default values for a number of NDB Cluster data node configuration parameters have been changed. The parameters and changes are described in the following list:

  - `HeartbeatIntervalDbDb`: Default increased from 1500 ms to 5000 ms.
  - `ArbitrationTimeout`: Default increased from 3000 ms to 7500 ms.
  - `TimeBetweenEpochsTimeout`: Now effectively disabled by default (default changed from 4000 ms to 0).
  - `SharedGlobalMemory`: Default increased from 20 MB to 128 MB.
  - `MaxParallelScansPerFragment`: Default increased from 32 to 256.
  - `CrashOnCorruptedTuple` changed from `FALSE` to `TRUE`.
  - Beginning with NDB 7.2.10, `DefaultOperationRedoProblemAction` changed from `ABORT` to `QUEUE`.

  In addition, the value computed for `MaxNoOfLocalScans` when this parameter is not set in `config.ini` has been increased by a factor of 4.

- **Fail-fast data nodes.** Beginning with NDB 7.2.1, data nodes handle corrupted tuples in a fail-fast manner by default. This is a change from previous versions of NDB Cluster where this behavior had to be enabled explicitly by enabling the `CrashOnCorruptedTuple` configuration parameter. In NDB 7.2.1 and later, this parameter is enabled by default and must be explicitly disabled, in which case data nodes merely log a warning whenever they detect a corrupted tuple.

- **Memcache API support (`ndbmemcache`).** The Memcached server is a distributed in-memory caching server that uses a simple text-based protocol. It is often employed with key-value stores. The Memcache API for NDB Cluster, available beginning with NDB 7.2.2, is implemented as a loadable storage engine for memcached version 1.6 and later. This API can be used to access a persistent NDB Cluster data store employing the memcache protocol. It is also possible for the `memcached` server to provide a strictly defined interface to existing NDB Cluster tables.

  Each memcache server can both cache data locally and access data stored in NDB Cluster directly. Caching policies are configurable. For more information, see `ndbmemcache—Memcache API for NDB Cluster`, in the *NDB Cluster API Developers Guide*.

- **Rows per partition limit removed.** Previously it was possible to store a maximum of 46137488 rows in a single NDB Cluster partition—that is, per data node. Beginning with NDB 7.2.9, this limitation has been lifted, and there is no longer any practical upper limit to this number. (Bug #13844405, Bug #14000373)

NDB Cluster 7.2 is also supported by MySQL Cluster Manager, which provides an advanced command-line interface that can simplify many complex NDB Cluster management tasks. See *MySQL™ Cluster Manager 1.3.6 User Manual*, for more information.
18.1.5 Options, Variables, and Parameters Added, Deprecated or Removed in NDB 7.2

- **Node Configuration Parameters Introduced in NDB 7.2**
- **Node Configuration Parameters Deprecated in NDB 7.2**
- **MySQL Server Options and Variables Removed in NDB 7.2**
- **MySQL Server Options and Variables Introduced in NDB 7.2**
- **MySQL Server Options and Variables Deprecated in NDB 7.2**
- **Node Configuration Parameters Removed in NDB 7.2**

The next few sections contain information about NDB configuration parameters and NDB-specific mysqld options and variables that have been added to, deprecated in, or removed from NDB 7.2.

**Node Configuration Parameters Introduced in NDB 7.2**

The following node configuration parameters have been added in NDB 7.2.

- **ConnectBackoffMaxTime**: Specifies longest time in milliseconds (~100ms resolution) to allow between connection attempts to any given data node by this API node. Excludes time elapsed while connection attempts are ongoing, which in worst case can take several seconds. Disable by setting to 0. If no data nodes are currently connected to this API node, StartConnectBackoffMaxTime is used instead. Added in NDB 7.2.18.

- **CrashOnCorruptedTuple**: When enabled, forces node to shut down whenever it detects a corrupted tuple. Added in NDB 7.2.1.

- **DefaultHashMapSize**: Set size (in buckets) to use for table hash maps. Three values are supported: 0, 240, and 3840. Intended primarily for upgrades and downgrades within NDB 7.2. Added in NDB 7.2.11.

- **DiskPageBufferEntries**: Number of 32 KB page entries to allocate in DiskPageBufferMemory. Very large disk transactions may require increasing this value. Added in NDB 7.2.19.

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB. Added in NDB 7.2.14.

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB. Added in NDB 7.2.14.

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB. Added in NDB 7.2.5.

- **HeartbeatIntervalMgmdMgmd**: Time between management-node-to-management-node heartbeats; connection between management nodes is considered lost after 3 missed heartbeats. Added in NDB 7.2.12.

- **IndexStatAutoCreate**: Enable/disable automatic statistics collection when indexes are created. Added in NDB 7.2.1.
Options, Variables, and Parameters Added, Deprecated or Removed in NDB 7.2

- **IndexStatAutoUpdate**: Monitor indexes for changes and trigger automatic statistics updates. Added in NDB 7.2.1.
- **IndexStatSaveScale**: Scaling factor used in determining size of stored index statistics. Added in NDB 7.2.1.
- **IndexStatSaveSize**: Maximum size in bytes for saved statistics per index. Added in NDB 7.2.1.
- **IndexStatTriggerPct**: Threshold percent change in DML operations for index statistics updates. Value is scaled down by IndexStatTriggerScale. Added in NDB 7.2.1.
- **IndexStatTriggerScale**: Scale down IndexStatTriggerPct by this amount, multiplied by base 2 logarithm of index size, for a large index. Set to 0 to disable scaling. Added in NDB 7.2.1.
- **IndexStatUpdateDelay**: Minimum delay between automatic index statistics updates for a given index. 0 means no delay. Added in NDB 7.2.1.
- **LcpScanProgressTimeout**: Maximum time that local checkpoint fragment scan can be stalled before node is shut down to ensure systemwide LCP progress. Use 0 to disable. Added in NDB 7.2.14.
- **MaxBufferedEpochBytes**: Total number of bytes allocated for buffering epochs. Added in NDB 7.2.13.
- **MinFreePct**: Percentage of memory resources to keep in reserve for restarts. Added in NDB 7.2.3.
- **NoOfFragmentLogParts**: Number of redo log file groups belonging to this data node; value must be an even multiple of 4. Added in NDB 7.2.5.
- **RestartSubscriberConnectTimeout**: Amount of time for data node to wait for subscribing API nodes to connect. Set to 0 to disable timeout, which is always resolved to nearest full second. Added in NDB 7.2.17.
- **StartConnectBackoffMaxTime**: Same as ConnectBackoffMaxTime except that this parameter is used in its place if no data nodes are connected to this API node. Added in NDB 7.2.18.
- **ThreadConfig**: Used for configuration of multithreaded data nodes (ndbmttd). Default is an empty string; see documentation for syntax and other information. Added in NDB 7.2.3.
- **TimeBetweenGlobalCheckpointsTimeout**: Minimum timeout for group commit of transactions to disk. Added in NDB 7.2.20.

### Node Configuration Parameters Deprecated in NDB 7.2

The following node configuration parameters have been deprecated in NDB 7.2.

- **ReservedSendBufferMemory**: This parameter is present in NDB code but is not enabled, and is now deprecated. Deprecated as of NDB 7.2.5.

### MySQL Server Options and Variables Removed in NDB 7.2

The following *mysqld* system variables, status variables, and options have been removed in NDB 7.2.

- **ndb_index_stat_cache_entries**: Sets the granularity of the statistics by determining the number of starting and ending keys. Removed in NDB 7.2.16.
- **ndb_index_stat_update_freq**: How often to query data nodes instead of the statistics cache. Removed in NDB 7.2.16.
Options, Variables, and Parameters Added, Deprecated or Removed in NDB 7.2

MySQL Server Options and Variables Introduced in NDB 7.2

The following `mysqld` system variables, status variables, and options have been added in NDB 7.2.

- **Ndb_conflict_fn_epoch**: Number of rows that have been found in conflict by the NDB$EPOCH() conflict detection function. Added in NDB 7.2.1.

- **Ndb_conflict_fn_epoch_trans**: Number of rows that have been found in conflict by the NDB $EPOCH_TRANS() conflict detection function. Added in NDB 7.2.1.

- **Ndb_conflict_trans_conflict_commit_count**: Number of epoch transactions committed after requiring transactional conflict handling. Added in NDB 7.2.1.

- **Ndb_conflict_trans_detect_iter_count**: Number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to Ndb_conflict_trans_conflict_commit_count. Added in NDB 7.2.1.

- **Ndb_conflict_trans_reject_count**: Number of transactions rejected after being found in conflict by a transactional conflict function. Added in NDB 7.2.1.

- **Ndb_conflict_trans_row_reject_count**: Total number of rows realigned after being found in conflict by a transactional conflict function. Includes Ndb_conflict_trans_row_conflict_count and any rows included in or dependent on conflicting transactions. Added in NDB 7.2.1.

- **Ndb_pushed_queries_defined**: Number of joins that API nodes have attempted to push down to the data nodes. Added in NDB 7.2.0.

- **Ndb_pushed_queries_dropped**: Number of joins that API nodes have tried to push down, but failed. Added in NDB 7.2.0.

- **Ndb_pushed_queries_executed**: Number of joins successfully pushed down and executed on the data nodes. Added in NDB 7.2.0.

- **Ndb_pushed_reads**: Number of reads executed on the data nodes by pushed-down joins. Added in NDB 7.2.0.

- **ndb-log-transaction-id**: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF. Added in NDB 7.2.1.

- **ndb-transid-mysql-connection-map**: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name. Added in NDB 7.2.2.

- **ndb_eventbuffer_max_alloc**: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit). Added in NDB 7.2.14.

- **ndb_index_stat_option**: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces. Added in NDB 7.2.1.

- **ndb_join_pushdown**: Enables pushing down of joins to data nodes. Added in NDB 7.2.0.

- **ndb_log_transaction_id**: Whether NDB transaction IDs are written into the binary log (Read-only.). Added in NDB 7.2.1.

MySQL Server Options and Variables Deprecated in NDB 7.2

No system variables, status variables, or options have been deprecated in NDB 7.2.
Node Configuration Parameters Removed in NDB 7.2

No node configuration parameters have been removed from NDB 7.2.

18.1.6 MySQL Server Using InnoDB Compared with NDB Cluster

MySQL Server offers a number of choices in storage engines. Since both NDB and InnoDB can serve as transactional MySQL storage engines, users of MySQL Server sometimes become interested in NDB Cluster. They see NDB as a possible alternative or upgrade to the default InnoDB storage engine in MySQL 5.5. While NDB and InnoDB share common characteristics, there are differences in architecture and implementation, so that some existing MySQL Server applications and usage scenarios can be a good fit for NDB Cluster, but not all of them.

In this section, we discuss and compare some characteristics of the NDB storage engine used by NDB Cluster 7.2 with InnoDB used in MySQL 5.5. The next few sections provide a technical comparison. In many instances, decisions about when and where to use NDB Cluster must be made on a case-by-case basis, taking all factors into consideration. While it is beyond the scope of this documentation to provide specifics for every conceivable usage scenario, we also attempt to offer some very general guidance on the relative suitability of some common types of applications for NDB as opposed to InnoDB back ends.

Recent NDB Cluster 7.2 releases use a mysqld based on MySQL 5.5, including support for InnoDB 1.1. While it is possible to use InnoDB tables with NDB Cluster, such tables are not clustered. It is also not possible to use programs or libraries from an NDB Cluster 7.2 distribution with MySQL Server 5.5, or the reverse.

While it is also true that some types of common business applications can be run either on NDB Cluster or on MySQL Server (most likely using the InnoDB storage engine), there are some important architectural and implementation differences. Section 18.1.6.1, “Differences Between the NDB and InnoDB Storage Engines”, provides a summary of the these differences. Due to the differences, some usage scenarios are clearly more suitable for one engine or the other; see Section 18.1.6.2, “NDB and InnoDB Workloads”. This in turn has an impact on the types of applications that better suited for use with NDB or InnoDB. See Section 18.1.6.3, “NDB and InnoDB Feature Usage Summary”, for a comparison of the relative suitability of each for use in common types of database applications.

For information about the relative characteristics of the NDB and MEMORY storage engines, see When to Use MEMORY or NDB Cluster.

See Chapter 15, Alternative Storage Engines, for additional information about MySQL storage engines.

18.1.6.1 Differences Between the NDB and InnoDB Storage Engines

The NDB storage engine is implemented using a distributed, shared-nothing architecture, which causes it to behave differently from InnoDB in a number of ways. For those unaccustomed to working with NDB, unexpected behaviors can arise due to its distributed nature with regard to transactions, foreign keys, table limits, and other characteristics. These are shown in the following table:

<table>
<thead>
<tr>
<th>Feature</th>
<th>InnoDB 1.1</th>
<th>NDB 7.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MySQL Server Version</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>InnoDB Version</td>
<td>InnoDB 1.1</td>
<td>InnoDB 1.1</td>
</tr>
<tr>
<td>NDB Cluster Version</td>
<td>N/A</td>
<td>NDB 7.2.39</td>
</tr>
<tr>
<td>Storage Limits</td>
<td>64TB</td>
<td>3TB (Practical upper limit based on 48 data nodes with 64GB RAM)</td>
</tr>
<tr>
<td>Feature</td>
<td>InnoDB 1.1</td>
<td>NDB 7.2</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>each; can be increased with disk-based data and BLOBs)</td>
</tr>
<tr>
<td>Foreign Keys</td>
<td>Yes</td>
<td>Available in NDB Cluster 7.3 and later (NDB 7.2 ignores them, as with MyISAM)</td>
</tr>
<tr>
<td>Transactions</td>
<td>All standard types</td>
<td>READ COMMITTED</td>
</tr>
<tr>
<td>MVCC</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Data Compression</td>
<td>Yes</td>
<td>No (NDB checkpoint and backup files can be compressed)</td>
</tr>
<tr>
<td>Large Row Support (&gt; 14K)</td>
<td>Supported for VARBINARY, VARCHAR, BLOB, and TEXT columns</td>
<td>Supported for BLOB and TEXT columns only (Using these types to store very large amounts of data can lower NDB performance)</td>
</tr>
<tr>
<td>Replication Support</td>
<td>Asynchronous and semisynchronous replication using MySQL Replication</td>
<td>Automatic synchronous replication within an NDB Cluster; asynchronous replication between NDB Clusters, using MySQL Replication (Semisynchronous replication is not supported)</td>
</tr>
<tr>
<td>Scaleout for Read Operations</td>
<td>Yes (MySQL Replication)</td>
<td>Yes (Automatic partitioning in NDB Cluster; NDB Cluster Replication)</td>
</tr>
<tr>
<td>Scaleout for Write Operations</td>
<td>Requires application-level partitioning (sharding)</td>
<td>Yes (Automatic partitioning in NDB Cluster is transparent to applications)</td>
</tr>
<tr>
<td>High Availability (HA)</td>
<td>Requires additional software</td>
<td>Yes (Designed for 99.999% uptime)</td>
</tr>
<tr>
<td>Node Failure Recovery and Failover</td>
<td>Requires additional software</td>
<td>Automatic (Key element in NDB architecture)</td>
</tr>
<tr>
<td>Time for Node Failure Recovery</td>
<td>30 seconds or longer</td>
<td>Typically &lt; 1 second</td>
</tr>
<tr>
<td>Real-Time Performance</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>In-Memory Tables</td>
<td>No</td>
<td>Yes (Some data can optionally be stored on disk; both in-memory and disk data storage are durable)</td>
</tr>
<tr>
<td>NoSQL Access to Storage Engine</td>
<td>Yes</td>
<td>Yes (Multiple APIs, including Memcached, Node.js/JavaScript, Java, JPA, C++, and HTTP/REST)</td>
</tr>
<tr>
<td>Concurrent and Parallel Writes</td>
<td>Not supported</td>
<td>Up to 48 writers, optimized for concurrent writes</td>
</tr>
<tr>
<td>Conflict Detection and Resolution (Multiple Replication Masters)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Hash Indexes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### 18.1.6.2 NDB and InnoDB Workloads

NDB Cluster has a range of unique attributes that make it ideal to serve applications requiring high availability, fast failover, high throughput, and low latency. Due to its distributed architecture and multi-node implementation, NDB Cluster also has specific constraints that may keep some workloads from performing well. A number of major differences in behavior between the NDB and InnoDB storage engines with regard to some common types of database-driven application workloads are shown in the following table:

**Table 18.2 Major differences between the InnoDB and NDB storage engines, common types of database-driven application workloads.**

<table>
<thead>
<tr>
<th>Workload</th>
<th>InnoDB</th>
<th>NDB Cluster (NDB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Volume OLTP Applications</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>DSS Applications (data marts, analytics)</td>
<td>Yes</td>
<td>Limited (Join operations across OLTP datasets not exceeding 3TB in size)</td>
</tr>
<tr>
<td>Custom Applications</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Packaged Applications</td>
<td>Yes</td>
<td>Limited (should be mostly primary key access); NDB Cluster 7.3 adds support for foreign keys</td>
</tr>
<tr>
<td>In-Network Telecoms Applications (HLR, HSS, SDP)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Session Management and Caching</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>E-Commerce Applications</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User Profile Management, AAA Protocol</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 18.1.6.3 NDB and InnoDB Feature Usage Summary

When comparing application feature requirements to the capabilities of InnoDB with NDB, some are clearly more compatible with one storage engine than the other.

The following table lists supported application features according to the storage engine to which each feature is typically better suited.

**Table 18.3 Supported application features according to the storage engine to which each feature is typically better suited**

<table>
<thead>
<tr>
<th>Preferred application requirements for InnoDB</th>
<th>Preferred application requirements for NDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Foreign keys</td>
<td>• Write scaling</td>
</tr>
<tr>
<td>• 99.999% uptime</td>
<td>• Online addition of nodes and online schema operations</td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td></td>
</tr>
<tr>
<td>NDB Cluster 7.3 adds support for foreign keys.</td>
<td></td>
</tr>
</tbody>
</table>
18.1.7 Known Limitations of NDB Cluster

In the sections that follow, we discuss known limitations in current releases of NDB Cluster as compared with the features available when using the MyISAM and InnoDB storage engines. If you check the "Cluster" category in the MySQL bugs database at http://bugs.mysql.com, you can find known bugs in the following categories under "MySQL Server:" in the MySQL bugs database at http://bugs.mysql.com, which we intend to correct in upcoming releases of NDB Cluster:

- NDB Cluster
- Cluster Direct API (NDBAPI)
- Cluster Disk Data
- Cluster Replication
- ClusterJ

This information is intended to be complete with respect to the conditions just set forth. You can report any discrepancies that you encounter to the MySQL bugs database using the instructions given in Section 1.6, "How to Report Bugs or Problems". If we do not plan to fix the problem in NDB Cluster 7.2, we will add it to the list.

See Section 18.1.7.11, "Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x" for a list of issues in NDB Cluster in MySQL 5.1 that have been resolved in the current version.

Note

Limitations and other issues specific to NDB Cluster Replication are described in Section 18.6.3, "Known Issues in NDB Cluster Replication".

18.1.7.1 Noncompliance with SQL Syntax in NDB Cluster

Some SQL statements relating to certain MySQL features produce errors when used with NDB tables, as described in the following list:

- **Temporary tables.** Temporary tables are not supported. Trying either to create a temporary table that uses the NDB storage engine or to alter an existing temporary table to use NDB fails with the error Table storage engine 'ndbcluster' does not support the create option 'TEMPORARY'.

- **Indexes and keys in NDB tables.** Keys and indexes on NDB Cluster tables are subject to the following limitations:

  - **Column width.** Attempting to create an index on an NDB table column whose width is greater than 3072 bytes succeeds, but only the first 3072 bytes are actually used for the index. In such cases, a warning Specified key was too long; max key length is 3072 bytes is issued, and a SHOW CREATE TABLE statement shows the length of the index as 3072.
• **TEXT and BLOB columns.** You cannot create indexes on NDB table columns that use any of the TEXT or BLOB data types.

• **FULLTEXT indexes.** The NDB storage engine does not support FULLTEXT indexes, which are possible for MyISAM tables only. However, you can create indexes on VARCHAR columns of NDB tables.

• **USING HASH keys and NULL.** Using nullable columns in unique keys and primary keys means that queries using these columns are handled as full table scans. To work around this issue, make the column NOT NULL, or re-create the index without the USING HASH option.

• **Prefixes.** There are no prefix indexes; only entire columns can be indexed. (The size of an NDB column index is always the same as the width of the column in bytes, up to and including 3072 bytes, as described earlier in this section. Also see Section 18.1.7.6, “Unsupported or Missing Features in NDB Cluster”, for additional information.)

• **BIT columns.** A BIT column cannot be a primary key, unique key, or index, nor can it be part of a composite primary key, unique key, or index.

• **AUTO_INCREMENT columns.** Like other MySQL storage engines, the NDB storage engine can handle a maximum of one AUTO_INCREMENT column per table, and this column must be indexed. However, in the case of an NDB table with no explicit primary key, an AUTO_INCREMENT column is automatically defined and used as a “hidden” primary key. For this reason, you cannot create an NDB table having an AUTO_INCREMENT column and no explicit primary key.

• **NDB Cluster and geometry data types.** Geometry data types (WKT and WKB) are supported for NDB tables. However, spatial indexes are not supported.

• **Character sets and binary log files.** Currently, the ndb_apply_status and ndb_binlog_index tables are created using the latin1 (ASCII) character set. Because names of binary logs are recorded in this table, binary log files named using non-Latin characters are not referenced correctly in these tables. This is a known issue, which we are working to fix. (Bug #50226) To work around this problem, use only Latin-1 characters when naming binary log files or setting any the --basedir, --log-bin, or --log-bin-index options.

• **Creating NDB tables with user-defined partitioning.** Support for user-defined partitioning in NDB Cluster is restricted to [LINEAR] KEY partitioning. Using any other partitioning type with ENGINE=NDB or ENGINE=NDBCLUSTER in a CREATE TABLE statement results in an error. It is possible to override this restriction, but doing so is not supported for use in production settings. For details, see User-defined partitioning and the NDB storage engine (NDB Cluster).

**Default partitioning scheme.** All NDB Cluster tables are by default partitioned by KEY using the table’s primary key as the partitioning key. If no primary key is explicitly set for the table, the “hidden” primary key automatically created by the NDB storage engine is used instead. For additional discussion of these and related issues, see Section 19.2.5, “KEY Partitioning”.

CREATE TABLE and ALTER TABLE statements that would cause a user-partitioned NDBCLUSTER table not to meet either or both of the following two requirements are not permitted, and fail with an error:

1. The table must have an explicit primary key.
2. All columns listed in the table’s partitioning expression must be part of the primary key.
Exception. If a user-partitioned `NDBCLUSTER` table is created using an empty column-list (that is, using `PARTITION BY [LINEAR] KEY()`), then no explicit primary key is required.

Maximum number of partitions for NDBCLUSTER tables. The maximum number of partitions that can be defined for a `NDBCLUSTER` table when employing user-defined partitioning is 8 per node group. (See Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information about NDB Cluster node groups.

DROP PARTITION not supported. It is not possible to drop partitions from NDB tables using `ALTER TABLE ... DROP PARTITION`. The other partitioning extensions to `ALTER TABLE`—`ADD PARTITION`, `REORGANIZE PARTITION`, and `COALESCE PARTITION`—are supported for NDB tables, but use copying and so are not optimized. See Section 19.3.1, “Management of RANGE and LIST Partitions” and Section 13.1.7, “ALTER TABLE Statement”.

• Row-based replication. When using row-based replication with NDB Cluster, binary logging cannot be disabled. That is, the NDB storage engine ignores the value of `sql_log_bin`. (Bug #16680)

### 18.1.7.2 Limits and Differences of NDB Cluster from Standard MySQL Limits

In this section, we list limits found in NDB Cluster that either differ from limits found in, or that are not found in, standard MySQL.

Memory usage and recovery. Memory consumed when data is inserted into an NDB table is not automatically recovered when deleted, as it is with other storage engines. Instead, the following rules hold true:

• A `DELETE` statement on an NDB table makes the memory formerly used by the deleted rows available for re-use by inserts on the same table only. However, this memory can be made available for general re-use by performing `OPTIMIZE TABLE`.

A rolling restart of the cluster also frees any memory used by deleted rows. See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”.

• A `DROP TABLE` or `TRUNCATE TABLE` operation on an NDB table frees the memory that was used by this table for re-use by any NDB table, either by the same table or by another NDB table.

Note

Recall that `TRUNCATE TABLE` drops and re-creates the table. See Section 13.1.33, “TRUNCATE TABLE Statement”.

• Limits imposed by the cluster’s configuration.

A number of hard limits exist which are configurable, but available main memory in the cluster sets limits. See the complete list of configuration parameters in Section 18.3.3, “NDB Cluster Configuration Files”.

Most configuration parameters can be upgraded online. These hard limits include:

• Database memory size and index memory size (`DataMemory` and `IndexMemory`, respectively).

`DataMemory` is allocated as 32KB pages. As each `DataMemory` page is used, it is assigned to a specific table; once allocated, this memory cannot be freed except by dropping the table.

See Section 18.3.3.6, “Defining NDB Cluster Data Nodes”, for more information.

• The maximum number of operations that can be performed per transaction is set using the configuration parameters `MaxNoOfConcurrentOperations` and `MaxNoOfLocalOperations`.
Note

Bulk loading, TRUNCATE TABLE, and ALTER TABLE are handled as special cases by running multiple transactions, and so are not subject to this limitation.

• Different limits related to tables and indexes. For example, the maximum number of ordered indexes in the cluster is determined by MaxNoOfOrderedIndexes, and the maximum number of ordered indexes per table is 16.

• Node and data object maximums. The following limits apply to numbers of cluster nodes and metadata objects:

  • The maximum number of data nodes is 48.

    A data node must have a node ID in the range of 1 to 48, inclusive. (Management and API nodes may use node IDs in the range 1 to 255, inclusive.)

  • The total maximum number of nodes in an NDB Cluster is 255. This number includes all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers.

  • The maximum number of metadata objects in current versions of NDB Cluster is 20320. This limit is hard-coded.

See Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”, for more information.

18.1.7.3 Limits Relating to Transaction Handling in NDB Cluster

A number of limitations exist in NDB Cluster with regard to the handling of transactions. These include the following:

• Transaction isolation level. The NDBCLUSTER storage engine supports only the READ COMMITTED transaction isolation level. (InnoDB, for example, supports READ COMMITTED, READ UNCOMMITTED, REPEATABLE READ, and SERIALIZABLE.) You should keep in mind that NDB implements READ COMMITTED on a per-row basis; when a read request arrives at the data node storing the row, what is returned is the last committed version of the row at that time.

Uncommitted data is never returned, but when a transaction modifying a number of rows commits concurrently with a transaction reading the same rows, the transaction performing the read can observe “before” values, “after” values, or both, for different rows among these, due to the fact that a given row read request can be processed either before or after the commit of the other transaction.

To ensure that a given transaction reads only before or after values, you can impose row locks using SELECT ... LOCK IN SHARE MODE. In such cases, the lock is held until the owning transaction is committed. Using row locks can also cause the following issues:

• Increased frequency of lock wait timeout errors, and reduced concurrency

• Increased transaction processing overhead due to reads requiring a commit phase

• Possibility of exhausting the available number of concurrent locks, which is limited by MaxNoOfConcurrentOperations

NDB uses READ COMMITTED for all reads unless a modifier such as LOCK IN SHARE MODE or FOR UPDATE is used. LOCK IN SHARE MODE causes shared row locks to be used; FOR UPDATE causes
exclusive row locks to be used. Unique key reads have their locks upgraded automatically by NDB to ensure a self-consistent read; BLOB reads also employ extra locking for consistency.

See Section 18.5.3.4, “NDB Cluster Backup Troubleshooting”, for information on how NDB Cluster’s implementation of transaction isolation level can affect backup and restoration of NDB databases.

- Transactions and BLOB or TEXT columns. NDB Cluster stores only part of a column value that uses any of MySQL’s BLOB or TEXT data types in the table visible to MySQL; the remainder of the BLOB or TEXT is stored in a separate internal table that is not accessible to MySQL. This gives rise to two related issues of which you should be aware whenever executing SELECT statements on tables that contain columns of these types:

  1. For any SELECT from an NDB Cluster table: If the SELECT includes a BLOB or TEXT column, the READ COMMITTED transaction isolation level is converted to a read with read lock. This is done to guarantee consistency.

  2. For any SELECT which uses a unique key lookup to retrieve any columns that use any of the BLOB or TEXT data types and that is executed within a transaction, a shared read lock is held on the table for the duration of the transaction—that is, until the transaction is either committed or aborted.

This issue does not occur for queries that use index or table scans, even against NDB tables having BLOB or TEXT columns.

For example, consider the table t defined by the following CREATE TABLE statement:

```
CREATE TABLE t (  
a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,  
b INT NOT NULL,  
c INT NOT NULL,  
d TEXT,  
INDEX i(b),  
UNIQUE KEY u(c)  
) ENGINE = NDB,
```

Either of the following queries on t causes a shared read lock, because the first query uses a primary key lookup and the second uses a unique key lookup:

```
SELECT * FROM t WHERE a = 1;  
SELECT * FROM t WHERE c = 1;
```

However, none of the four queries shown here causes a shared read lock:

```
SELECT * FROM t WHERE b = 1;  
SELECT * FROM t WHERE d = '1';  
SELECT * FROM t;  
SELECT b,c WHERE a = 1;
```

This is because, of these four queries, the first uses an index scan, the second and third use table scans, and the fourth, while using a primary key lookup, does not retrieve the value of any BLOB or TEXT columns.

You can help minimize issues with shared read locks by avoiding queries that use unique key lookups that retrieve BLOB or TEXT columns, or, in cases where such queries are not avoidable, by committing transactions as soon as possible afterward.
• **Rollbacks.** There are no partial transactions, and no partial rollbacks of transactions. A duplicate key or similar error causes the entire transaction to be rolled back.

This behavior differs from that of other transactional storage engines such as InnoDB that may roll back individual statements.

• **Transactions and memory usage.**
As noted elsewhere in this chapter, NDB Cluster does not handle large transactions well: it is better to perform a number of small transactions with a few operations each than to attempt a single large transaction containing a great many operations. Among other considerations, large transactions require very large amounts of memory. Because of this, the transactional behavior of a number of MySQL statements is affected as described in the following list:

• **TRUNCATE TABLE** is not transactional when used on NDB tables. If a **TRUNCATE TABLE** fails to empty the table, then it must be re-run until it is successful.

• **DELETE FROM** (even with no **WHERE** clause) is transactional. For tables containing a great many rows, you may find that performance is improved by using several **DELETE FROM ... LIMIT ...** statements to “chunk” the delete operation. If your objective is to empty the table, then you may wish to use **TRUNCATE TABLE** instead.

• **LOAD DATA statements.** **LOAD DATA** is not transactional when used on NDB tables.

  ![Important]

  When executing a **LOAD DATA** statement, the **NDB** engine performs commits at irregular intervals that enable better utilization of the communication network. It is not possible to know ahead of time when such commits take place.

• **ALTER TABLE and transactions.** When copying an NDB table as part of an **ALTER TABLE**, the creation of the copy is nontransactional. (In any case, this operation is rolled back when the copy is deleted.)

• **Transactions and the COUNT() function.** When using NDB Cluster Replication, it is not possible to guarantee the transactional consistency of the **COUNT()** function on the slave. In other words, when performing on the master a series of statements (**INSERT, DELETE, or both**) that changes the number of rows in a table within a single transaction, executing **SELECT COUNT(*)** **FROM table** queries on the slave may yield intermediate results. This is due to the fact that **SELECT COUNT(...)** may perform dirty reads, and is not a bug in the **NDB** storage engine. (See Bug #31321 for more information.)

### 18.1.7.4 NDB Cluster Error Handling

Starting, stopping, or restarting a node may give rise to temporary errors causing some transactions to fail. These include the following cases:

• **Temporary errors.** When first starting a node, it is possible that you may see Error 1204 **Temporary failure, distribution changed** and similar temporary errors.

• **Errors due to node failure.** The stopping or failure of any data node can result in a number of different node failure errors. (However, there should be no aborted transactions when performing a planned shutdown of the cluster.)

In either of these cases, any errors that are generated must be handled within the application. This should be done by retrying the transaction.

See also Section 18.1.7.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”.
18.1.7.5 Limits Associated with Database Objects in NDB Cluster

Some database objects such as tables and indexes have different limitations when using the NDBCLUSTER storage engine:

- **Database and table names.** When using the NDB storage engine, the maximum allowed length both for database names and for table names is 63 characters.

- **Number of database objects.** The maximum number of all NDB database objects in a single NDB Cluster—including databases, tables, and indexes—is limited to 20320.

- **Attributes per table.** The maximum number of attributes (that is, columns and indexes) that can belong to a given table is 512.

- **Attributes per key.** The maximum number of attributes per key is 32.

- **Row size.** The maximum permitted size of any one row is 14000 bytes.

Each BLOB or TEXT column contributes 256 + 8 = 264 bytes to this total; see String Type Storage Requirements, for more information relating to these types.

In addition, the maximum offset for a fixed-width column of an NDB table is 8188 bytes; attempting to create a table that violates this limitation fails with NDB error 851 Maximum offset for fixed-size columns exceeded. For memory-based columns, you can work around this limitation by using a variable-width column type such as VARCHAR or defining the column as COLUMN_FORMAT=DYNAMIC; this does not work with columns stored on disk. For disk-based columns, you may be able to do so by reordering one or more of the table's disk-based columns such that the combined width of all but the disk-based column defined last in the CREATE TABLE statement used to create the table does not exceed 8188 bytes, less any possible rounding performed for some data types such as CHAR or VARCHAR; otherwise it is necessary to use memory-based storage for one or more of the offending column or columns instead.

- **BIT column storage per table.** The maximum combined width for all BIT columns used in a given NDB table is 4096.

- **FIXED column storage.** NDB Cluster supports a maximum of 16 GB per fragment of data in FIXED columns.

18.1.7.6 Unsupported or Missing Features in NDB Cluster

A number of features supported by other storage engines are not supported for NDB tables. Trying to use any of these features in NDB Cluster does not cause errors in or of itself; however, errors may occur in applications that expects the features to be supported or enforced. Statements referencing such features, even if effectively ignored by NDB, must be syntactically and otherwise valid.

- **Foreign key constraints.** Prior to NDB Cluster 7.3, the foreign key construct is ignored, just as it is by MyISAM tables. Foreign keys are supported in NDB Cluster 7.3 and later.

- **Index prefixes.** Prefixes on indexes are not supported for NDB tables. If a prefix is used as part of an index specification in a statement such as CREATE TABLE, ALTER TABLE, or CREATE INDEX, the prefix is not created by NDB.

A statement containing an index prefix, and creating or modifying an NDB table, must still be syntactically valid. For example, the following statement always fails with Error 1089 Incorrect prefix key; the used key part isn't a string, the used length is longer than the key part, or the storage engine doesn't support unique prefix keys, regardless of storage engine:
Known Limitations of NDB Cluster

CREATE TABLE t1 (     
c1 INT NOT NULL,     
c2 VARCHAR(100),  
INDEX i1 (c2(500)) 
);

This happens on account of the SQL syntax rule that no index may have a prefix larger than itself.

- **Savepoints and rollbacks.** Savepoints and rollbacks to savepoints are ignored as in *MyISAM*.

- **Durability of commits.** There are no durable commits on disk. Commits are replicated, but there is no guarantee that logs are flushed to disk on commit.

- **Replication.** Statement-based replication is not supported. Use *--binlog-format=ROW* (or *--binlog-format=MIXED*) when setting up cluster replication. See Section 18.6, “NDB Cluster Replication”, for more information.

Semisynchronous replication is not supported in NDB Cluster.

### Note
See Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”, for more information relating to limitations on transaction handling in *NDB*.

#### 18.1.7.7 Limitations Relating to Performance in NDB Cluster

The following performance issues are specific to or especially pronounced in NDB Cluster:

- **Range scans.** There are query performance issues due to sequential access to the *NDB* storage engine; it is also relatively more expensive to do many range scans than it is with either *MyISAM* or *InnoDB*.

- **Reliability of Records in range.** The *Records in range* statistic is available but is not completely tested or officially supported. This may result in nonoptimal query plans in some cases. If necessary, you can employ *USE INDEX* or *FORCE INDEX* to alter the execution plan. See Section 8.9.3, “Index Hints”, for more information on how to do this.

- **Unique hash indexes.** Unique hash indexes created with *USING HASH* cannot be used for accessing a table if *NULL* is given as part of the key.

#### 18.1.7.8 Issues Exclusive to NDB Cluster

The following are limitations specific to the *NDB* storage engine:

- **Machine architecture.** All machines used in the cluster must have the same architecture. That is, all machines hosting nodes must be either big-endian or little-endian, and you cannot use a mixture of both. For example, you cannot have a management node running on a PowerPC which directs a data node that is running on an x86 machine. This restriction does not apply to machines simply running *mysql* or other clients that may be accessing the cluster's SQL nodes.

- **Binary logging.** NDB Cluster has the following limitations or restrictions with regard to binary logging:

  - *sql_log_bin* has no effect on data operations; however, it is supported for schema operations.

  - NDB Cluster cannot produce a binary log for tables having *BLOB* columns but no primary key.

  - Only the following schema operations are logged in a cluster binary log which is *not* on the *mysqld* executing the statement:
Known Limitations of NDB Cluster

- **CREATE TABLE**
- **ALTER TABLE**
- **DROP TABLE**
- **CREATE DATABASE/CREATE SCHEMA**
- **DROP DATABASE/DROP SCHEMA**
- **CREATE TABLESPACE**
- **ALTER TABLESPACE**
- **DROP TABLESPACE**
- **CREATE LOGFILE GROUP**
- **ALTER LOGFILE GROUP**
- **DROP LOGFILE GROUP**

- **Schema operations.** Schema operations (DDL statements) are rejected while any data node restarts. Schema operations are also not supported while performing an online upgrade or downgrade.

- **Number of replicas.** The number of replicas, as determined by the `NoOfReplicas` data node configuration parameter, is the number of copies of all data stored by NDB Cluster. Setting this parameter to 1 means there is only a single copy; in this case, no redundancy is provided, and the loss of a data node entails loss of data. To guarantee redundancy, and thus preservation of data even if a data node fails, set this parameter to 2, which is the default and recommended value in production.

  Setting `NoOfReplicas` to a value greater than 2 is possible (to a maximum of 4) but unnecessary to guard against loss of data. In addition, *values greater than 2 for this parameter are not supported in production.*

  See also Section 18.1.7.10, “Limitations Relating to Multiple NDB Cluster Nodes”.

### 18.1.7.9 Limitations Relating to NDB Cluster Disk Data Storage

**Disk Data object maximums and minimums.** Disk data objects are subject to the following maximums and minimums:

- Maximum number of tablespaces: $2^{32}$ (4294967296)
- Maximum number of data files per tablespace: $2^{16}$ (65536)
- The minimum and maximum possible sizes of extents for tablespace data files are 32K and 2G, respectively. See Section 13.1.18, “CREATE TABLESPACE Statement”, for more information.

In addition, when working with NDB Disk Data tables, you should be aware of the following issues regarding data files and extents:

- Data files use `DataMemory`. Usage is the same as for in-memory data.
- Data files use file descriptors. It is important to keep in mind that data files are always open, which means the file descriptors are always in use and cannot be re-used for other system tasks.
• Extents require sufficient DiskPageBufferMemory; you must reserve enough for this parameter to account for all memory used by all extents (number of extents times size of extents).

Disk Data tables and diskless mode. Use of Disk Data tables is not supported when running the cluster in diskless mode. Beginning with MySQL 5.1.12, it is prohibited altogether. (Bug #20008)

18.1.7.10 Limitations Relating to Multiple NDB Cluster Nodes

Multiple SQL nodes. The following are issues relating to the use of multiple MySQL servers as NDB Cluster SQL nodes, and are specific to the NDBCLUSTER storage engine:

• No distributed table locks. A LOCK TABLES works only for the SQL node on which the lock is issued; no other SQL node in the cluster “sees” this lock. This is also true for a lock issued by any statement that locks tables as part of its operations. (See next item for an example.)

• ALTER TABLE operations. ALTER TABLE is not fully locking when running multiple MySQL servers (SQL nodes). (As discussed in the previous item, NDB Cluster does not support distributed table locks.)

Multiple management nodes. When using multiple management servers:

• If any of the management servers are running on the same host, you must give nodes explicit IDs in connection strings because automatic allocation of node IDs does not work across multiple management servers on the same host. This is not required if every management server resides on a different host.

• When a management server starts, it first checks for any other management server in the same NDB Cluster, and upon successful connection to the other management server uses its configuration data. This means that the management server --reload and --initial startup options are ignored unless the management server is the only one running. It also means that, when performing a rolling restart of an NDB Cluster with multiple management nodes, the management server reads its own configuration file if (and only if) it is the only management server running in this NDB Cluster. See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”, for more information.

Multiple network addresses. Multiple network addresses per data node are not supported. Use of these is liable to cause problems: In the event of a data node failure, an SQL node waits for confirmation that the data node went down but never receives it because another route to that data node remains open. This can effectively make the cluster inoperable.

Note

It is possible to use multiple network hardware interfaces (such as Ethernet cards) for a single data node, but these must be bound to the same address. This also means that it not possible to use more than one [tcp] section per connection in the config.ini file. See Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, for more information.

18.1.7.11 Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x

A number of limitations and related issues existing in earlier versions of NDB Cluster have been resolved:

• Variable-length column support. The NDBCLUSTER storage engine now supports variable-length column types for in-memory tables.

Previously, for example, any Cluster table having one or more VARCHAR fields which contained only relatively small values, much more memory and disk space were required when using the NDBCLUSTER storage engine than would have been the case for the same table and data using the MyISAM engine.
other words, in the case of a VARCHAR column, such a column required the same amount of storage as a CHAR column of the same size. In MySQL 5.1, this is no longer the case for in-memory tables, where storage requirements for variable-length column types such as VARCHAR and BINARY are comparable to those for these column types when used in MyISAM tables (see Section 11.6, “Data Type Storage Requirements”).

Important

For NDB Cluster Disk Data tables, the fixed-width limitation continues to apply. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

• Replication with NDB Cluster. It is now possible to use MySQL replication with Cluster databases. For details, see Section 18.6, “NDB Cluster Replication”.

Circular Replication. Circular replication is also supported with NDB Cluster, beginning with MySQL 5.1.18. See Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”.

• auto_increment_increment and auto_increment_offset. The auto_increment_increment and auto_increment_offset server system variables are supported for NDB Cluster Replication.

• Backup and restore between architectures. It is possible to perform a Cluster backup and restore between different architectures. Previously—for example—you could not back up a cluster running on a big-endian platform and then restore from that backup to a cluster running on a little-endian system. (Bug #19255)

• Multiple data nodes, multithreaded data nodes. NDB Cluster 7.2 supports multiple data node processes on a single host as well as multithreaded data node processes. See Section 18.4.3, “ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)”, for more information.

• Identifiers. Formerly (in MySQL 5.0 and earlier), database names, table names and attribute names could not be as long for NDB tables as tables using other storage engines, because attribute names were truncated internally. In MySQL 5.1 and later, names of NDB Cluster databases, tables, and table columns follow the same rules regarding length as they do for any other storage engine.

• Length of CREATE TABLE statements. CREATE TABLE statements may be no more than 4096 characters in length. This limitation affects MySQL 5.1.6, 5.1.7, and 5.1.8 only. (See Bug #17813)

• IGNORE and REPLACE functionality. In MySQL 5.1.7 and earlier, INSERT IGNORE, UPDATE IGNORE, and REPLACE were supported only for primary keys, but not for unique keys. It was possible to work around this issue by removing the constraint, then dropping the unique index, performing any inserts, and then adding the unique index again.

This limitation was removed for INSERT IGNORE and REPLACE in MySQL 5.1.8. (See Bug #17431.)

• AUTO_INCREMENT columns. In MySQL 5.1.10 and earlier versions, the maximum number of tables having AUTO_INCREMENT columns—including those belonging to hidden primary keys—was 2048.

This limitation was lifted in MySQL 5.1.11.

• Maximum number of cluster nodes. The total maximum number of nodes in an NDB Cluster is 255, including all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers. The total number of data nodes and management nodes is 63, of which up to 48 can be data nodes.

Note

A data node cannot have a node ID greater than 49.
Known Limitations of NDB Cluster

- **Recovery of memory from deleted rows.** Memory can be reclaimed from an NDB table for reuse with any NDB table by employing `OPTIMIZE TABLE`, subject to the following limitations:
  
  - Only in-memory tables are supported; the `OPTIMIZE TABLE` statement has no effect on NDB Cluster Disk Data tables.
  
  - Only variable-length columns (such as those declared as `VARCHAR`, `TEXT`, or `BLOB`) are supported.

  However, you can force columns defined using fixed-length data types (such as `CHAR`) to be dynamic using the `ROW_FORMAT` or `COLUMN_FORMAT` option with a `CREATE TABLE` or `ALTER TABLE` statement.

  See Section 13.1.17, “CREATE TABLE Statement”, and Section 13.1.7, “ALTER TABLE Statement”, for information on these options.

  You can regulate the effects of `OPTIMIZE` on performance by adjusting the value of the global system variable `ndb_optimization_delay`, which sets the number of milliseconds to wait between batches of rows being processed by `OPTIMIZE`. The default value is 10 milliseconds. It is possible to set a lower value (to a minimum of 0), but not recommended. The maximum is 100000 milliseconds (that is, 100 seconds).

- **Number of tables.** The maximum number of `NDBCLUSTER` tables in a single NDB Cluster is included in the total maximum number of `NDBCLUSTER` database objects (20320). (See Section 18.1.7.5, “Limits Associated with Database Objects in NDB Cluster”.)

- **Adding and dropping of data nodes.** In NDB Cluster 7.2 (NDB Cluster 7.0 and later), it is possible to add new data nodes to a running NDB Cluster by performing a rolling restart, so that the cluster and the data stored in it remain available to applications.

  When planning to increase the number of data nodes in the cluster online, you should be aware of and take into account the following issues:

  - New data nodes can be added online to an NDB Cluster only as part of a new node group.

  - New data nodes can be added online, but cannot be dropped online. Reducing the number of data nodes requires a system restart of the cluster.

  - As in previous NDB Cluster releases, it is not possible to change online either the number of replicas (`NoOfReplicas` configuration parameter) or the number of data nodes per node group. These changes require a system restart.

  - Redistribution of existing cluster data using the new data nodes is not automatic; however, this can be accomplished using simple SQL statements in the `mysql` client or other MySQL client application once the nodes have been added. During this procedure, it is not possible to perform DDL operations, although DML operations can continue as normal.

    The distribution of new cluster data (that is, data stored in the cluster after the new nodes have been added) uses the new nodes without manual intervention.

  For more information, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

- **Native support for default column values.** Starting with NDB 7.1.0, default values for table columns are stored by `NDBCLUSTER`, rather than by the MySQL server as was previously the case. Because less
data must be sent from an SQL node to the data nodes, inserts on tables having column value defaults can be performed more efficiently than before.

Tables created using previous NDB Cluster releases can still be used in NDB 7.1.0 and later, although they do not support native default values and continue to use defaults supplied by the MySQL server until they are upgraded. This can be done by means of an offline `ALTER TABLE` statement.

**Important**

You cannot set or change a table column’s default value using an online `ALTER TABLE` operation.

- **Distribution of MySQL users and privileges.** Previously, MySQL users and privileges created on one node were unique to that SQL node, due to the fact that the MySQL grant tables were restricted to using the MyISAM storage engine. Beginning with NDB 7.2.0, it is possible, following installation of the NDB Cluster software and setup of the desired users and privileges on one SQL node, to convert the grant tables to use NDB and thus to distribute the users and privileges across all SQL nodes connected to the cluster. You can do this by loading and making use of a set of stored procedures defined in an SQL script supplied with the NDB Cluster distribution. For more information, see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”.

- **Number of rows per partition.** Previously, a single NDB Cluster partition could hold a maximum of 46137488 rows. This limitation was removed in NDB 7.2.9. (Bug #13844405, Bug #14000373)

  If you are still using a previous NDB Cluster release, you can work around this limitation by taking advantage of the fact that the number of partitions is the same as the number of data nodes in the cluster (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”). This means that, by increasing the number of data nodes, you can increase the available space for storing data.

  NDB Cluster 7.2 also supports increasing the number of data nodes in the cluster while the cluster remains in operation. See Section 18.5.14, “Adding NDB Cluster Data Nodes Online”, for more information.

  It is also possible to increase the number of partitions for NDB tables by using explicit `KEY` or `LINEAR KEY` partitioning (see Section 19.2.5, “KEY Partitioning”).

### 18.2 NDB Cluster Installation

This section describes the basics for planning, installing, configuring, and running an NDB Cluster.

Whereas the examples in Section 18.3, “Configuration of NDB Cluster” provide more in-depth information on a variety of clustering options and configuration, the result of following the guidelines and procedures outlined here should be a usable NDB Cluster which meets the minimum requirements for availability and safeguarding of data.

For information about upgrading or downgrading an NDB Cluster between release versions, see Section 18.2.7, “Upgrading and Downgrading NDB Cluster”.

This section covers hardware and software requirements; networking issues; installation of NDB Cluster; basic configuration issues; starting, stopping, and restarting the cluster; loading of a sample database; and performing queries.

**Assumptions.** The following sections make a number of assumptions regarding the cluster's physical and network configuration. These assumptions are discussed in the next few paragraphs.

**Cluster nodes and host computers.** The cluster consists of four nodes, each on a separate host computer, and each with a fixed network address on a typical Ethernet network as shown here:
Table 18.4 Network addresses of nodes in example cluster

<table>
<thead>
<tr>
<th>Node</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management node (mgmd)</td>
<td>198.51.100.10</td>
</tr>
<tr>
<td>SQL node (mysqld)</td>
<td>198.51.100.20</td>
</tr>
<tr>
<td>Data node “A” (ndbd)</td>
<td>198.51.100.30</td>
</tr>
<tr>
<td>Data node &quot;B&quot; (ndbd)</td>
<td>198.51.100.40</td>
</tr>
</tbody>
</table>

This may be made clearer by the following diagram:

**Figure 18.4 NDB Cluster Multi-Computer Setup**

Network addressing. In the interest of simplicity (and reliability), this How-To uses only numeric IP addresses. However, if DNS resolution is available on your network, it is possible to use host names in lieu of IP addresses in configuring Cluster. Alternatively, you can use the hosts file (typically `/etc/hosts` for Linux and other Unix-like operating systems, `C:\WINDOW$\system32\drivers\etc\hosts` on Windows, or your operating system’s equivalent) for providing a means to do host lookup if such is available.

Potential hosts file issues. A common problem when trying to use host names for Cluster nodes arises because of the way in which some operating systems (including some Linux distributions) set up the system’s own host name in the `/etc/hosts` during installation. Consider two machines with the host names `ndb1` and `ndb2`, both in the `cluster` network domain. Red Hat Linux (including some derivatives such as CentOS and Fedora) places the following entries in these machines’ `/etc/hosts` files:

```plaintext
# ndb1 /etc/hosts:
127.0.0.1   ndb1.cluster ndb1 localhost.localdomain localhost
```

```plaintext
# ndb2 /etc/hosts:
127.0.0.1   ndb2.cluster ndb2 localhost.localdomain localhost
```

SUSE Linux (including OpenSUSE) places these entries in the machines’ `/etc/hosts` files:

```plaintext
# ndb1 /etc/hosts:
127.0.0.1   localhost
127.0.0.2   ndb1.cluster ndb1
```
Installing NDB Cluster on Linux

# ndb2 /etc/hosts:
127.0.0.1 localhost
127.0.0.2 ndb2.cluster ndb2

In both instances, ndb1 routes ndb1.cluster to a loopback IP address, but gets a public IP address from DNS for ndb2.cluster, while ndb2 routes ndb2.cluster to a loopback address and obtains a public address for ndb1.cluster. The result is that each data node connects to the management server, but cannot tell when any other data nodes have connected, and so the data nodes appear to hang while starting.

Caution
You cannot mix localhost and other host names or IP addresses in config.ini. For these reasons, the solution in such cases (other than to use IP addresses for all config.ini HostName entries) is to remove the fully qualified host names from /etc/hosts and use these in config.ini for all cluster hosts.

Host computer type. Each host computer in our installation scenario is an Intel-based desktop PC running a supported operating system installed to disk in a standard configuration, and running no unnecessary services. The core operating system with standard TCP/IP networking capabilities should be sufficient. Also for the sake of simplicity, we also assume that the file systems on all hosts are set up identically. In the event that they are not, you should adapt these instructions accordingly.

Network hardware. Standard 100 Mbps or 1 gigabit Ethernet cards are installed on each machine, along with the proper drivers for the cards, and that all four hosts are connected through a standard-issue Ethernet networking appliance such as a switch. (All machines should use network cards with the same throughput. That is, all four machines in the cluster should have 100 Mbps cards or all four machines should have 1 Gbps cards.) NDB Cluster works in a 100 Mbps network; however, gigabit Ethernet provides better performance.

Important
NDB Cluster is not intended for use in a network for which throughput is less than 100 Mbps or which experiences a high degree of latency. For this reason (among others), attempting to run an NDB Cluster over a wide area network such as the Internet is not likely to be successful, and is not supported in production.

Sample data. We use the world database which is available for download from the MySQL website (see https://dev.mysql.com/doc/index-other.html). We assume that each machine has sufficient memory for running the operating system, required NDB Cluster processes, and (on the data nodes) storing the database.

For general information about installing MySQL, see Chapter 2, Installing and Upgrading MySQL. For information about installation of NDB Cluster on Linux and other Unix-like operating systems, see Section 18.2.1, “Installing NDB Cluster on Linux”. For information about installation of NDB Cluster on Windows operating systems, see Section 18.2.2, “Installing NDB Cluster on Windows”.

For general information about NDB Cluster hardware, software, and networking requirements, see Section 18.1.3, “NDB Cluster Hardware, Software, and Networking Requirements”.

18.2.1 Installing NDB Cluster on Linux

This section covers installation of NDB Cluster on Linux and other Unix-like operating systems. While the next few sections refer to a Linux operating system, the instructions and procedures given there should be easily adaptable to other supported Unix-like platforms.

NDB Cluster 7.2 is also available for Windows operating systems; for installation and setup instructions specific to Windows, see Section 18.2.2, “Installing NDB Cluster on Windows”. 
Installing NDB Cluster on Linux

Each NDB Cluster host computer must have the correct executable programs installed. A host running an SQL node must have installed on it a MySQL Server binary (`mysqld`). Management nodes require the management server daemon (`ndb_mgmd`); data nodes require the data node daemon (`ndbd` or `ndbmtd`). It is not necessary to install the MySQL Server binary on management node hosts and data node hosts. It is recommended that you also install the management client (`ndb_mgm`) on the management server host.

Installation of NDB Cluster on Linux can be done using precompiled binaries from Oracle (downloaded as a .tar.gz archive), with RPM packages (also available from Oracle), or from source code. All three of these installation methods are described in the section that follow.

Regardless of the method used, it is still necessary following installation of the NDB Cluster binaries to create configuration files for all cluster nodes, before you can start the cluster. See Section 18.2.3, “Initial Configuration of NDB Cluster”.

18.2.1.1 Installing an NDB Cluster Binary Release on Linux

This section covers the steps necessary to install the correct executables for each type of Cluster node from precompiled binaries supplied by Oracle.

For setting up a cluster using precompiled binaries, the first step in the installation process for each cluster host is to download the binary archive from the NDB Cluster downloads page. (For the most recent 64-bit NDB 7.2 release, this is `mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64x86_64glibc2.12.tar.gz`.) We assume that you have placed this file in each machine's `/var/tmp` directory.

If you require a custom binary, see Section 2.9.5, “Installing MySQL Using a Development Source Tree”.

Note

After completing the installation, do not yet start any of the binaries. We show you how to do so following the configuration of the nodes (see Section 18.2.3, “Initial Configuration of NDB Cluster”).

SQL nodes. On each of the machines designated to host SQL nodes, perform the following steps as the system `root` user:

1. Check your `/etc/passwd` and `/etc/group` files (or use whatever tools are provided by your operating system for managing users and groups) to see whether there is already a `mysql` group and `mysql` user on the system. Some OS distributions create these as part of the operating system installation process. If they are not already present, create a new `mysql` user group, and then add a `mysql` user to this group:

```
shell> groupadd mysql
shell> useradd -g mysql -s /bin/false mysql
```

The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix, or they may have different names such as `adduser` and `addgroup`.

2. Change location to the directory containing the downloaded file, unpack the archive, and create a symbolic link named `mysql` to the `mysql` directory.

Note

The actual file and directory names vary according to the NDB Cluster version number.

```
shell> cd /var/tmp
shell> tar -C /usr/local -xzvf mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64.tar.gz
```
Installing NDB Cluster on Linux

3. Change location to the mysql directory and run the supplied script for creating the system databases:

shell> ln -s /usr/local/mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64 /usr/local/mysql

shell> cd mysql
shell> scripts/mysql_install_db --user=mysql

4. Set the necessary permissions for the MySQL server and data directories:

shell> chown -R root .
shell> chown -R mysql data
shell> chgrp -R mysql .

5. Copy the MySQL startup script to the appropriate directory, make it executable, and set it to start when the operating system is booted up:

shell> cp support-files/mysql.server /etc/rc.d/init.d/
shell> chmod +x /etc/rc.d/init.d/mysql.server
shell> chkconfig --add mysql.server

(The startup scripts directory may vary depending on your operating system and version—for example, in some Linux distributions, it is /etc/init.d.)

Here we use Red Hat’s chkconfig for creating links to the startup scripts; use whatever means is appropriate for this purpose on your platform, such as update-rc.d on Debian.

Remember that the preceding steps must be repeated on each machine where an SQL node is to reside.

Data nodes. Installation of the data nodes does not require the mysqld binary. Only the NDB Cluster data node executable ndbd (single-threaded) or ndbmtd (multithreaded) is required. These binaries can also be found in the .tar.gz archive. Again, we assume that you have placed this archive in /var/tmp.

As system root (that is, after using sudo, su root, or your system’s equivalent for temporarily assuming the system administrator account’s privileges), perform the following steps to install the data node binaries on the data node hosts:

1. Change location to the /var/tmp directory, and extract the ndbd and ndbmtd binaries from the archive into a suitable directory such as /usr/local/bin:

shell> cd /var/tmp
shell> tar -zxvf mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64.tar.gz
shell> cd mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64
shell> cp bin/ndbd /usr/local/bin/ndbd
shell> cp bin/ndbmtd /usr/local/bin/ndbmtd

(You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from /var/tmp once ndb_mgm and ndb_mgmd have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

shell> cd /usr/local/bin
shell> chmod +x ndb*

The preceding steps should be repeated on each data node host.

Although only one of the data node executables is required to run an NDB Cluster data node, we have shown you how to install both ndbd and ndbmtd in the preceding instructions. We recommend that you do this when installing or upgrading NDB Cluster, even if you plan to use only one of them, since this will save time and trouble in the event that you later decide to change from one to the other.
Management nodes. Installation of the management node does not require the mysqld binary. Only the NDB Cluster management server (ndb_mgmd) is required; you most likely want to install the management client (ndb_mgm) as well. Both of these binaries also be found in the .tar.gz archive. Again, we assume that you have placed this archive in /var/tmp.

As system root, perform the following steps to install ndb_mgm and ndb_mgmd on the management node host:

1. Change location to the /var/tmp directory, and extract the ndb_mgm and ndb_mgmd from the archive into a suitable directory such as /usr/local/bin:

```
shell> cd /var/tmp
shell> tar -zxvf mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64.tar.gz
shell> cd mysql-cluster-gpl-7.2.39-linux-glibc2.12-x86_64
shell> cp bin/ndb_mgm* /usr/local/bin
```

(You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from /var/tmp once ndb_mgm and ndb_mgmd have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

```
shell> cd /usr/local/bin
shell> chmod +x ndb_mgm*
```

In Section 18.2.3, “Initial Configuration of NDB Cluster”, we create configuration files for all of the nodes in our example NDB Cluster.

18.2.1.2 Installing NDB Cluster from RPM

This section covers the steps necessary to install the correct executables for each type of NDB Cluster node using RPM packages supplied by Oracle.

RPMs are available for both 32-bit and 64-bit Linux platforms. The filenames for these RPMs use the following pattern:

```
MySQL-Cluster-component-producttype-ndbversion.distribution.architecture.rpm
```

- component: {server | client [ | other]}
- producttype: {gpl | advanced}
- ndbversion: major.minor.release
- distribution: {sles10 | rhel5 | el6}
- architecture: {i386 | x86_64}

The component can be server or client. (Other values are possible, but since only the server and client components are required for a working NDB Cluster installation, we do not discuss them here.) The producttype for Community RPMs downloaded from https://dev.mysql.com/downloads/cluster/ is always gpl; advanced is used to indicate commercial releases. ndbversion represents the three-part NDB storage engine version number in 7.2.x format. The distribution can be one of sles11 (SUSE
Installing NDB Cluster on Linux

Enterprise Linux 11), rhel5 (Oracle Linux 5, Red Hat Enterprise Linux 4 and 5), or el6 (Oracle Linux 6, Red Hat Enterprise Linux 6) The architecture is i386 for 32-bit RPMs and x86_64 for 64-bit versions.

For an NDB Cluster, one and possibly two RPMs are required:

- The server RPM (for example, MySQL-Cluster-server-gpl-7.2.39-1.sles11.i386.rpm), which supplies the core files needed to run a MySQL Server with NDBCLUSTER storage engine support (that is, as an NDB Cluster SQL node) as well as all NDB Cluster executables, including the management node, data node, and ndb_mgm client binaries. This RPM is always required for installing NDB Cluster.

- If you do not have your own client application capable of administering a MySQL server, you should also obtain and install the client RPM (for example, MySQL-Cluster-client-gpl-7.2.39-1.sles11.i386.rpm), which supplies the mysql client

The NDB Cluster version number in the RPM file names (shown here as 7.2.39) can vary according to the version which you are actually using. It is very important that all of the Cluster RPMs to be installed have the same version number. The architecture designation should be appropriate to the machine on which the RPM is to be installed; in particular, you should keep in mind that 64-bit RPMs cannot be used with 32-bit operating systems.

Data nodes. On a computer that is to host a cluster data node it is necessary to install only the server RPM. To do so, copy this RPM to the data node host, and run the following command as the system root user, replacing the name shown for the RPM as necessary to match that of the RPM downloaded from the MySQL website:

    shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.39-1.sles11.i386.rpm

Although this installs all NDB Cluster binaries, only the program ndbd or ndbmtd (both in /usr/sbin) is actually needed to run an NDB Cluster data node.

SQL nodes. On each machine to be used for hosting a cluster SQL node, install the server RPM by executing the following command as the system root user, replacing the name shown for the RPM as necessary to match the name of the RPM downloaded from the MySQL website:

    shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.39-1.sles11.i386.rpm

This installs the MySQL server binary (mysqld) with NDB storage engine support in the /usr/sbin directory, as well as all needed MySQL Server support files. It also installs the mysql.server and mysql_safe startup scripts (in /usr/share/mysql and /usr/bin, respectively). The RPM installer should take care of general configuration issues (such as creating the mysql user and group, if needed) automatically.

To administer the SQL node (MySQL server), you should also install the client RPM, as shown here:

    shell> rpm -Uhv MySQL-Cluster-client-gpl-7.2.39-1.sles11.i386.rpm

This installs the mysql client program.

Management nodes. To install the NDB Cluster management server, it is necessary only to use the server RPM. Copy this RPM to the computer intended to host the management node, and then install it by running the following command as the system root user (replace the name shown for the RPM as necessary to match that of the server RPM downloaded from the MySQL website):

    shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.39-1.sles11.i386.rpm

Although this RPM installs many other files, only the management server binary ndb_mgmd (in the /usr/sbin directory) is actually required for running a management node. The server RPM also installs ndb_mgm, the NDB management client.
See Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”, for general information about installing MySQL using RPMs supplied by Oracle.

After installing from RPM, you still need to configure the cluster as discussed in Section 18.2.3, “Initial Configuration of NDB Cluster”.

Note
A number of RPMs used by NDB Cluster 7.1 were made obsolete and discontinued in NDB Cluster 7.2. These include the former MySQL-Cluster-clusterj, MySQL-Cluster-extra, MySQL-Cluster-management, MySQL-Cluster-storage, and NDB Cluster-tools RPMs; all of these have been merged into the MySQL-Cluster-server RPM. When upgrading from an NDB Cluster 7.1 RPM installation to NDB 7.2.3 or an earlier NDB Cluster 7.2 release, it was necessary to remove these packages manually before installing the NDB Cluster 7.2 MySQL-Cluster-server RPM. This issue is fixed in NDB 7.2.4 and later, where the MySQL-Cluster-server package specifically obsoletes the discontinued packages (BUG #13545589).

18.2.1.3 Installing NDB Cluster Using .deb Files

The section provides information about installing NDB Cluster on Debian and related Linux distributions such as Ubuntu using the .deb files supplied by Oracle for this purpose.

Oracle provides .deb installer files for NDB Cluster 7.2 for 32-bit and 64-bit platforms. For a Debian-based system, only a single installer file is necessary. This file is named using the pattern shown here, according to the applicable NDB Cluster version, Debian version, and architecture:

```
mysql-cluster-gpl-ndbver-debian-debianver-arch.deb
```

Here, ndbver is the 3-part NDB engine version number, debianver is the major version of Debian (for NDB Cluster 7.2, this is always 6.0), and arch is one of i686 or x86_64. In the examples that follow, we assume you wish to install NDB 7.2.21 on a 64-bit Debian 6 system; in this case, the installer file is named mysql-cluster-gpl-7.2.21-debian6.0-x86_64.deb.

Once you have downloaded the appropriate .deb file, you can install it from the command line using dpkg, like this:

```
shell> dpkg -i mysql-cluster-gpl-7.2.21-debian6.0-i686.deb
```

You can also remove it using dpkg as shown here:

```
shell> dpkg --r mysql
```

The installer file should also be compatible with most graphical package managers that work with .deb files, such as GDebi for the Gnome desktop.

The .deb file installs NDB Cluster under /opt/mysql/server-version/, where version is the 2-part release series version for the included MySQL server. For NDB Cluster 7.2, this is always 5.5. The directory layout is the same as that for the generic Linux binary distribution (see Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”), with the exception that startup scripts and configuration files are found in support-files instead of share. All NDB Cluster executables, such as ndb_mgm, ndbd, and ndb_mgmd, are placed in the bin directory.

18.2.1.4 Building NDB Cluster from Source on Linux

This section provides information about compiling NDB Cluster on Linux and other Unix-like platforms. Building NDB Cluster from source is similar to building the standard MySQL Server, although it differs in a few key respects discussed here. For general information about building MySQL from source, see
Installing NDB Cluster on Linux

Section 2.9, “Installing MySQL from Source”. For information about compiling NDB Cluster on Windows platforms, see Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”.

Building NDB Cluster requires using the NDB Cluster sources. These are available from the NDB Cluster downloads page at https://dev.mysql.com/downloads/cluster/. The archived source file should have a name similar to mysql-cluster-gpl-7.2.39.tar.gz. You can also obtain NDB Cluster 7.2 sources from GitHub at https://github.com/mysql/mysql-server/tree/cluster-7.2. Building NDB Cluster 7.2 from standard MySQL Server 5.5 sources is not supported.

For NDB Cluster 7.2 on Linux and similar platforms, GCC 4 (4.2.1 or later) or GCC 5 is required to compile from source; GCC 6 and later versions of GCC are not supported.

The WITH_NDBCLUSTER_STORAGE_ENGINE option for CMake causes the binaries for the management nodes, data nodes, and other NDB Cluster programs to be built; it also causes mysqld to be compiled with NDB storage engine support. This option (or its alias WITH_NDBCLUSTER) is required when building NDB Cluster.

Important

Beginning with NDB 7.2.9, the WITH_NDB_JAVA option is enabled by default. This means that, by default, if CMake cannot find the location of Java on your system, the configuration process fails; if you do not wish to enable Java and ClusterJ support, you must indicate this explicitly by configuring the build using -DWITH_NDB_JAVA=OFF. (Bug #12379735) Use WITH_CLASSPATH to provide the Java classpath if needed.

For more information about CMake options specific to building NDB Cluster, see Options for Compiling NDB Cluster.

After you have run make && make install (or your system’s equivalent), the result is similar to what is obtained by unpacking a precompiled binary to the same location.

Management nodes. When building from source and running the default make install, the management server and management client binaries (ndb_mgmd and ndb_mgm) can be found in /usr/local/mysql/bin. Only ndb_mgmd is required to be present on a management node host; however, it is also a good idea to have ndb_mgm present on the same host machine. Neither of these executables requires a specific location on the host machine's file system.

Data nodes. The only executable required on a data node host is the data node binary ndbd or ndbmtd. (mysqld, for example, does not have to be present on the host machine.) By default, when building from source, this file is placed in the directory /usr/local/mysql/bin. For installing on multiple data node hosts, only ndbd or ndbmtd need be copied to the other host machine or machines. (This assumes that all data node hosts use the same architecture and operating system; otherwise you may need to compile separately for each different platform.) The data node binary need not be in any particular location on the host's file system, as long as the location is known.

When compiling NDB Cluster from source, no special options are required for building multithreaded data node binaries. Configuring the build with NDB storage engine support causes ndbmtd to be built automatically; make install places the ndbmtd binary in the installation bin directory along with mysqld, ndbd, and ndb_mgm.

SQL nodes. If you compile MySQL with clustering support, and perform the default installation (using make install as the system root user), mysqld is placed in /usr/local/mysql/bin. Follow the steps given in Section 2.9, “Installing MySQL from Source” to make mysqld ready for use. If you want to run multiple SQL nodes, you can use a copy of the same mysqld executable and its associated support files on several machines. The easiest way to do this is to copy the entire /usr/local/mysql directory and all directories and files contained within it to the other SQL node host or hosts, then repeat the steps.
from Section 2.9, “Installing MySQL from Source” on each machine. If you configure the build with a nondefault `PREFIX` option, you must adjust the directory accordingly.

In Section 18.2.3, “Initial Configuration of NDB Cluster”, we create configuration files for all of the nodes in our example NDB Cluster.

### 18.2.2 Installing NDB Cluster on Windows

NDB Cluster 7.2 binaries for Windows can be obtained from [https://dev.mysql.com/downloads/cluster/](https://dev.mysql.com/downloads/cluster/). For information about installing NDB Cluster on Windows from a binary release provided by Oracle, see Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”.

It is also possible to compile and install NDB Cluster from source on Windows using Microsoft Visual Studio. For more information, see Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”.

#### 18.2.2.1 Installing NDB Cluster on Windows from a Binary Release

This section describes a basic installation of NDB Cluster on Windows using a binary “no-install” NDB Cluster release provided by Oracle, using the same 4-node setup outlined in the beginning of this section (see Section 18.2, “NDB Cluster Installation”), as shown in the following table:

<table>
<thead>
<tr>
<th>Table 18.5 Network addresses of nodes in example cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Node</strong></td>
</tr>
<tr>
<td>Management node (<code>mgmd</code>)</td>
</tr>
<tr>
<td>SQL node (<code>mysqld</code>)</td>
</tr>
<tr>
<td>Data node &quot;A&quot; (<code>ndbd</code>)</td>
</tr>
<tr>
<td>Data node &quot;B&quot; (<code>ndbd</code>)</td>
</tr>
</tbody>
</table>

As on other platforms, the NDB Cluster host computer running an SQL node must have installed on it a MySQL Server binary (`mysqld.exe`). You should also have the MySQL client (`mysql.exe`) on this host. For management nodes and data nodes, it is not necessary to install the MySQL Server binary; however, each management node requires the management server daemon (`ndb_mgmd.exe`); each data node requires the data node daemon (`ndbd.exe` or `ndbmtd.exe`). For this example, we refer to `ndbd.exe` as the data node executable, but you can install `ndb_mgm.exe`, the multithreaded version of this program, instead, in exactly the same way. You should also install the management client (`ndb_mgm.exe`) on the management server host. This section covers the steps necessary to install the correct Windows binaries for each type of NDB Cluster node.

**Note**

As with other Windows programs, NDB Cluster executables are named with the `.exe` file extension. However, it is not necessary to include the `.exe` extension when invoking these programs from the command line. Therefore, we often simply refer to these programs in this documentation as `mysqld`, `mysql`, `ndb_mgmd`, and so on. You should understand that, whether we refer (for example) to `mysqld` or `mysql`, either name means the same thing (the MySQL Server program).

For setting up an NDB Cluster using Oracle's `no-install` binaries, the first step in the installation process is to download the latest NDB Cluster Windows ZIP binary archive from [https://dev.mysql.com/downloads/cluster/](https://dev.mysql.com/downloads/cluster/). This archive has a filename of the `mysql-cluster-gpl-ver-winarch.zip`, where `ver` is the NDB storage engine version (such as `7.2.39`), and `arch` is the architecture (`32` for 32-bit binaries, and `64` for 64-bit binaries). For example, the NDB Cluster 7.2.39 archive for 64-bit Windows systems is named `mysql-cluster-gpl-7.2.39-win64.zip`. 2155
You can run 32-bit NDB Cluster binaries on both 32-bit and 64-bit versions of Windows; however, 64-bit NDB Cluster binaries can be used only on 64-bit versions of Windows. If you are using a 32-bit version of Windows on a computer that has a 64-bit CPU, then you must use the 32-bit NDB Cluster binaries.

To minimize the number of files that need to be downloaded from the Internet or copied between machines, we start with the computer where you intend to run the SQL node.

**SQL node.** We assume that you have placed a copy of the archive in the directory `C:\Documents and Settings\username\My Documents\Downloads` on the computer having the IP address 198.51.100.20, where `username` is the name of the current user. (You can obtain this name using `ECHO %USERNAME%` on the command line.) To install and run NDB Cluster executables as Windows services, this user should be a member of the `Administrators` group.

Extract all the files from the archive. The Extraction Wizard integrated with Windows Explorer is adequate for this task. (If you use a different archive program, be sure that it extracts all files and directories from the archive, and that it preserves the archive's directory structure.) When you are asked for a destination directory, enter `C:\`, which causes the Extraction Wizard to extract the archive to the directory `C:\mysql-cluster-gpl-ver-winarch`. Rename this directory to `C:\mysql`.

It is possible to install the NDB Cluster binaries to directories other than `C:\mysql\bin`; however, if you do so, you must modify the paths shown in this procedure accordingly. In particular, if the MySQL Server (SQL node) binary is installed to a location other than `C:\mysql` or `C:\Program Files\MySQL\MySQL Server 5.5`, or if the SQL node's data directory is in a location other than `C:\mysql\data` or `C:\Program Files\MySQL\MySQL Server 5.5\data`, extra configuration options must be used on the command line or added to the `my.ini` or `my.cnf` file when starting the SQL node. For more information about configuring a MySQL Server to run in a nonstandard location, see Section 2.3.6, “Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive”.

For a MySQL Server with NDB Cluster support to run as part of an NDB Cluster, it must be started with the options `--ndbcluster` and `--ndb-connectstring`. While you can specify these options on the command line, it is usually more convenient to place them in an option file. To do this, create a new text file in Notepad or another text editor. Enter the following configuration information into this file:

```
[mysqld]
# Options for mysqld process:
ndbcluster                       # run NDB storage engine
ndb-connectstring=198.51.100.10   # location of management server
```

You can add other options used by this MySQL Server if desired (see Section 2.3.6.2, “Creating an Option File”), but the file must contain the options shown, at a minimum. Save this file as `C:\mysql\my.ini`. This completes the installation and setup for the SQL node.

**Data nodes.** An NDB Cluster data node on a Windows host requires only a single executable, one of either `ndbd.exe` or `ndbmtd.exe`. For this example, we assume that you are using `ndbd.exe`, but the same instructions apply when using `ndbmtd.exe`. On each computer where you wish to run a data node (the computers having the IP addresses 198.51.100.30 and 198.51.100.40), create the directories `C:\mysql`, `C:\mysql\bin`, and `C:\mysql\cluster-data`; then, on the computer where you downloaded and extracted the `no-install` archive, locate `ndbd.exe` in the `C:\mysql\bin` directory. Copy this file to the `C:\mysql\bin` directory on each of the two data node hosts.

To function as part of an NDB Cluster, each data node must be given the address or hostname of the management server. You can supply this information on the command line using the `--ndb-connectstring` or `-c` option when starting each data node process. However, it is usually preferable to put this information in an option file. To do this, create a new text file in Notepad or another text editor and enter the following text:

```
[ndbd]
# Options for ndbd process:
connectstring=198.51.100.10   # location of management server
```

This completes the installation and setup for the data nodes.
Installing NDB Cluster on Windows

# Options for data node process:
ndb-connectstring=198.51.100.10  # location of management server

Save this file as C:\mysql\my.ini on the data node host. Create another text file containing the same information and save it on as C:\mysql\my.ini on the other data node host, or copy the my.ini file from the first data node host to the second one, making sure to place the copy in the second data node’s C:\mysql directory. Both data node hosts are now ready to be used in the NDB Cluster, which leaves only the management node to be installed and configured.

Management node. The only executable program required on a computer used for hosting an NDB Cluster management node is the management server program ndb_mgmd.exe. However, in order to administer the NDB Cluster once it has been started, you should also install the NDB Cluster management client program ndb_mgm.exe on the same machine as the management server. Locate these two programs on the machine where you downloaded and extracted the no-install archive; this should be the directory C:\mysql\bin on the SQL node host. Create the directory C:\mysql\bin on the computer having the IP address 198.51.100.10, then copy both programs to this directory.

You should now create two configuration files for use by ndb_mgmd.exe:

1. A local configuration file to supply configuration data specific to the management node itself. Typically, this file needs only to supply the location of the NDB Cluster global configuration file (see item 2).

   To create this file, start a new text file in Notepad or another text editor, and enter the following information:

   ```
   [mysql_cluster]
   # Options for management node process
   config-file=C:/mysql/bin/config.ini
   ```

   Save this file as the text file C:\mysql\bin\my.ini.

2. A global configuration file from which the management node can obtain configuration information governing the NDB Cluster as a whole. At a minimum, this file must contain a section for each node in the NDB Cluster, and the IP addresses or hostnames for the management node and all data nodes (HostName configuration parameter). It is also advisable to include the following additional information:

   - The IP address or hostname of any SQL nodes
   - The data memory and index memory allocated to each data node (DataMemory and IndexMemory configuration parameters)
   - The number of replicas, using the NoOfReplicas configuration parameter (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”)
   - The directory where each data node stores it data and log file, and the directory where the management node keeps its log files (in both cases, the DataDir configuration parameter)

   Create a new text file using a text editor such as Notepad, and input the following information:

   ```
   [ndbd default]
   # Options affecting ndbd processes on all data nodes:
   NoOfReplicas=2                      # Number of replicas
   DataDir=C:/mysql/cluster-data       # Directory for each data node's data files
   # Forward slashes used in directory path, rather than backslashes. This is correct;
   # see Important note in text
   DataMemory=80M  # Memory allocated to data storage
   IndexMemory=18M # Memory allocated to index storage
   # For DataMemory and IndexMemory, we have used the # default values. Since the "world" database takes up
   ```

   Important note in text:

   "Use forward slashes (\/) instead of backslashes (\) in directory paths. This is correct, as shown by the
   # symbol at the beginning of each line. This is especially important when using Linux and Unix systems,
   where backslashes are used to escape special characters, such as the "directory" character (\). However, on
   Windows systems, backslashes are used for directory paths, so you should use forward slashes instead.

   For example, the following directory path is correct on a Windows system:
   "C:\mysql\bin"

   And the following path is correct on a Linux or Unix system:
   "C:/mysql/bin"

   Thus, when creating configuration files for use with the NDB Cluster, you should always use forward slashes in directory paths, even if you are creating these files on a Windows system.

2157
Installing NDB Cluster on Windows

# only about 500KB, this should be more than enough for
# this example Cluster setup.

[ndb_mgmd]
# Management process options:
HostName=198.51.100.10                  # Hostname or IP address of management node
DataDir=C:/mysql/bin/cluster-logs       # Directory for management node log files

[ndbd]
# Options for data node "A":
HostName=198.51.100.30                  # Hostname or IP address

[ndbd]
# Options for data node "B":
HostName=198.51.100.40                  # Hostname or IP address

[mysqld]
# SQL node options:
HostName=198.51.100.20                  # Hostname or IP address

Save this file as the text file C:\mysql\bin\config.ini.

Important

A single backslash character (\) cannot be used when specifying directory paths in program options or configuration files used by NDB Cluster on Windows. Instead, you must either escape each backslash character with a second backslash (\\), or replace the backslash with a forward slash character (/). For example, the following line from the [ndb_mgmd] section of an NDB Cluster config.ini file does not work:

DataDir=C:\mysql\bin\cluster-logs

Instead, you may use either of the following:

DataDir=C:\\mysql\bin\cluster-logs # Escaped backslashes

DataDir=C:/mysql/bin/cluster-logs    # Forward slashes

For reasons of brevity and legibility, we recommend that you use forward slashes in directory paths used in NDB Cluster program options and configuration files on Windows.

18.2.2.2 Compiling and Installing NDB Cluster from Source on Windows

Oracle provides precompiled NDB Cluster binaries for Windows which should be adequate for most users. However, if you wish, it is also possible to compile NDB Cluster for Windows from source code. The procedure for doing this is almost identical to the procedure used to compile the standard MySQL Server binaries for Windows, and uses the same tools. However, there are two major differences:

- Building NDB Cluster requires using the NDB Cluster sources. These are available from the NDB Cluster downloads page at https://dev.mysql.com/downloads/cluster/. The archived source file should have a name similar to mysql-cluster-gpl-7.2.39.tar.gz. You can also obtain NDB Cluster 7.2 sources from GitHub at https://github.com/mysql/mysql-server/tree/cluster-7.2. Building NDB Cluster 7.2 from standard MySQL Server 5.5 sources is not supported.

- You must configure the build using the WITH_NDBCLUSTER_STORAGE_ENGINE or WITH_NDBCLUSTER option in addition to any other build options you wish to use with CMake. (WITH_NDBCLUSTER is supported as an alias for WITH_NDBCLUSTER_STORAGE_ENGINE, and works in exactly the same way.)
Installing NDB Cluster on Windows

Important

Beginning with NDB 7.2.9, the \texttt{WITH\_NDB\_JAVA} option is enabled by default. This means that, by default, if \texttt{CMake} cannot find the location of Java on your system, the configuration process fails; if you do not wish to enable Java and ClusterJ support, you must indicate this explicitly by configuring the build using \texttt{-DWITH\_NDB\_JAVA=OFF}. (Bug \#12379735) Use \texttt{WITH\_CLASSPATH} to provide the Java classpath if needed.

For more information about \texttt{CMake} options specific to building NDB Cluster, see \texttt{Options for Compiling NDB Cluster}.

Once the build process is complete, you can create a Zip archive containing the compiled binaries; \texttt{Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”} provides the commands needed to perform this task on Windows systems. The NDB Cluster binaries can be found in the \texttt{bin} directory of the resulting archive, which is equivalent to the \texttt{no-install} archive, and which can be installed and configured in the same manner. For more information, see \texttt{Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”}.

18.2.2.3 Initial Startup of NDB Cluster on Windows

Once the NDB Cluster executables and needed configuration files are in place, performing an initial start of the cluster is simply a matter of starting the NDB Cluster executables for all nodes in the cluster. Each cluster node process must be started separately, and on the host computer where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes.

1. On the management node host, issue the following command from the command line to start the management node process. The output should appear similar to what is shown here:

```bash
C:\mysql\bin> ndb_mgmd
2010-06-23 07:53:34 [MgmtSrvr] INFO -- Reading cluster configuration from 'config.ini'
```

The management node process continues to print logging output to the console. This is normal, because the management node is not running as a Windows service. (If you have used NDB Cluster on a Unix-like platform such as Linux, you may notice that the management node’s default behavior in this regard on Windows is effectively the opposite of its behavior on Unix systems, where it runs by default as a Unix daemon process. This behavior is also true of NDB Cluster data node processes running on Windows.) For this reason, do not close the window in which \texttt{ndb\_mgmd.exe} is running; doing so kills the management node process. (See \texttt{Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”}, where we show how to install and run NDB Cluster processes as Windows services.)

The required \texttt{-f} option tells the management node where to find the global configuration file \texttt{(config.ini)}. The long form of this option is \texttt{--config-file}.

Important

An NDB Cluster management node caches the configuration data that it reads from \texttt{config.ini}; once it has created a configuration cache, it ignores the \texttt{config.ini} file on subsequent starts unless forced to do otherwise. This means that, if the management node fails to start due to an error in this file, you must make the management node re-read \texttt{config.ini} after you have corrected any errors in it. You can do this by starting \texttt{ndb\_mgmd.exe} with the \texttt{--reload} or \texttt{--initial} option on the command line. Either of these options works to refresh the configuration cache.
It is not necessary or advisable to use either of these options in the management node's my.ini file.

For additional information about options which can be used with ndb_mgmd, see Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon", as well as Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs".

2. On each of the data node hosts, run the command shown here to start the data node processes:

```
C:\mysql\bin> ndbd
```


In each case, the first line of output from the data node process should resemble what is shown in the preceding example, and is followed by additional lines of logging output. As with the management node process, this is normal, because the data node is not running as a Windows service. For this reason, do not close the console window in which the data node process is running; doing so kills ndbd.exe. (For more information, see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”.)

3. Do not start the SQL node yet; it cannot connect to the cluster until the data nodes have finished starting, which may take some time. Instead, in a new console window on the management node host, start the NDB Cluster management client ndb_mgm.exe, which should be in C:\mysql\bin on the management node host. (Do not try to re-use the console window where ndb_mgmd.exe is running by typing CTRL+C, as this kills the management node.) The resulting output should look like this:

```
C:\mysql\bin> ndb_mgm

-- NDB Cluster -- Management Client --
```

When the prompt ndb_mgm> appears, this indicates that the management client is ready to receive NDB Cluster management commands. You can observe the status of the data nodes as they start by entering ALL STATUS at the management client prompt. This command causes a running report of the data nodes' startup sequence, which should look something like this:

```
ndb_mgm> ALL STATUS
Connected to Management Server at: localhost:1186
Node 2: starting (Last completed phase 3) (mysql-5.5.65-ndb-7.2.39)
Node 3: starting (Last completed phase 3) (mysql-5.5.65-ndb-7.2.39)

Node 2: starting (Last completed phase 4) (mysql-5.5.65-ndb-7.2.39)
Node 3: starting (Last completed phase 4) (mysql-5.5.65-ndb-7.2.39)

Node 2: Started (version 7.2.39)
Node 3: Started (version 7.2.39)
```

Note

Commands issued in the management client are not case-sensitive; we use uppercase as the canonical form of these commands, but you are not required to observe this convention when inputting them into the ndb_mgm client. For more information, see Section 18.5.2, "Commands in the NDB Cluster Management Client".

The output produced by ALL STATUS is likely to vary from what is shown here, according to the speed at which the data nodes are able to start, the release version number of the NDB Cluster software.
you are using, and other factors. What is significant is that, when you see that both data nodes have started, you are ready to start the SQL node.

You can leave ndb_mgm.exe running; it has no negative impact on the performance of the NDB Cluster, and we use it in the next step to verify that the SQL node is connected to the cluster after you have started it.

4. On the computer designated as the SQL node host, open a console window and navigate to the directory where you unpacked the NDB Cluster binaries (if you are following our example, this is C: \mysql\bin).

Start the SQL node by invoking mysqld.exe from the command line, as shown here:

```
C:\mysql\bin> mysqld --console
```

The --console option causes logging information to be written to the console, which can be helpful in the event of problems. (Once you are satisfied that the SQL node is running in a satisfactory manner, you can stop it and restart it out without the --console option, so that logging is performed normally.)

In the console window where the management client (ndb_mgm.exe) is running on the management node host, enter the SHOW command, which should produce output similar to what is shown here:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)] 2 node(s)
id=2 198.51.100.30 (Version: 5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=3 198.51.100.40 (Version: 5.5.65-ndb-7.2.39, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=1 198.51.100.10 (Version: 5.5.65-ndb-7.2.39)

[mysqld(API)] 1 node(s)
id=4 198.51.100.20 (Version: 5.5.65-ndb-7.2.39)
```

You can also verify that the SQL node is connected to the NDB Cluster in the mysql client (mysql.exe) using the SHOW ENGINE NDB STATUS statement.

You should now be ready to work with database objects and data using NDB Cluster’s NDBCLUSTER storage engine. See Section 18.2.5, “NDB Cluster Example with Tables and Data”, for more information and examples.

You can also install ndb_mgmd.exe, ndbd.exe, and ndbmtd.exe as Windows services. For information on how to do this, see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”).

### 18.2.2.4 Installing NDB Cluster Processes as Windows Services

Once you are satisfied that NDB Cluster is running as desired, you can install the management nodes and data nodes as Windows services, so that these processes are started and stopped automatically whenever Windows is started or stopped. This also makes it possible to control these processes from the command line with the appropriate SC START and SC STOP commands, or using the Windows graphical Services utility. NET START and NET STOP commands can also be used.

Installing programs as Windows services usually must be done using an account that has Administrator rights on the system.

To install the management node as a service on Windows, invoke ndb_mgm.exe from the command line on the machine hosting the management node, using the --install option, as shown here:
Installing NDB Cluster on Windows

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install
Installing service 'NDB Cluster Management Server'
  as "C:\mysql\bin\ndb.exe" "--service=ndb_mgmd"
Service successfully installed.
```

**Important**

When installing an NDB Cluster program as a Windows service, you should always specify the complete path; otherwise the service installation may fail with the error _The system cannot find the file specified._

The `--install` option must be used first, ahead of any other options that might be specified for `ndb_mgmd.exe`. However, it is preferable to specify such options in an options file instead. If your options file is not in one of the default locations as shown in the output of `ndb_mgmd.exe --help`, you can specify the location using the `--config-file` option.

Now you should be able to start and stop the management server like this:

```
C:\> SC START ndb_mgmd
C:\> SC STOP ndb_mgmd
```

**Note**

If using NET commands, you can also start or stop the management server as a Windows service using the descriptive name, as shown here:

```
C:\> NET START 'NDB Cluster Management Server'
The NDB Cluster Management Server service is starting.
The NDB Cluster Management Server service was started successfully.

C:\> NET STOP 'NDB Cluster Management Server'
The NDB Cluster Management Server service is stopping..
The NDB Cluster Management Server service was stopped successfully.
```

It is usually simpler to specify a short service name or to permit the default service name to be used when installing the service, and then reference that name when starting or stopping the service. To specify a service name other than `ndb_mgmd`, append it to the `--install` option, as shown in this example:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install=mgmd1
Installing service 'NDB Cluster Management Server'
  as "C:\mysql\bin\ndb_mgmd.exe" "--service=mgmd1"
Service successfully installed.
```

Now you should be able to start or stop the service using the name you have specified, like this:

```
C:\> SC START mgmd1
C:\> SC STOP mgmd1
```

To remove the management node service, use `SC DELETE service_name`:

```
C:\> SC DELETE mgmd1
```

Alternatively, invoke `ndb_mgmd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove
Removing service 'NDB Cluster Management Server'
Service successfully removed.
```

If you installed the service using a service name other than the default, pass the service name as the value of the `ndb_mgmd.exe --remove` option, like this:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove=mgmd1
```
### Initial Configuration of NDB Cluster

Removing service 'mgmd1'
Service successfully removed.

Installation of an NDB Cluster data node process as a Windows service can be done in a similar fashion, using the `--install` option for `ndbd.exe` (or `ndbtd.exe`), as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --install
Installing service 'NDB Cluster Data Node Daemon' as 'C:\mysql\bin\ndbd.exe' '--service=ndbd'
Service successfully installed.
```

Now you can start or stop the data node as shown in the following example:

```
C:\> SC START ndbd
C:\> SC STOP ndbd
```

To remove the data node service, use `SC DELETE service_name`:

```
C:\> SC DELETE ndbd
```

Alternatively, invoke `ndbd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove
Removing service 'NDB Cluster Data Node Daemon'
Service successfully removed.
```

As with `ndb_mgmd.exe` (and `mysqld.exe`), when installing `ndbd.exe` as a Windows service, you can also specify a name for the service as the value of `--install`, and then use it when starting or stopping the service, like this:

```
C:\> C:\mysql\bin\ndbd.exe --install=dnode1
Installing service 'dnode1' as 'C:\mysql\bin\ndbd.exe' '--service=dnode1'
Service successfully installed.
```

```
C:\> SC START dnode1
C:\> SC STOP dnode1
```

If you specified a service name when installing the data node service, you can use this name when removing it as well, as shown here:

```
C:\> SC DELETE dnode1
```

Alternatively, you can pass the service name as the value of the `ndbd.exe --remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove=dnode1
Removing service 'dnode1'
Service successfully removed.
```

Installation of the SQL node as a Windows service, starting the service, stopping the service, and removing the service are done in a similar fashion, using `mysqld --install, SC START, SC STOP, and SC DELETE` (or `mysqld --remove`). NET commands can also be used to start or stop a service. For additional information, see Section 2.3.6.7, “Starting MySQL as a Windows Service”.

#### 18.2.3 Initial Configuration of NDB Cluster

For our four-node, four-host NDB Cluster, it is necessary to write four configuration files, one per node host.

- Each data node or SQL node requires a `my.cnf` file that provides two pieces of information: a `connection string` that tells the node where to find the management node, and a line telling the MySQL server on this host (the machine hosting the data node) to enable the `NDBCLUSTER` storage engine.
For more information on connection strings, see Section 18.3.3.3, “NDB Cluster Connection Strings”.

- The management node needs a `config.ini` file telling it how many replicas to maintain, how much memory to allocate for data and indexes on each data node, where to find the data nodes, where to save data to disk on each data node, and where to find any SQL nodes.

**Configuring the data nodes and SQL nodes.** The `my.cnf` file needed for the data nodes is fairly simple. The configuration file should be located in the `/etc` directory and can be edited using any text editor. (Create the file if it does not exist.) For example:

```
shell> vi /etc/my.cnf
```

![Note]

We show `vi` being used here to create the file, but any text editor should work just as well.

For each data node and SQL node in our example setup, `my.cnf` should look like this:

```ini
[mysqld]
# Options for mysqld process:
ndbcluster  # run NDB storage engine

[mysql_cluster]
# Options for NDB Cluster processes:
ndb-connectstring=198.51.100.10  # location of management server
```

After entering the preceding information, save this file and exit the text editor. Do this for the machines hosting data node “A”, data node “B”, and the SQL node.

![Important]

Once you have started a `mysqld` process with the `ndbcluster` and `ndb-connectstring` parameters in the `[mysqld]` and `[mysql_cluster]` sections of the `my.cnf` file as shown previously, you cannot execute any `CREATE TABLE` or `ALTER TABLE` statements without having actually started the cluster. Otherwise, these statements will fail with an error. This is by design.

**Configuring the management node.** The first step in configuring the management node is to create the directory in which the configuration file can be found and then to create the file itself. For example (running as `root`):

```
shell> mkdir /var/lib/mysql-cluster
shell> cd /var/lib/mysql-cluster
shell> vi config.ini
```

For our representative setup, the `config.ini` file should read as follows:

```ini
[nbd default]
# Options affecting ndbd processes on all data nodes:
NoOfReplicas=2  # Number of replicas
DataMemory=80M   # How much memory to allocate for data storage
IndexMemory=18M  # How much memory to allocate for index storage
# For DataMemory and IndexMemory, we have used the default values. Since the "world" database takes up only about 500KB, this should be more than enough for this example Cluster setup.

[tcp default]
# TCP/IP options:
```
PortNumber=2202  # This is the default; however, you can use any
port that is free for all the hosts in the cluster
# Note: It is recommended that you do not specify the port
# number at all and simply allow the default value to be used
# instead

[ndb_mgmd]
  # Management process options:
  HostName=198.51.100.10          # Hostname or IP address of MGM node
  DataDir=/var/lib/mysql-cluster  # Directory for MGM node log files

[ndbd]
  # Options for data node "A":
  HostName=198.51.100.30          # Hostname or IP address
  NodeId=2                        # Node ID for this data node
  DataDir=/usr/local/mysql/data   # Directory for this data node's data files

[ndbd]
  # Options for data node "B":
  HostName=198.51.100.40          # Hostname or IP address
  NodeId=3                        # Node ID for this data node
  DataDir=/usr/local/mysql/data   # Directory for this data node's data files

[mysqld]
  # SQL node options:
  HostName=198.51.100.20          # Hostname or IP address
  # (additional mysqld connections can be
  # specified for this node for various
  # purposes such as running ndb_restore)

---

**Note**

The world database can be downloaded from https://dev.mysql.com/doc/index-other.html.

After all the configuration files have been created and these minimal options have been specified, you are ready to proceed with starting the cluster and verifying that all processes are running. We discuss how this is done in Section 18.2.4, “Initial Startup of NDB Cluster”.

For more detailed information about the available NDB Cluster configuration parameters and their uses, see Section 18.3.3, “NDB Cluster Configuration Files”, and Section 18.3, “Configuration of NDB Cluster”. For configuration of NDB Cluster as relates to making backups, see Section 18.5.3.3, “Configuration for NDB Cluster Backups”.

**Note**

The default port for Cluster management nodes is 1186; the default port for data nodes is 2202. However, the cluster can automatically allocate ports for data nodes from those that are already free.

### 18.2.4 Initial Startup of NDB Cluster

Starting the cluster is not very difficult after it has been configured. Each cluster node process must be started separately, and on the host where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes:

1. On the management host, issue the following command from the system shell to start the management node process:

   ```
   shell> ndb_mgmd -f /var/lib/mysql-cluster/config.ini
   ```
The first time that it is started, `ndb_mgmd` must be told where to find its configuration file, using the `-f` or `--config-file` option. (See Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon", for details.)

For additional options which can be used with `ndb_mgmd`, see Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs".

2. On each of the data node hosts, run this command to start the `ndbd` process:

   ```shell
   ndbd
   ```

3. If you used RPM files to install MySQL on the cluster host where the SQL node is to reside, you can (and should) use the supplied startup script to start the MySQL server process on the SQL node.

   If all has gone well, and the cluster has been set up correctly, the cluster should now be operational. You can test this by invoking the `ndb_mgm` management node client. The output should look like that shown here, although you might see some slight differences in the output depending upon the exact version of MySQL that you are using:

   ```shell
   ndb_mgm
   -- NDB Cluster -- Management Client --
   ndb_mgm> SHOW
   Connected to Management Server at: localhost:1186
   Cluster Configuration
   ---------------------
   [ndbd(NDB)]     2 node(s)
       id=2    @198.51.100.30  (Version: 5.5.65-ndb-7.2.39, Nodegroup: 0, *)
       id=3    @198.51.100.40  (Version: 5.5.65-ndb-7.2.39, Nodegroup: 0)
   [ndb_mgmd(MGM)] 1 node(s)
       id=1    @198.51.100.10  (Version: 5.5.65-ndb-7.2.39)
   [mysqld(API)]   1 node(s)
       id=4    @198.51.100.20  (Version: 5.5.65-ndb-7.2.39)
   ```

   The SQL node is referenced here as `[mysqld(API)]`, which reflects the fact that the `mysqld` process is acting as an NDB Cluster API node.

   **Note**

   The IP address shown for a given NDB Cluster SQL or other API node in the output of `SHOW` is the address used by the SQL or API node to connect to the cluster data nodes, and not to any management node.

   You should now be ready to work with databases, tables, and data in NDB Cluster. See Section 18.2.5, "NDB Cluster Example with Tables and Data", for a brief discussion.

### 18.2.5 NDB Cluster Example with Tables and Data

**Note**

The information in this section applies to NDB Cluster running on both Unix and Windows platforms.

Working with database tables and data in NDB Cluster is not much different from doing so in standard MySQL. There are two key points to keep in mind:

- For a table to be replicated in the cluster, it must use the `NDBCLUSTER` storage engine. To specify this, use the `ENGINE=NDBCLUSTER` or `ENGINE=NDB` option when creating the table:
CREATE TABLE tbl_name (col_name column_definitions) ENGINE=NDBCLUSTER;

Alternatively, for an existing table that uses a different storage engine, use ALTER TABLE to change the table to use NDBCLUSTER:

ALTER TABLE tbl_name ENGINE=NDBCLUSTER;

• Every NDBCLUSTER table has a primary key. If no primary key is defined by the user when a table is created, the NDBCLUSTER storage engine automatically generates a hidden one. Such a key takes up space just as does any other table index. (It is not uncommon to encounter problems due to insufficient memory for accommodating these automatically created indexes.)

If you are importing tables from an existing database using the output of mysqldump, you can open the SQL script in a text editor and add the ENGINE option to any table creation statements, or replace any existing ENGINE options. Suppose that you have the world sample database on another MySQL server that does not support NDB Cluster, and you want to export the City table:

shell> mysqldump --add-drop-table world City > city_table.sql

The resulting city_table.sql file will contain this table creation statement (and the INSERT statements necessary to import the table data):

DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (  
`ID` int(11) NOT NULL auto_increment,  
`Name` char(35) NOT NULL default '',  
`CountryCode` char(3) NOT NULL default '',  
`District` char(20) NOT NULL default '',  
`Population` int(11) NOT NULL default '0',  
PRIMARY KEY  (`ID`)  
) ENGINE=MyISAM DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);  
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);  
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);  
(remaining INSERT statements omitted)

You need to make sure that MySQL uses the NDBCLUSTER storage engine for this table. There are two ways that this can be accomplished. One of these is to modify the table definition before importing it into the Cluster database. Using the City table as an example, modify the ENGINE option of the definition as follows:

DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (  
`ID` int(11) NOT NULL auto_increment,  
`Name` char(35) NOT NULL default '',  
`CountryCode` char(3) NOT NULL default '',  
`District` char(20) NOT NULL default '',  
`Population` int(11) NOT NULL default '0',  
PRIMARY KEY  (`ID`)  
) ENGINE=NDBCLUSTER DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);  
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);  
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);  
(remaining INSERT statements omitted)

This must be done for the definition of each table that is to be part of the clustered database. The easiest way to accomplish this is to do a search-and-replace on the file that contains the definitions and replace all instances of TYPE=engine_name or ENGINE=engine_name with ENGINE=NDBCLUSTER. If you do not want to modify the file, you can use the unmodified file to create the tables, and then use ALTER TABLE to change their storage engine. The particulars are given later in this section.
Assuming that you have already created a database named `world` on the SQL node of the cluster, you can then use the `mysql` command-line client to read `city_table.sql`, and create and populate the corresponding table in the usual manner:

```
shell> mysql world < city_table.sql
```

It is very important to keep in mind that the preceding command must be executed on the host where the SQL node is running (in this case, on the machine with the IP address `198.51.100.20`).

To create a copy of the entire `world` database on the SQL node, use `mysqldump` on the noncluster server to export the database to a file named `world.sql` (for example, in the `/tmp` directory). Then modify the table definitions as just described and import the file into the SQL node of the cluster like this:

```
shell> mysql world < /tmp/world.sql
```

If you save the file to a different location, adjust the preceding instructions accordingly.

Running `SELECT` queries on the SQL node is no different from running them on any other instance of a MySQL server. To run queries from the command line, you first need to log in to the MySQL Monitor in the usual way (specify the `root` password at the `Enter password:` prompt):

```
shell> mysql -u root -p
Enter password: 
Welcome to the MySQL monitor.  Commands end with ; or \g. 
Your MySQL connection id is 1 to server version: 5.5.65-ndb-7.2.39 
Type 'help;' or '\h' for help. Type '\c' to clear the buffer. 
mysql>
```

We simply use the MySQL server's `root` account and assume that you have followed the standard security precautions for installing a MySQL server, including setting a strong `root` password. For more information, see Section 2.10.4, "Securing the Initial MySQL Accounts".

It is worth taking into account that Cluster nodes do *not* make use of the MySQL privilege system when accessing one another. Setting or changing MySQL user accounts (including the `root` account) effects only applications that access the SQL node, not interaction between nodes. See Section 18.5.11.2, "NDB Cluster and MySQL Privileges", for more information.

If you did not modify the `ENGINE` clauses in the table definitions prior to importing the SQL script, you should run the following statements at this point:

```
mysql> USE world;
mysql> ALTER TABLE city ENGINE=NDBCLUSTER;
mysql> ALTER TABLE country ENGINE=NDBCLUSTER;
mysql> ALTER TABLE countrylanguage ENGINE=NDBCLUSTER;
```

Selecting a database and running a `SELECT` query against a table in that database is also accomplished in the usual manner, as is exiting the MySQL Monitor:

```
mysql> USE world;
mysql> SELECT Name, Population FROM city ORDER BY Population DESC LIMIT 5;
```

```
+-----------+------------+
| Name      | Population |
+-----------+------------+
| Bombay    |   10500000 |
| Seoul     |    9981619 |
| São Paulo |    9968485 |
| Shanghai  |    9696300 |
| Jakarta   |    9604900 |
+-----------+------------+
5 rows in set (0.34 sec)
```
Applications that use MySQL can employ standard APIs to access NDB tables. It is important to remember that your application must access the SQL node, and not the management or data nodes. This brief example shows how we might execute the `SELECT` statement just shown by using the PHP 5.0 mysqli extension running on a Web server elsewhere on the network:

```php
<?php
# connect to SQL node:
$link = new mysqli('198.51.100.20', 'root', 'root_password', 'world');
# parameters for mysqli constructor are:
#   host, user, password, database
if( mysqli_connect_errno() )
  die("Connect failed: " . mysqli_connect_error());

$query = "SELECT Name, Population
FROM City
ORDER BY Population DESC
LIMIT 5";

# if no errors...
if( $result = $link->query($query) )
{
  ?
  <table border="1" width="40%" cellspacing="1">
    <tr><th width="10%">City</th><th>Population</th></tr>
    <tbody>
    <?
    # then display the results...
    while($row = $result->fetch_object())
      printf("<tr><td align="center">%s</td><td>%d</td></tr>",
             $row->Name, $row->Population);
    ?>
  </tbody>
</table>
?
  # ...and verify the number of rows that were retrieved
  printf("<p>Affected rows: %d</p>", $link->affected_rows);
}
else
  # otherwise, tell us what went wrong
  echo mysqli_error();

# free the result set and the mysqli connection object
$result->close();
$link->close();
?>
</body>
</html>
```
We assume that the process running on the Web server can reach the IP address of the SQL node.

In a similar fashion, you can use the MySQL C API, Perl-DBI, Python-mysql, or MySQL Connectors to perform the tasks of data definition and manipulation just as you would normally with MySQL.

### 18.2.6 Safe Shutdown and Restart of NDB Cluster

To shut down the cluster, enter the following command in a shell on the machine hosting the management node:

```shell
ndb_mgm -e shutdown
```

The `-e` option here is used to pass a command to the `ndb_mgm` client from the shell. (See Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”, for more information about this option.) The command causes the `ndb_mgm`, `ndb_mgmd`, and any `ndbd` or `ndbmtd` processes to terminate gracefully. Any SQL nodes can be terminated using `mysqladmin shutdown` and other means. On Windows platforms, assuming that you have installed the SQL node as a Windows service, you can use `SC STOP service_name` or `NET STOP service_name`.

To restart the cluster on Unix platforms, run these commands:

- On the management host (198.51.100.10 in our example setup):

```shell
ndb_mgmd -f /var/lib/mysql-cluster/config.ini
```

- On each of the data node hosts (198.51.100.30 and 198.51.100.40):

```shell
ndbd
```

- Use the `ndb_mgm` client to verify that both data nodes have started successfully.

- On the SQL host (198.51.100.20):

```shell
mysqld_safe &
```

On Windows platforms, assuming that you have installed all NDB Cluster processes as Windows services using the default service names (see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”), you can restart the cluster as follows:

- On the management host (198.51.100.10 in our example setup), execute the following command:

```cmd
C:\> SC START ndb_mgmd
```

- On each of the data node hosts (198.51.100.30 and 198.51.100.40), execute the following command:

```cmd
C:\> SC START ndbd
```

- On the management node host, use the `ndb_mgm` client to verify that the management node and both data nodes have started successfully (see Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”).

- On the SQL node host (198.51.100.20), execute the following command:

```cmd
C:\> SC START mysql
```

In a production setting, it is usually not desirable to shut down the cluster completely. In many cases, even when making configuration changes, or performing upgrades to the cluster hardware or software (or both),
which require shutting down individual host machines, it is possible to do so without shutting down the
cluster as a whole by performing a rolling restart of the cluster. For more information about doing this, see
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”.

18.2.7 Upgrading and Downgrading NDB Cluster

This section provides information about NDB Cluster software and table file compatibility between different
NDB Cluster 7.2 releases with regard to performing upgrades and downgrades as well as compatibility
matrices and notes. You should already be familiar with installing and configuring NDB Cluster prior to
attempting an upgrade or downgrade. See Section 18.3, “Configuration of NDB Cluster”.

Schema operations, including SQL DDL statements, cannot be performed while any data nodes are
restarting, and thus during an online upgrade or downgrade of the cluster. For other information regarding
the rolling restart procedure used to perform an online upgrade, see Section 18.5.5, “Performing a Rolling
Restart of an NDB Cluster”.

Important

Only compatibility between MySQL versions with regard to NDBCLUSTER is taken
into account in this section, and there are likely other issues to be considered.
As with any other MySQL software upgrade or downgrade, you are strongly
couraged to review the relevant portions of the MySQL Manual for the MySQL
versions from which and to which you intend to migrate, before attempting an
upgrade or downgrade of the NDB Cluster software. This is especially true when
planning a migration from NDB Cluster 7.1 (or earlier) to NDB Cluster 7.2, since the
version of the underlying MySQL Server also changes from MySQL 5.1 to MySQL
5.5. See Section 2.11, “Upgrading MySQL”.

The table shown here provides information on NDB Cluster upgrade and downgrade compatibility among
different releases of NDB Cluster 7.2. Additional notes about upgrades and downgrades to, from, or within
the NDB Cluster 7.2 release series can be found immediately following the table.
Notes: NDB Cluster 7.2

Versions supported. The following versions of NDB Cluster are supported for upgrades to NDB Cluster 7.2 (7.2.4 and later):

- NDB Cluster 7.1 GA releases (7.1.3 and later)
- NDB Cluster 7.0 GA releases (7.0.5 and later)
- NDB Cluster 6.3 GA releases (6.3.8 and later) that can be upgraded to NDB Cluster 7.1
For information about upgrades to and downgrades from NDB Cluster 7.3, see Upgrading and Downgrading NDB Cluster. For information about upgrades and downgrades in previous NDB Cluster release series, see the MySQL 5.1 Reference Manual.

NDB API, ClusterJ, and other applications used with recent releases of NDB Cluster 6.3 and later should continue to work with NDB 7.2.4 and later without rewriting or recompiling.

In NDB Cluster 7.2, the default values for a number of node configuration parameters have changed. See Improved default values for data node configuration parameters, for a listing of these.

Other known issues include the following:

• In NDB 7.2.7 and later, the size of the hash map is 3840 LDM threads, an increase from 240 in previous versions. When upgrading an NDB Cluster from NDB 7.2.6 and earlier to NDB 7.2.9 or later, you can modify existing tables online to take advantage of the new size: following the upgrade, increase the number of fragments by (for example) adding new data nodes to the cluster, and then execute ALTER ONLINE TABLE ... REORGANIZE PARTITION on any tables that were created in the older version. Following this, these tables can use the larger hash map size. (Bug #14645319)

Due to this change, it was not possible to downgrade online to NDB 7.2.6 or earlier. This issue was resolved in NDB 7.2.11, where the size is made configurable using the DefaultHashMapSize parameter. (Bug #14800539) See the description of this parameter for more information.

• It is not possible to downgrade online to NDB 7.2.13 or earlier from NDB 7.2.14 or later. Online upgrades from NDB 7.2.13 to later NDB Cluster 7.2 releases are supported.

18.3 Configuration of NDB Cluster

A MySQL server that is part of an NDB Cluster differs in one chief respect from a normal (nonclustered) MySQL server, in that it employs the NDB storage engine. This engine is also referred to sometimes as NDBCLUSTER, although NDB is preferred.

To avoid unnecessary allocation of resources, the server is configured by default with the NDB storage engine disabled. To enable NDB, you must modify the server's my.cnf configuration file, or start the server with the --ndbcluster option.

This MySQL server is a part of the cluster, so it also must know how to access a management node to obtain the cluster configuration data. The default behavior is to look for the management node on localhost. However, should you need to specify that its location is elsewhere, this can be done in my.cnf, or with the mysql client. Before the NDB storage engine can be used, at least one management node must be operational, as well as any desired data nodes.

For more information about --ndbcluster and other mysqld options specific to NDB Cluster, see MySQL Server Options for NDB Cluster.

For information about installing NDB Cluster, see Section 18.2, “NDB Cluster Installation”.

18.3.1 Quick Test Setup of NDB Cluster

To familiarize you with the basics, we will describe the simplest possible configuration for a functional NDB Cluster. After this, you should be able to design your desired setup from the information provided in the other relevant sections of this chapter.

First, you need to create a configuration directory such as /var/lib/mysql-cluster, by executing the following command as the system root user:

```
shell> mkdir /var/lib/mysql-cluster
```
Quick Test Setup of NDB Cluster

In this directory, create a file named `config.ini` that contains the following information. Substitute appropriate values for `HostName` and `DataDir` as necessary for your system.

```ini
# file "config.ini" - showing minimal setup consisting of 1 data node, # 1 management server, and 3 MySQL servers. # The empty default sections are not required, and are shown only for # the sake of completeness. # Data nodes must provide a hostname but MySQL Servers are not required # to do so. # If you don't know the hostname for your machine, use localhost. # The DataDir parameter also has a default value, but it is recommended to # set it explicitly. # Note: [db], [api], and [mgm] are aliases for [ndbd], [mysqld], and [ndb_mgmd], # respectively. [db] is deprecated and should not be used in new installations.

[ndbd default]
NoOfReplicas= 1

[mysqld  default]
[ndb_mgmd default]
[tcp default]

[ndb_mgmd]
HostName= myhost.example.com

[ndbd]
HostName= myhost.example.com
DataDir= /var/lib/mysql-cluster

[mysqld]

You can now start the `ndb_mgmd` management server. By default, it attempts to read the `config.ini` file in its current working directory, so change location into the directory where the file is located and then invoke `ndb_mgmd`:

```
shell> cd /var/lib/mysql-cluster
shell> ndb_mgmd
```

Then start a single data node by running `ndbd`:

```
shell> ndbd
```

For command-line options which can be used when starting `ndbd`, see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

By default, `ndbd` looks for the management server at `localhost` on port 1186.

**Note**

If you have installed MySQL from a binary tarball, you will need to specify the path of the `ndb_mgmd` and `ndbd` servers explicitly. (Normally, these will be found in `/usr/local/mysql/bin`.)

Finally, change location to the MySQL data directory (usually `/var/lib/mysql` or `/usr/local/mysql/data`), and make sure that the `my.cnf` file contains the option necessary to enable the NDB storage engine:

```ini
[mysqld]
ndbcluster
```

You can now start the MySQL server as usual:
Quick Test Setup of NDB Cluster

```
shell> mysqld_safe --user=mysql &
```

Wait a moment to make sure the MySQL server is running properly. If you see the notice `mysql ended`, check the server's `.err` file to find out what went wrong.

If all has gone well so far, you now can start using the cluster. Connect to the server and verify that the `NDBCLUSTER` storage engine is enabled:

```
shell> mysql
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 1 to server version: 5.5.62
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.
mysql>
SHOW ENGINES\G
...
*************************** 12. row ***************************
Engine: NDBCLUSTER
Support: YES
Comment: Clustered, fault-tolerant, memory-based tables
*************************** 13. row ***************************
Engine: NDB
Support: YES
Comment: Alias for NDBCLUSTER
...
```

The row numbers shown in the preceding example output may be different from those shown on your system, depending upon how your server is configured.

Try to create an `NDBCLUSTER` table:

```
shell> mysql
mysql> USE test;
Database changed
mysql>
CREATE TABLE ctest (i INT) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (0.09 sec)
mysql>
SHOW CREATE TABLE ctest \G
*************************** 1. row ***************************
Table: ctest
Create Table: CREATE TABLE `ctest` (  
`i` int(11) default NULL ) ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

To check that your nodes were set up properly, start the management client:

```
shell> ndb_mgm
```

Use the `SHOW` command from within the management client to obtain a report on the cluster's status:

```
ndb_mgm> SHOW
Cluster Configuration
---------------------
[ndbd(NDB)] 1 node(s)
id=2 @127.0.0.1 (Version: 5.5.65-ndb-7.2.39, Nodegroup: 0, *)

[ndb_mgmd(MGM)] 1 node(s)
id=1 @127.0.0.1 (Version: 5.5.65-ndb-7.2.39)

[mysqld(API)] 3 node(s)
id=3 @127.0.0.1 (Version: 5.5.65-ndb-7.2.39)
id=4 (not connected, accepting connect from any host)
id=5 (not connected, accepting connect from any host)
```
At this point, you have successfully set up a working NDB Cluster. You can now store data in the cluster by using any table created with ENGINE=NDDBCLUSTER or its alias ENGINE=NDB.

18.3.2 Overview of NDB Cluster Configuration Parameters, Options, and Variables

The next several sections provide summary tables of NDB Cluster node configuration parameters used in the config.ini file to govern various aspects of node behavior, as well as of options and variables read by mysqld from a my.cnf file or from the command line when run as an NDB Cluster process. Each of the node parameter tables lists the parameters for a given type (ndbd, ndb_mgmd, mysql, computer, tcp, shm, or sci). All tables include the data type for the parameter, option, or variable, as well as its default, minimum, and maximum values as applicable.

Considerations when restarting nodes. For node parameters, these tables also indicate what type of restart is required (node restart or system restart)—and whether the restart must be done with --initial—to change the value of a given configuration parameter. When performing a node restart or an initial node restart, all of the cluster's data nodes must be restarted in turn (also referred to as a rolling restart). It is possible to update cluster configuration parameters marked as node online—that is, without shutting down the cluster—in this fashion. An initial node restart requires restarting each ndbd process with the --initial option.

A system restart requires a complete shutdown and restart of the entire cluster. An initial system restart requires taking a backup of the cluster, wiping the cluster file system after shutdown, and then restoring from the backup following the restart.

In any cluster restart, all of the cluster's management servers must be restarted for them to read the updated configuration parameter values.

Important

Values for numeric cluster parameters can generally be increased without any problems, although it is advisable to do so progressively, making such adjustments in relatively small increments. Many of these can be increased online, using a rolling restart.

However, decreasing the values of such parameters—whether this is done using a node restart, node initial restart, or even a complete system restart of the cluster—is not to be undertaken lightly; it is recommended that you do so only after careful planning and testing. This is especially true with regard to those parameters that relate to memory usage and disk space, such as MaxNoOfTables, MaxNoOfOrderedIndexes, and MaxNoOfUniqueHashIndexes. In addition, it is generally the case that configuration parameters relating to memory and disk usage can be raised using a simple node restart, but they require an initial node restart to be lowered.

Because some of these parameters can be used for configuring more than one type of cluster node, they may appear in more than one of the tables.

Note

4294967039 often appears as a maximum value in these tables. This value is defined in the NDDBCLUSTER sources as MAX_INT_RNIL and is equal to 0xFFFFFEFF, or \(2^{32} - 2^8 - 1\).

18.3.2.1 NDB Cluster Data Node Configuration Parameters
Overview of NDB Cluster Configuration Parameters, Options, and Variables

The listings in this section provide information about parameters used in the [ndbd] or [ndbd default] sections of a config.ini file for configuring NDB Cluster data nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.

These parameters also apply to ndbmtd, the multithreaded version of ndbd. For more information, see Section 18.4.3, “ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)”.

- **Arbitration**: How arbitration should be performed to avoid split-brain issues in event of node failure.
- **ArbitrationTimeout**: Maximum time (milliseconds) database partition waits for arbitration signal.
- **BackupDataBufferSize**: Default size of databuffer for a backup (in bytes).
- **BackupDataDir**: Path to where to store backups. Note that string '/BACKUP' is always appended to this setting, so that “effective” default is FileSystemPath/BACKUP.
- **BackupLogBufferSize**: Default size of log buffer for a backup (in bytes).
- **BackupMaxWriteSize**: Maximum size of file system writes made by backup (in bytes).
- **BackupMemory**: Total memory allocated for backups per node (in bytes).
- **BackupReportFrequency**: Frequency of backup status reports during backup in seconds.
- **BackupWriteSize**: Default size of file system writes made by backup (in bytes).
- **BatchSizePerLocalScan**: Used to calculate number of lock records for scan with hold lock.
- **BuildIndexThreads**: Number of threads to use for building ordered indexes during a system or node restart. Also applies when running ndb_restore --rebuild-indexes. Setting this parameter to 0 disables multithreaded building of ordered indexes.
- **CompressedBackup**: Use zlib to compress backups as they are written.
- **CompressedLCP**: Write compressed LCPs using zlib.
- **ConnectCheckIntervalDelay**: Time between data node connectivity check stages. Data node is considered suspect after 1 interval and dead after 2 intervals with no response.
- **CrashOnCorruptedTuple**: When enabled, forces node to shut down whenever it detects a corrupted tuple.
- **DataDir**: Data directory for this node.
- **DataMemory**: Number of bytes on each data node allocated for storing data; subject to available system RAM and size of IndexMemory.
- **DefaultHashMapSize**: Set size (in buckets) to use for table hash maps. Three values are supported: 0, 240, and 3840. Intended primarily for upgrades and downgrades within NDB 7.2.
- **DictTrace**: Enable DBDICT debugging; for NDB development.
- **DiskCheckpointSpeed**: Bytes allowed to be written by checkpoint, per second.
- **DiskCheckpointSpeedInRestart**: Bytes allowed to be written by checkpoint during restart, per second.
- **DiskIOThreadPool**: Number of unbound threads for file access, applies to disk data only.
- **Diskless**: Run without using disk.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **DiskPageBufferEntries**: Number of 32 KB page entries to allocate in DiskPageBufferMemory. Very large disk transactions may require increasing this value.

- **DiskPageBufferMemory**: Number of bytes on each data node allocated for disk page buffer cache.

- **DiskSyncSize**: Amount of data written to file before a synch is forced.

- **EventLogBufferSize**: Size of circular buffer for NDB log events within data nodes.

- **ExecuteOnComputer**: String referencing an earlier defined COMPUTER.

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB.

- **FileSystemPath**: Path to directory where data node stores its data (directory must exist).

- **FileSystemPathDataFiles**: Path to directory where data node stores its Disk Data files. The default value is FilesystemPathDD, if set; otherwise, FilesystemPath is used if it is set; otherwise, value of DataDir is used.

- **FileSystemPathDD**: Path to directory where data node stores its Disk Data and undo files. Default value is FileSystemPath, if set; otherwise, value of DataDir is used.

- **FileSystemPathUndoFiles**: Path to directory where data node stores its undo files for Disk Data. Default value is FilesystemPathDD, if set; otherwise, FilesystemPath is used if it is set; otherwise, value of DataDir is used.

- **FragmentLogFileSize**: Size of each redo log file.

- **HeartbeatIntervalDbApi**: Time between API node-data node heartbeats. (API connection closed after 3 missed heartbeats).

- **HeartbeatIntervalDbDb**: Time between data node-to-data node heartbeats; data node considered dead after 3 missed heartbeats.

- **HeartbeatOrder**: Sets order in which data nodes check each others' heartbeats for determining whether given node is still active and connected to cluster. Must be zero for all data nodes or distinct nonzero values for all data nodes; see documentation for further guidance.

- **HostName**: Host name or IP address for this data node.

- **Id**: Number identifying data node. Now deprecated; use NodeId instead.

- **IndexMemory**: Number of bytes on each data node allocated for storing indexes; subject to available system RAM and size of DataMemory.

- **IndexStatAutoCreate**: Enable/disable automatic statistics collection when indexes are created.

- **IndexStatAutoUpdate**: Monitor indexes for changes and trigger automatic statistics updates.

- **IndexStatSaveScale**: Scaling factor used in determining size of stored index statistics.

- **IndexStatSaveSize**: Maximum size in bytes for saved statistics per index.

- **IndexStatTriggerPct**: Threshold percent change in DML operations for index statistics updates. Value is scaled down by IndexStatTriggerScale.

- **IndexStatTriggerScale**: Scale down IndexStatTriggerPct by this amount, multiplied by base 2 logarithm of index size, for a large index. Set to 0 to disable scaling.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **IndexStatUpdateDelay**: Minimum delay between automatic index statistics updates for a given index. 0 means no delay.
- **InitFragmentLogFiles**: Initialize fragment logfiles (sparse/full).
- **InitialLogFileGroup**: Describes a log file group that is created during an initial start. See documentation for format.
- **InitialNoOfOpenFiles**: Initial number of files open per data node. (One thread is created per file).
- **InitialTablespace**: Describes a tablespace that is created during an initial start. See documentation for format.
- **LateAlloc**: Allocate memory after connection to management server has been established.
- **LcpScanProgressTimeout**: Maximum time that local checkpoint fragment scan can be stalled before node is shut down to ensure systemwide LCP progress. Use 0 to disable.
- **LockExecuteThreadToCPU**: A comma-delimited list of CPU IDs.
- **LockMaintThreadsToCPU**: CPU ID indicating which CPU runs maintenance threads.
- **LockPagesInMainMemory**: 0=disable locking, 1=lock after memory allocation, 2=lock before memory allocation.
- **LogLevelCheckpoint**: Log level of local and global checkpoint information printed to stdout.
- **LogLevelCongestion**: Level of congestion information printed to stdout.
- **LogLevelConnection**: Level of node connect/disconnect information printed to stdout.
- **LogLevelError**: Transporter, heartbeat errors printed to stdout.
- **LogLevelInfo**: Heartbeat and log information printed to stdout.
- **LogLevelNodeRestart**: Level of node restart and node failure information printed to stdout.
- **LogLevelShutdown**: Level of node shutdown information printed to stdout.
- **LogLevelStartup**: Level of node startup information printed to stdout.
- **LogLevelStatistic**: Level of transaction, operation, and transporter information printed to stdout.
- **LongMessageBuffer**: Number of bytes allocated on each data node for internal long messages.
- **MaxAllocate**: Maximum size of allocation to use when allocating memory for tables.
- **MaxBufferedEpochs**: Allowed number of epochs that a subscribing node can lag behind (unprocessed epochs). Exceeding will cause lagging subscribers to be disconnected.
- **MaxBufferedEpochBytes**: Total number of bytes allocated for buffering epochs.
- **MaxDMLOperationsPerTransaction**: Limit size of a transaction; aborts transaction if it requires more than this many DML operations. Set to 0 to disable.
- **MaxLCPStartDelay**: Time in seconds that LCP polls for checkpoint mutex (to allow other data nodes to complete metadata synchronization), before putting itself in lock queue for parallel recovery of table data.
- **MaxNoOfAttributes**: Suggests a total number of attributes stored in database (sum over all tables).
- **MaxNoOfConcurrentIndexOperations**: Total number of index operations that can execute simultaneously on one data node.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **MaxNoOfConcurrentOperations**: Maximum number of operation records in transaction coordinator.
- **MaxNoOfConcurrentScans**: Maximum number of scans executing concurrently on data node.
- **MaxNoOfConcurrentSubOperations**: Maximum number of concurrent subscriber operations.
- **MaxNoOfConcurrentTransactions**: Maximum number of transactions executing concurrently on this data node, total number of transactions that can be executed concurrently is this value times number of data nodes in cluster.
- **MaxNoOfFiredTriggers**: Total number of triggers that can fire simultaneously on one data node.
- **MaxNoOfLocalOperations**: Maximum number of operation records defined on this data node.
- **MaxNoOfLocalScans**: Maximum number of fragment scans in parallel on this data node.
- **MaxNoOfOpenFiles**: Maximum number of files open per data node. (One thread is created per file).
- **MaxNoOfOrderedIndexes**: Total number of ordered indexes that can be defined in system.
- **MaxNoOfSavedMessages**: Maximum number of error messages to write in error log and maximum number of trace files to retain.
- **MaxNoOfSubscribers**: Maximum number of subscribers (default 0 = MaxNoOfTables * 2).
- **MaxNoOfSubscriptions**: Maximum number of subscriptions (default 0 = MaxNoOfTables).
- **MaxNoOfTables**: Suggests a total number of NDB tables stored in database.
- **MaxNoOfTriggers**: Total number of triggers that can be defined in system.
- **MaxNoOfUniqueHashIndexes**: Total number of unique hash indexes that can be defined in the system.
- **MaxParallelScansPerFragment**: Maximum number of parallel scans per fragment. Once this limit is reached, scans are serialized.
- **MaxStartFailRetries**: Maximum retries when data node fails on startup, requires StopOnError = 0. Setting to 0 causes start attempts to continue indefinitely.
- **MemReportFrequency**: Frequency of memory reports in seconds; 0 = report only when exceeding percentage limits.
- **MinFreePct**: Percentage of memory resources to keep in reserve for restarts.
- **NodeGroup**: Node group to which data node belongs; used only during initial start of cluster.
- **NodeId**: Number uniquely identifying data node among all nodes in cluster.
- **NoOfFragmentLogFiles**: Number of 16 MB redo log files in each of 4 file sets belonging to data node.
- **NoOfReplicas**: Number of copies of all data in database.
- **Numa**: (Linux only; requires libnuma) Controls NUMA support. Setting to 0 permits system to determine use of interleaving by data node process; 1 means that it is determined by data node.
- **ODirect**: Use O_DIRECT file reads and writes when possible.
- **RealtimeScheduler**: When true, data node threads are scheduled as real-time threads. Default is false.
- **RedoBuffer**: Number of bytes on each data node allocated for writing redo logs.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **RedoOverCommitCounter**: When RedoOverCommitLimit has been exceeded this many times, transactions are aborted, and operations are handled as specified by DefaultOperationRedoProblemAction.
- **RedoOverCommitLimit**: Each time that flushing current redo buffer takes longer than this many seconds, number of times that this has happened is compared to RedoOverCommitCounter.
- **ReservedSendBufferMemory**: This parameter is present in NDB code but is not enabled, and is now deprecated.
- **RestartOnErrorInsert**: Control type of restart caused by inserting an error (when StopOnError is enabled).
- **SchedulerExecutionTimer**: Number of microseconds to execute in scheduler before sending.
- **SchedulerSpinTimer**: Number of microseconds to execute in scheduler before sleeping.
- **ServerPort**: Port used to set up transporter for incoming connections from API nodes.
- **SharedGlobalMemory**: Total number of bytes on each data node allocated for any use.
- **StartFailRetryDelay**: Delay in seconds after start failure prior to retry; requires StopOnError = 0.
- **StartFailureTimeout**: Milliseconds to wait before terminating. (0=Wait forever).
- **StartNoNodeGroupTimeout**: Time to wait for nodes without a nodegroup before trying to start (0=forever).
- **StartPartialTimeout**: Milliseconds to wait before trying to start without all nodes. (0=Wait forever).
- **StartPartitionedTimeout**: Milliseconds to wait before trying to start partitioned. (0=Wait forever).
- **StartupStatusReportFrequency**: Frequency of status reports during startup.
- **StopOnError**: When set to 0, data node automatically restarts and recovers following node failures.
- **StringMemory**: Default size of string memory (0 to 100 = % of maximum, 101+ = actual bytes).
- **TcpBind_INADDR_ANY**: Bind IP_ADDR_ANY so that connections can be made from anywhere (for autogenerated connections).
- **TimeBetweenEpochs**: Time between epochs (synchronization used for replication).
- **TimeBetweenEpochsTimeout**: Timeout for time between epochs. Exceeding will cause node shutdown.
- **TimeBetweenGlobalCheckpoints**: Time between group commits of transactions to disk.
- **TimeBetweenGlobalCheckpointsTimeout**: Minimum timeout for group commit of transactions to disk.
- **TimeBetweenInactiveTransactionAbortCheck**: Time between checks for inactive transactions.
- **TimeBetweenLocalCheckpoints**: Time between taking snapshots of database (expressed in base-2 logarithm of bytes).
- **TimeBetweenWatchDogCheck**: Time between execution checks inside a data node.
- **TimeBetweenWatchDogCheckInitial**: Time between execution checks inside a data node (early start phases when memory is allocated).
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **TotalSendBufferMemory**: Total memory to use for all transporter send buffers.

- **TransactionBufferMemory**: Dynamic buffer space (in bytes) for key and attribute data allocated for each data node.

- **TransactionDeadlockDetectionTimeout**: Time transaction can spend executing within a data node. This is time that transaction coordinator waits for each data node participating in transaction to execute a request. If data node takes more than this amount of time, transaction is aborted.

- **TransactionInactiveTimeout**: Milliseconds that application waits before executing another part of transaction. This is time transaction coordinator waits for application to execute or send another part (query, statement) of transaction. If application takes too much time, then transaction is aborted. Timeout = 0 means that application never times out.

- **TwoPassInitialNodeRestartCopy**: Copy data in 2 passes during initial node restart, which enables multithreaded building of ordered indexes for such restarts.

- **UndoDataBuffer**: Number of bytes on each data node allocated for writing data undo logs.

- **UndoIndexBuffer**: Number of bytes on each data node allocated for writing index undo logs.

The following parameters are specific to `ndbmtd`:

- **MaxNoOfExecutionThreads**: For ndbmtd only, specify maximum number of execution threads.

- **NoOfFragmentLogParts**: Number of redo log file groups belonging to this data node; value must be an even multiple of 4.

- **ThreadConfig**: Used for configuration of multithreaded data nodes (ndbmtd). Default is an empty string; see documentation for syntax and other information.

### 18.3.2.2 NDB Cluster Management Node Configuration Parameters

The listing in this section provides information about parameters used in the `[ndb_mgmd]` or `[mgm]` section of a `config.ini` file for configuring NDB Cluster management nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.5, “Defining an NDB Cluster Management Server”.

- **ArbitrationDelay**: When asked to arbitrate, arbitrator waits this long before voting (milliseconds).

- **ArbitrationRank**: If 0, then management node is not arbitrator. Kernel selects arbitrators in order 1, 2.

- **DataDir**: Data directory for this node.

- **ExecuteOnComputer**: String referencing an earlier defined COMPUTER.

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB.

- **HeartbeatIntervalMgmdMgmd**: Time between management-node-to-management-node heartbeats; connection between management nodes is considered lost after 3 missed heartbeats.

- **HeartbeatThreadPriority**: Set heartbeat thread policy and priority for management nodes; see manual for allowed values.

- **HostName**: Host name or IP address for this management node.

- **Id**: Number identifying management node. Now deprecated; use NodeId instead.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **LogDestination**: Where to send log messages: console, system log, or specified log file.
- **MaxNoOfSavedEvents**: Not used.
- **NodeId**: Number uniquely identifying management node among all nodes in cluster.
- **PortNumber**: Port number to send commands to and fetch configuration from management server.
- **PortNumberStats**: Port number used to get statistical information from a management server.
- **TotalSendBufferMemory**: Total memory to use for all transporter send buffers.
- **wan**: Use WAN TCP setting as default.

**Note**

After making changes in a management node’s configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect. See Section 18.3.3.5, “Defining an NDB Cluster Management Server”, for more information.

To add new management servers to a running NDB Cluster, it is also necessary to perform a rolling restart of all cluster nodes after modifying any existing `config.ini` files. For more information about issues arising when using multiple management nodes, see Section 18.1.7.10, “Limitations Relating to Multiple NDB Cluster Nodes”.

### 18.3.2.3 NDB Cluster SQL Node and API Node Configuration Parameters

The listing in this section provides information about parameters used in the `[mysqld]` and `[api]` sections of a `config.ini` file for configuring NDB Cluster SQL nodes and API nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”.

- **ArbitrationDelay**: When asked to arbitrate, arbitrator waits this many milliseconds before voting.
- **ArbitrationRank**: If 0, then API node is not arbitrator. Kernel selects arbitrators in order 1, 2.
- **AutoReconnect**: Specifies whether an API node should reconnect fully when disconnected from cluster.
- **BatchByteSize**: Default batch size in bytes.
- **BatchSize**: Default batch size in number of records.
- **ConnectBackoffMaxTime**: Specifies longest time in milliseconds (~100ms resolution) to allow between connection attempts to any given data node by this API node. Excludes time elapsed while connection attempts are ongoing, which in worst case can take several seconds. Disable by setting to 0. If no data nodes are currently connected to this API node, StartConnectBackoffMaxTime is used instead.
- **ConnectionMap**: Specifies which data nodes to connect.
- **DefaultHashMapSize**: Set size (in buckets) to use for table hash maps. Three values are supported: 0, 240, and 3840. Intended primarily for upgrades and downgrades within NDB 7.2.
- **DefaultOperationRedoProblemAction**: How operations are handled in event that RedoOverCommitCounter is exceeded.
- **ExecuteOnComputer**: String referencing an earlier defined COMPUTER.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **ExtraSendBufferMemory**: Memory to use for send buffers in addition to any allocated by TotalSendBufferMemory or SendBufferMemory. Default (0) allows up to 16MB.
- **HeartbeatThreadPriority**: Set heartbeat thread policy and priority for API nodes; see manual for allowed values.
- **HostName**: Host name or IP address for this SQL or API node.
- **Id**: Number identifying MySQL server or API node (Id). Now deprecated; use NodeId instead.
- **MaxScanBatchSize**: Maximum collective batch size for one scan.
- **NodeId**: Number uniquely identifying SQL node or API node among all nodes in cluster.
- **StartConnectBackoffMaxTime**: Same as ConnectBackoffMaxTime except that this parameter is used in its place if no data nodes are connected to this API node.
- **TotalSendBufferMemory**: Total memory to use for all transporter send buffers.
- **wan**: Use WAN TCP setting as default.

For a discussion of MySQL server options for NDB Cluster, see MySQL Server Options for NDB Cluster. For information about MySQL server system variables relating to NDB Cluster, see NDB Cluster System Variables.

**Note**

To add new SQL or API nodes to the configuration of a running NDB Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new [mysqld] or [api] sections to the config.ini file (or files, if you are using more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

It is *not* necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

### 18.3.2.4 Other NDB Cluster Configuration Parameters

The listings in this section provide information about parameters used in the [computer], [tcp], [shm], and [sci] sections of a config.ini file for configuring NDB Cluster. For detailed descriptions and additional information about individual parameters, see Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”, or Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”, as appropriate.

The following parameters apply to the config.ini file's [computer] section:

- **HostName**: Host name or IP address of this computer.
- **Id**: A unique identifier for this computer.

The following parameters apply to the config.ini file's [tcp] section:

- **Checksum**: If checksum is enabled, all signals between nodes are checked for errors.
- **Group**: Used for group proximity; smaller value is interpreted as being closer.
- **NodeId1**: ID of node (data node, API node, or management node) on one side of connection.
- **NodeId2**: ID of node (data node, API node, or management node) on one side of connection.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **NodeIdServer:** Set server side of TCP connection.
- **OverloadLimit:** When more than this many unsent bytes are in send buffer, connection is considered overloaded.
- **PortNumber:** Port used for this TCP transporter (DEPRECATED).
- **Proxy:**
- **ReceiveBufferMemory:** Bytes of buffer for signals received by this node.
- **SendBufferMemory:** Bytes of TCP buffer for signals sent from this node.
- **SendSignalId:** Sends ID in each signal. Used in trace files. Defaults to true in debug builds.
- **TCP_MAXSEG_SIZE:** Value used for TCP_MAXSEG.
- **TCP_RCV_BUF_SIZE:** Value used for SO_RCVBUF.
- **TCP_SND_BUF_SIZE:** Value used for SO_SNDBUF.
- **TcpBind_INADDR_ANY:** Bind InAddrAny instead of host name for server part of connection.

The following parameters apply to the `config.ini` file's `[shm]` section:

- **Checksum:** If checksum is enabled, all signals between nodes are checked for errors.
- **Group:** Used for group proximity; smaller value is interpreted as being closer.
- **NodeId1:** ID of node (data node, API node, or management node) on one side of connection.
- **NodeId2:** ID of node (data node, API node, or management node) on one side of connection.
- **NodeIdServer:** Set server side of SHM connection.
- **OverloadLimit:** When more than this many unsent bytes are in send buffer, connection is considered overloaded.
- **PortNumber:** Port used for this SHM transporter (DEPRECATED).
- **SendSignalId:** Sends ID in each signal. Used in trace files.
- **ShmKey:** A shared memory key; when set to 1, this is calculated by NDB.
- **ShmSize:** Size of shared memory segment.
- **Signum:** Signal number to be used for signalling.

The following parameters apply to the `config.ini` file's `[sci]` section:

- **Checksum:** If checksum is enabled, all signals between nodes are checked for errors.
- **Group:**
- **Host1SciId0:** SCI-node ID for adapter 0 on Host1 (a computer can have two adapters).
- **Host1SciId1:** SCI-node ID for adapter 1 on Host1 (a computer can have two adapters).
- **Host2SciId0:** SCI-node ID for adapter 0 on Host2 (a computer can have two adapters).
- **Host2SciId1:** SCI-node ID for adapter 1 on Host2 (a computer can have two adapters).
- **NodeId1:** ID of node (data node, API node, or management node) on one side of connection.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **NodeId2**: ID of node (data node, API node, or management node) on one side of connection.
- **NodeIdServer**: Set server side of SCI connection.
- **OverloadLimit**: When more than this many unsent bytes are in send buffer, connection is considered overloaded.
- **PortNumber**: Port used for this SCI transporter (DEPRECATED).
- **SendLimit**: Transporter send buffer contents are sent when this number of bytes is buffered.
- **SendSignalId**: Sends ID in each signal. Used in trace files.
- **SharedBufferSize**: Size of shared memory segment.

### 18.3.2.5 NDB Cluster `mysqld` Option and Variable Reference

The following table provides a list of the command-line options, server and status variables applicable within `mysqld` when it is running as an SQL node in an NDB Cluster. For a table showing all command-line options, server and status variables available for use with `mysqld`, see Section 5.1.3, “Server Option, System Variable, and Status Variable Reference”.

- **Com_show_ndb_status**: Count of SHOW NDB STATUS statements.
- **Handler_discover**: Number of times that tables have been discovered.
- **have_ndbcluster**: Whether mysqld supports NDB Cluster tables (set by --ndbcluster option).
- **ndb-batch-size**: Size (in bytes) to use for NDB transaction batches.
- **ndb-blob-read-batch-bytes**: Specifies size in bytes that large BLOB reads should be batched into. 0 = no limit.
- **ndb-blob-write-batch-bytes**: Specifies size in bytes that large BLOB writes should be batched into. 0 = no limit.
- **ndb-cluster-connection-pool**: Number of connections to the cluster used by MySQL.
- **ndb-connectstring**: Point to the management server that distributes the cluster configuration.
- **ndb-deferred-constraints**: Specifies that constraint checks on unique indexes (where these are supported) should be deferred until commit time. Not normally needed or used; for testing purposes only.
- **ndb-distribution**: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).
- **ndb-log-apply-status**: Cause a MySQL server acting as a slave to log mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID. Effective only if the server is started with the --ndbcluster option.
- **ndb-log-empty-epochs**: When enabled, causes epochs in which there were no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled.
- **ndb-log-empty-update**: When enabled, causes updates that produced no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled.
- **ndb-log-orig**: Log originating server id and epoch in mysql.ndb_binlog_index table.
- **ndb-log-transaction-id**: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **ndb-log-update-as-write**: Toggles logging of updates on the master between updates (OFF) and writes (ON).

- **ndb-mgmd-host**: Set the host (and port, if desired) for connecting to management server.

- **ndb-nodeid**: NDB Cluster node ID for this MySQL server.

- **ndb-transid-mysql-connection-map**: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name.

- **ndb-wait-connected**: Time (in seconds) for the MySQL server to wait for connection to cluster management and data nodes before accepting MySQL client connections.

- **ndb-wait-setup**: Time (in seconds) for the MySQL server to wait for NDB engine setup to complete.

- **Ndb_api_bytes_received_count**: Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).

- **Ndb_api_bytes_received_count_session**: Amount of data (in bytes) received from the data nodes in this client session.

- **Ndb_api_bytes_received_count_slave**: Amount of data (in bytes) received from the data nodes by this slave.

- **Ndb_api_bytes_sent_count**: Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).

- **Ndb_api_bytes_sent_count_session**: Amount of data (in bytes) sent to the data nodes in this client session.

- **Ndb_api_bytes_sent_count_slave**: Amount of data (in bytes) sent to the data nodes by this slave.

- **Ndb_api_event_bytes_count**: Number of bytes of events received by this MySQL Server (SQL node).

- **Ndb_api_event_bytes_count_injector**: Number of bytes of events received by the NDB binary log injector thread.

- **Ndb_api_event_data_count**: Number of row change events received by this MySQL Server (SQL node).

- **Ndb_api_event_data_count_injector**: Number of row change events received by the NDB binary log injector thread.

- **Ndb_api_event_nondata_count**: Number of events received, other than row change events, by this MySQL Server (SQL node).

- **Ndb_api_event_nondata_count_injector**: Number of events received, other than row change events, by the NDB binary log injector thread.

- **Ndb_api_pk_op_count**: Number of operations based on or using primary keys by this MySQL Server (SQL node).

- **Ndb_api_pk_op_count_session**: Number of operations based on or using primary keys in this client session.

- **Ndb_api_pk_op_count_slave**: Number of operations based on or using primary keys by this slave.

- **Ndb_api_pruned_scan_count**: Number of scans that have been pruned to a single partition by this MySQL Server (SQL node).
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **Ndb_api_pruned_scan_count_session**: Number of scans that have been pruned to a single partition in this client session.

- **Ndb_api_pruned_scan_count_slave**: Number of scans that have been pruned to a single partition by this slave.

- **Ndb_api_range_scan_count**: Number of range scans that have been started by this MySQL Server (SQL node).

- **Ndb_api_range_scan_count_session**: Number of range scans that have been started in this client session.

- **Ndb_api_range_scan_count_slave**: Number of range scans that have been started by this slave.

- **Ndb_api_read_row_count**: Total number of rows that have been read by this MySQL Server (SQL node).

- **Ndb_api_read_row_count_session**: Total number of rows that have been read in this client session.

- **Ndb_api_read_row_count_slave**: Total number of rows that have been read by this slave.

- **Ndb_api_scan_batch_count**: Number of batches of rows received by this MySQL Server (SQL node).

- **Ndb_api_scan_batch_count_session**: Number of batches of rows received in this client session.

- **Ndb_api_scan_batch_count_slave**: Number of batches of rows received by this slave.

- **Ndb_api_table_scan_count**: Number of table scans that have been started, including scans of internal tables, by this MySQL Server (SQL node).

- **Ndb_api_table_scan_count_session**: Number of table scans that have been started, including scans of internal tables, in this client session.

- **Ndb_api_table_scan_count_slave**: Number of table scans that have been started, including scans of internal tables, by this slave.

- **Ndb_api_trans_abort_count**: Number of transactions aborted by this MySQL Server (SQL node).

- **Ndb_api_trans_abort_count_session**: Number of transactions aborted in this client session.

- **Ndb_api_trans_abort_count_slave**: Number of transactions aborted by this slave.

- **Ndb_api_trans_close_count**: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this MySQL Server (SQL node).

- **Ndb_api_trans_close_count_session**: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) in this client session.

- **Ndb_api_trans_close_count_slave**: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this slave.

- **Ndb_api_trans_commit_count**: Number of transactions committed by this MySQL Server (SQL node).

- **Ndb_api_trans_commit_count_session**: Number of transactions committed in this client session.

- **Ndb_api_trans_commit_count_slave**: Number of transactions committed by this slave.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **Ndb_api_trans_local_read_row_count**: Total number of rows that have been read by this MySQL Server (SQL node).

- **Ndb_api_trans_local_read_row_count_session**: Total number of rows that have been read in this client session.

- **Ndb_api_trans_local_read_row_count_slave**: Total number of rows that have been read by this slave.

- **Ndb_api_trans_start_count**: Number of transactions started by this MySQL Server (SQL node).

- **Ndb_api_trans_start_count_session**: Number of transactions started in this client session.

- **Ndb_api_trans_start_count_slave**: Number of transactions started by this slave.

- **Ndb_api_uk_op_count**: Number of operations based on or using unique keys by this MySQL Server (SQL node).

- **Ndb_api_uk_op_count_session**: Number of operations based on or using unique keys in this client session.

- **Ndb_api_uk_op_count_slave**: Number of operations based on or using unique keys by this slave.

- **Ndb_api_wait_exec_complete_count**: Number of times thread has been blocked while waiting for execution of an operation to complete by this MySQL Server (SQL node).

- **Ndb_api_wait_exec_complete_count_session**: Number of times thread has been blocked while waiting for execution of an operation to complete in this client session.

- **Ndb_api_wait_exec_complete_count_slave**: Number of times thread has been blocked while waiting for execution of an operation to complete by this slave.

- **Ndb_api_wait_meta_request_count**: Number of times thread has been blocked waiting for a metadata-based signal by this MySQL Server (SQL node).

- **Ndb_api_wait_meta_request_count_session**: Number of times thread has been blocked waiting for a metadata-based signal in this client session.

- **Ndb_api_wait_meta_request_count_slave**: Number of times thread has been blocked waiting for a metadata-based signal by this slave.

- **Ndb_api_wait_nanos_count**: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this MySQL Server (SQL node).

- **Ndb_api_wait_nanos_count_session**: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes in this client session.

- **Ndb_api_wait_nanos_count_slave**: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this slave.

- **Ndb_api_wait_scan_result_count**: Number of times thread has been blocked while waiting for a scan-based signal by this MySQL Server (SQL node).

- **Ndb_api_wait_scan_result_count_session**: Number of times thread has been blocked while waiting for a scan-based signal in this client session.

- **Ndb_api_wait_scan_result_count_slave**: Number of times thread has been blocked while waiting for a scan-based signal by this slave.

- **ndb_autoincrement_prefetch_sz**: NDB auto-increment prefetch size.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **ndb_cache_check_time**: Number of milliseconds between checks of cluster SQL nodes made by the MySQL query cache.

- **Ndb_cluster_node_id**: If the server is acting as an NDB Cluster node, then the value of this variable its node ID in the cluster.

- **Ndb_config_from_host**: The host name or IP address of the Cluster management server. Formerly Ndb_connected_host.

- **Ndb_config_from_port**: The port for connecting to Cluster management server. Formerly Ndb_connected_port.

- **Ndb_conflict_fn_epoch**: Number of rows that have been found in conflict by the NDB$EPOCH() conflict detection function.

- **Ndb_conflict_fn_epoch_trans**: Number of rows that have been found in conflict by the NDB$EPOCH_TRANS() conflict detection function.

- **Ndb_conflict_fn_max**: If the server is part of an NDB Cluster involved in cluster replication, the value of this variable indicates the number of times that conflict resolution based on “greater timestamp wins” has been applied.

- **Ndb_conflict_fn_old**: If the server is part of an NDB Cluster involved in cluster replication, the value of this variable indicates the number of times that “same timestamp wins” conflict resolution has been applied.

- **Ndb_conflict_trans_conflict_commit_count**: Number of epoch transactions committed after requiring transactional conflict handling.

- **Ndb_conflict_trans_detect_iter_count**: Number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to Ndb_conflict_trans_conflict_commit_count.

- **Ndb_conflict_trans_reject_count**: Number of transactions rejected after being found in conflict by a transactional conflict function.

- **Ndb_conflict_trans_row_reject_count**: Total number of rows realigned after being found in conflict by a transactional conflict function. Includes Ndb_conflict_trans_row_conflict_count and any rows included in or dependent on conflicting transactions.

- **ndb_deferred_constraints**: Specifies that constraint checks should be deferred (where these are supported). Not normally needed or used; for testing purposes only.

- **ndb_distribution**: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).

- **ndb_eventbuffer_max_alloc**: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit).

- **Ndb_execute_count**: Provides the number of round trips to the NDB kernel made by operations.

- **ndb_extra_logging**: Controls logging of NDB Cluster schema, connection, and data distribution events in the MySQL error log.

- **ndb_force_send**: Forces sending of buffers to NDB immediately, without waiting for other threads.

- **ndb_index_stat_cache_entries**: Sets the granularity of the statistics by determining the number of starting and ending keys.

- **ndb_index_stat_enable**: Use NDB index statistics in query optimization.
Overview of NDB Cluster Configuration Parameters, Options, and Variables

- **ndb_index_stat_option**: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces.

- **ndb_index_stat_update_freq**: How often to query data nodes instead of the statistics cache.

- **ndb_join_pushdown**: Enables pushing down of joins to data nodes.

- **ndb_log_apply_status**: Whether or not a MySQL server acting as a slave logs mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID.

- **ndb_log_bin**: Write updates to NDB tables in the binary log. Effective only if binary logging is enabled with --log-bin.

- **ndb_log_binlog_index**: Insert mapping between epochs and binary log positions into the ndb_binlog_index table. Defaults to ON. Effective only if binary logging is enabled on the server.

- **ndb_log_empty_epochs**: When enabled, epochs in which there were no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.

- **ndb_log_empty_update**: When enabled, updates which produce no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.

- **ndb_log_orig**: Whether the id and epoch of the originating server are recorded in the mysql.ndb_binlog_index table. Set using the --ndb-log-orig option when starting mysqld.

- **ndb_log_transaction_id**: Whether NDB transaction IDs are written into the binary log (Read-only.).

- **ndb-log-updated-only**: Log complete rows (ON) or updates only (OFF).

- **Ndb_number_of_data_nodes**: If the server is part of an NDB Cluster, the value of this variable is the number of data nodes in the cluster.

- **ndb-optimization-delay**: Sets the number of milliseconds to wait between processing sets of rows by OPTIMIZE TABLE on NDB tables.

- **ndb_optimized_node_selection**: Determines how an SQL node chooses a cluster data node to use as transaction coordinator.

- **Ndb_pruned_scan_count**: Number of scans executed by NDB since the cluster was last started where partition pruning could be used.

- **Ndb_pushed_queries_defined**: Number of joins that API nodes have attempted to push down to the data nodes.

- **Ndb_pushed_queries_dropped**: Number of joins that API nodes have tried to push down, but failed.

- **Ndb_pushed_queries_executed**: Number of joins successfully pushed down and executed on the data nodes.

- **Ndb_pushed_reads**: Number of reads executed on the data nodes by pushed-down joins.

- **ndb_report_thresh_binlog_epoch_slip**: NDB 7.5.4 and later: Threshold for number of epochs completely buffered, but not yet consumed by binlog injector thread which when exceeded generates BUFFERED_EPOCHS_OVER_THRESHOLD event buffer status message; prior to NDB 7.5.4: Threshold for number of epochs to lag behind before reporting binary log status.

- **ndb_report_thresh_binlog_mem_usage**: This is a threshold on the percentage of free memory remaining before reporting binary log status.
NDB Cluster Configuration Files

- **Ndb_scan_count**: The total number of scans executed by NDB since the cluster was last started.
- **ndb_table_no_logging**: NDB tables created when this setting is enabled are not checkpointed to disk (although table schema files are created). The setting in effect when the table is created with or altered to use NDBCLUSTER persists for the lifetime of the table.
- **ndb_table_temporary**: NDB tables are not persistent on disk: no schema files are created and the tables are not logged.
- **ndb_use_copying_alter_table**: Use copying ALTER TABLE operations in NDB Cluster.
- **ndb_use_exact_count**: Use exact row count when planning queries.
- **ndb_use_transactions**: Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query.
- **ndb_version**: Shows build and NDB engine version as an integer.
- **ndb_version_string**: Shows build information including NDB engine version in ndb-x.y.z format.
- **ndbcluster**: Enable NDB Cluster (if this version of MySQL supports it). Disabled by `--skip-ndbcluster`.
- **ndbinfo_database**: The name used for the NDB information database; read only.
- **ndbinfo_max_bytes**: Used for debugging only.
- **ndbinfo_max_rows**: Used for debugging only.
- **ndbinfo_offline**: Put the ndbinfo database into offline mode, in which no rows are returned from tables or views.
- **ndbinfo_show_hidden**: Whether to show ndbinfo internal base tables in the mysql client. The default is OFF.
- **ndbinfo_table_prefix**: The prefix to use for naming ndbinfo internal base tables.
- **ndbinfo_version**: The version of the ndbinfo engine; read only.
- **server_id_bits**: Sets the number of least significant bits in the server_id actually used for identifying the server, permitting NDB API applications to store application data in the most significant bits. server_id must be less than 2 to the power of this value.
- **skip-ndbcluster**: Disable the NDB Cluster storage engine.
- **slave_allow_batching**: Turns update batching on and off for a replication slave.
- **transaction_allow_batching**: Allows batching of statements within a transaction. Disable AUTOCOMMIT to use.

18.3.3 NDB Cluster Configuration Files

Configuring NDB Cluster requires working with two files:

- **my.cnf**: Specifies options for all NDB Cluster executables. This file, with which you should be familiar with from previous work with MySQL, must be accessible by each executable running in the cluster.
- **config.ini**: This file, sometimes known as the global configuration file, is read only by the NDB Cluster management server, which then distributes the information contained therein to all processes participating in the cluster. **config.ini** contains a description of each node involved in the cluster.
includes configuration parameters for data nodes and configuration parameters for connections between all nodes in the cluster. For a quick reference to the sections that can appear in this file, and what sorts of configuration parameters may be placed in each section, see Sections of the config.ini File.

**Caching of configuration data.** In NDB Cluster 7.2, NDB Cluster uses *stateful configuration*. Rather than reading the global configuration file every time the management server is restarted, the management server caches the configuration the first time it is started, and thereafter, the global configuration file is read only when one of the following conditions is true:

- **The management server is started using the --initial option.** When `--initial` is used, the global configuration file is re-read, any existing cache files are deleted, and the management server creates a new configuration cache.

- **The management server is started using the --reload option.** The `--reload` option causes the management server to compare its cache with the global configuration file. If they differ, the management server creates a new configuration cache; any existing configuration cache is preserved, but not used. If the management server's cache and the global configuration file contain the same configuration data, then the existing cache is used, and no new cache is created.

- **The management server is started using --config-cache=FALSE.** This disables `--config-cache` (enabled by default), and can be used to force the management server to bypass configuration caching altogether. In this case, the management server ignores any configuration files that may be present, always reading its configuration data from the `config.ini` file instead.

- **No configuration cache is found.** In this case, the management server reads the global configuration file and creates a cache containing the same configuration data as found in the file.

**Configuration cache files.** The management server by default creates configuration cache files in a directory named `mysql-cluster` in the MySQL installation directory. (If you build NDB Cluster from source on a Unix system, the default location is `/usr/local/mysql-cluster`.) This can be overridden at runtime by starting the management server with the `--configdir` option. Configuration cache files are binary files named according to the pattern `ndb_node_id_config.bin.seq_id`, where `node_id` is the management server's node ID in the cluster, and `seq_id` is a cache identifier. Cache files are numbered sequentially using `seq_id`, in the order in which they are created. The management server uses the latest cache file as determined by the `seq_id`.

**Note**

It is possible to roll back to a previous configuration by deleting later configuration cache files, or by renaming an earlier cache file so that it has a higher `seq_id`. However, since configuration cache files are written in a binary format, you should not attempt to edit their contents by hand.

For more information about the `--configdir`, `--config-cache`, `--initial`, and `--reload` options for the NDB Cluster management server, see Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon".

We are continuously making improvements in Cluster configuration and attempting to simplify this process. Although we strive to maintain backward compatibility, there may be times when introduce an incompatible change. In such cases we will try to let Cluster users know in advance if a change is not backward compatible. If you find such a change and we have not documented it, please report it in the MySQL bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”.

### 18.3.3.1 NDB Cluster Configuration: Basic Example

To support NDB Cluster, you will need to update `my.cnf` as shown in the following example. You may also specify these parameters on the command line when invoking the executables.
The options shown here should not be confused with those that are used in config.ini global configuration files. Global configuration options are discussed later in this section.

```
# my.cnf
# example additions to my.cnf for NDB Cluster
# (valid in MySQL 5.5)
# enable ndbcluster storage engine, and provide connection string for
# management server host (default port is 1186)
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com

# provide connection string for management server host (default port: 1186)
[ndbd]
connect-string=ndb_mgmd.mysql.com

# provide connection string for management server host (default port: 1186)
[ndb_mgm]
connect-string=ndb_mgmd.mysql.com

# provide location of cluster configuration file
[ndb_mgm]
config-file=/etc/config.ini
```

(For more information on connection strings, see Section 18.3.3.3, “NDB Cluster Connection Strings”.)

```
# my.cnf
# example additions to my.cnf for NDB Cluster
# (will work on all versions)
# enable ndbcluster storage engine, and provide connection string for management
# server host to the default port 1186
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

Important

Once you have started a mysqld process with the NDBCLUSTER and ndb-connectstring parameters in the [mysqld] in the my.cnf file as shown previously, you cannot execute any CREATE TABLE or ALTER TABLE statements without having actually started the cluster. Otherwise, these statements will fail with an error. This is by design.

You may also use a separate [mysql_cluster] section in the cluster my.cnf file for settings to be read and used by all executables:

```
# cluster-specific settings
[mysql_cluster]
nfdb-cluster
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

For additional NDB variables that can be set in the my.cnf file, see NDB Cluster System Variables.

The NDB Cluster global configuration file is by convention named config.ini (but this is not required). If needed, it is read by ndb_mgmd at startup and can be placed in any location that can be read by it. The location and name of the configuration are specified using --config-file=path_name with ndb_mgmd on the command line. This option has no default value, and is ignored if ndb_mgmd uses the configuration cache.
The global configuration file for NDB Cluster uses INI format, which consists of sections preceded by section headings (surrounded by square brackets), followed by the appropriate parameter names and values. One deviation from the standard INI format is that the parameter name and value can be separated by a colon (:) as well as the equal sign (=); however, the equal sign is preferred. Another deviation is that sections are not uniquely identified by section name. Instead, unique sections (such as two different nodes of the same type) are identified by a unique ID specified as a parameter within the section.

Default values are defined for most parameters, and can also be specified in config.ini. To create a default value section, simply add the word default to the section name. For example, an [ndbd] section contains parameters that apply to a particular data node, whereas an [ndbd default] section contains parameters that apply to all data nodes. Suppose that all data nodes should use the same data memory size. To configure them all, create an [ndbd default] section that contains a DataMemory line to specify the data memory size.

If used, the [ndbd default] section must precede any [ndbd] sections in the configuration file. This is also true for default sections of any other type.

Note

In some older releases of NDB Cluster, there was no default value for NoOfReplicas, which always had to be specified explicitly in the [ndbd default] section. Although this parameter now has a default value of 2, which is the recommended setting in most common usage scenarios, it is still recommended practice to set this parameter explicitly.

The global configuration file must define the computers and nodes involved in the cluster and on which computers these nodes are located. An example of a simple configuration file for a cluster consisting of one management server, two data nodes and two MySQL servers is shown here:

```ini
# file "config.ini" - 2 data nodes and 2 SQL nodes
# This file is placed in the startup directory of ndb_mgmd (the management server)
# The first MySQL Server can be started from any host. The second can be started only on the host mysqld_5.mysql.com

[ndbd default]
NoOfReplicas= 2
DataDir= /var/lib/mysql-cluster

[ndbd_mgmd]
Hostname= ndb_mgmd.mysql.com
DataDir= /var/lib/mysql-cluster

[ndbd]
Hostname= ndbd_2.mysql.com

[ndbd]
Hostname= ndbd_3.mysql.com

[mysqld]

[mysqld]
Hostname= mysqld_5.mysql.com
```

Note

The preceding example is intended as a minimal starting configuration for purposes of familiarization with NDB Cluster, and is almost certain not to be sufficient for production settings. See Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”, which provides a more complete example starting configuration.
NDB Cluster Configuration Files

Each node has its own section in the `config.ini` file. For example, this cluster has two data nodes, so the preceding configuration file contains two `[ndbd]` sections defining these nodes.

**Note**

Do not place comments on the same line as a section heading in the `config.ini` file; this causes the management server not to start because it cannot parse the configuration file in such cases.

**Sections of the `config.ini` File**

There are six different sections that you can use in the `config.ini` configuration file, as described in the following list:

- **[computer]**: Defines cluster hosts. This is not required to configure a viable NDB Cluster, but be may used as a convenience when setting up a large cluster. See Section 18.3.3.4, “Defining Computers in an NDB Cluster”, for more information.

- **[ndbd]**: Defines a cluster data node (`ndbd` process). See Section 18.3.3.6, “Defining NDB Cluster Data Nodes”, for details.

- **[mysqld]**: Defines the cluster’s MySQL server nodes (also called SQL or API nodes). For a discussion of SQL node configuration, see Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”.

- **[mgm]** or **[ndb_mgmd]**: Defines a cluster management server (MGM) node. For information concerning the configuration of management nodes, see Section 18.3.3.5, “Defining an NDB Cluster Management Server”.

- **[tcp]**: Defines a TCP/IP connection between cluster nodes, with TCP/IP being the default connection protocol. Normally, [tcp] or [tcp default] sections are not required to set up an NDB Cluster, as the cluster handles this automatically; however, it may be necessary in some situations to override the defaults provided by the cluster. See Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, for information about available TCP/IP configuration parameters and how to use them. (You may also find Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections” to be of interest in some cases.)

- **[shm]**: Defines shared-memory connections between nodes. In MySQL 5.5, it is enabled by default, but should still be considered experimental. For a discussion of SHM interconnects, see Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”.

- **[sci]**: Defines Scalable Coherent Interface connections between cluster data nodes. Not supported in NDB 7.2 or later.

You can define default values for each section. If used, a default section should come before any other sections of that type. For example, an `[ndbd default]` section should appear in the configuration file before any `[ndbd]` sections.

NDB Cluster parameter names are case-insensitive, unless specified in MySQL Server `my.cnf` or `my.ini` files.

**18.3.3.2 Recommended Starting Configuration for NDB Cluster**

Achieving the best performance from an NDB Cluster depends on a number of factors including the following:

- NDB Cluster software version
- Numbers of data nodes and SQL nodes
NDB Cluster Configuration Files

- Hardware
- Operating system
- Amount of data to be stored
- Size and type of load under which the cluster is to operate

Therefore, obtaining an optimum configuration is likely to be an iterative process, the outcome of which can vary widely with the specifics of each NDB Cluster deployment. Changes in configuration are also likely to be indicated when changes are made in the platform on which the cluster is run, or in applications that use the NDB Cluster's data. For these reasons, it is not possible to offer a single configuration that is ideal for all usage scenarios. However, in this section, we provide a recommended base configuration.

Starting config.ini file. The following config.ini file is a recommended starting point for configuring a cluster running NDB Cluster 7.2:

```ini
# TCP PARAMETERS
[tcp default] SendBufferMemory=2M
ReceiveBufferMemory=2M

# Increasing the sizes of these 2 buffers beyond the default values helps prevent bottlenecks due to slow disk I/O.

# MANAGEMENT NODE PARAMETERS
[ndb_mgmd default]
DataDir=path/to/management/server/data/directory

# It is possible to use a different data directory for each management server, but for ease of administration it is preferable to be consistent.

[ndb_mgmd]
HostName=management-server-A-hostname
# NodeId=management-server-A-nodeid

[ndb_mgmd]
HostName=management-server-B-hostname
# NodeId=management-server-B-nodeid

# Using 2 management servers helps guarantee that there is always an arbitrator in the event of network partitioning, and so is recommended for high availability. Each management server must be identified by a HostName. You may for the sake of convenience specify a NodeId for any management server, although one will be allocated for it automatically; if you do so, it must be in the range 1-255 inclusive and must be unique among all IDs specified for cluster nodes.

# DATA NODE PARAMETERS
[ndbd default]
NoOfReplicas=2

# Using 2 replicas is recommended to guarantee availability of data; using only 1 replica does not provide any redundancy, which means that the failure of a single data node causes the entire cluster to shut down. We do not recommend using more than 2 replicas, since 2 is sufficient to provide high availability, and we do not currently test with greater values for this parameter.

LockPagesInMainMemory=1
```
# On Linux and Solaris systems, setting this parameter locks data node processes into memory. Doing so prevents them from swapping to disk, which can severely degrade cluster performance.

DataMemory=3072M
IndexMemory=384M

# The values provided for DataMemory and IndexMemory assume 4 GB RAM per data node. However, for best results, you should first calculate the memory that would be used based on the data you actually plan to store (you may find the ndb_size.pl utility helpful in estimating this), then allow an extra 20% over the calculated values. Naturally, you should ensure that each data node host has at least as much physical memory as the sum of these two values.

ODirect=1

# Enabling this parameter causes NDBCLUSTER to try using O_DIRECT writes for local checkpoints and redo logs; this can reduce load on CPUs. We recommend doing so when using NDB Cluster on systems running Linux kernel 2.6 or later.

NoOfFragmentLogFiles=300
DataDir=path/to/data/node/data/directory
MaxNoOfConcurrentOperations=100000
SchedulerSpinTimer=400
SchedulerExecutionTimer=100
RealTimeScheduler=1

# Setting these parameters allows you to take advantage of real-time scheduling of NDB threads to achieve increased throughput when using ndbd. They are not needed when using ndbmd; in particular, you should not set RealTimeScheduler for ndbmd data nodes.

TimeBetweenGlobalCheckpoints=1000
TimeBetweenEpochs=200
DiskCheckpointSpeed=10M
DiskCheckpointSpeedInRestart=100M
RedoBuffer=32M

# CompressedLCP=1
# CompressedBackup=1

# Enabling CompressedLCP and CompressedBackup causes, respectively, local checkpoint files and backup files to be compressed, which can result in a space savings of up to 50% over noncompressed LCPs and backups.

MaxNoOfLocalScans=64
MaxNoOfTables=1024
MaxNoOfOrderedIndexes=256

[ndbd]
HostName=data-node-A-hostname
# NodeId=data-node-A-nodeid
LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0

# On systems with multiple CPUs, these parameters can be used to lock NDBCLUSTER threads to specific CPUs

[ndbd]
HostName=data-node-B-hostname
# NodeId=data-node-B-nodeid
LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0

# You must have an [ndbd] section for every data node in the cluster;
NDB Cluster Configuration Files

# each of these sections must include a HostName. Each section may
# optionally include a NodeId for convenience, but in most cases, it is
# sufficient to allow the cluster to allocate node IDs dynamically. If
# you do specify the node ID for a data node, it must be in the range 1
to 48 inclusive and must be unique among all IDs specified for
cluster nodes.

# SQL NODE / API NODE PARAMETERS

[mysqld]
HostName=sql-node-A-hostname
NodeId=sql-node-A-nodeid

[mysqld]

Each API or SQL node that connects to the cluster requires a [mysqld]
or [api] section of its own. Each such section defines a connection
"slot"; you should have at least as many of these sections in the
config.ini file as the total number of API nodes and SQL nodes that
you wish to have connected to the cluster at any given time. There is
no performance or other penalty for having extra slots available in
case you find later that you want or need more API or SQL nodes to
connect to the cluster at the same time.

If no HostName is specified for a given [mysqld] or [api] section, then
any API or SQL node may use that slot to connect to the
cluster. You may wish to use an explicit HostName for one connection slot
to guarantee that an API or SQL node from that host can always
connect to the cluster. If you wish to prevent API or SQL nodes from
connecting from other than a desired host or hosts, then use a
HostName for every [mysqld] or [api] section in the config.ini file.
You can if you wish define a node ID (NodeId parameter) for any API or
SQL node, but this is not necessary; if you do so, it must be in the
range 1 to 255 inclusive and must be unique among all IDs specified
for cluster nodes.

**Recommended my.cnf options for SQL nodes.** MySQL Servers acting as NDB Cluster SQL nodes
must always be started with the --ndbcluster and --ndb-connectstring options, either on the
command line or in my.cnf. In addition, set the following options for all mysqld processes in the cluster,
unless your setup requires otherwise:

- --ndb-use-exact-count=0
- --ndb-index-stat-enable=0
- --ndb-force-send=1
- --engine-condition-pushdown=1

**18.3.3.3 NDB Cluster Connection Strings**

With the exception of the NDB Cluster management server (ndb_mgmd), each node that is part of an NDB
Cluster requires a **connection string** that points to the management server's location. This connection
string is used in establishing a connection to the management server as well as in performing other tasks
depending on the node's role in the cluster. The syntax for a connection string is as follows:

```
[nodeId= node_id, ]host-definition[, host-definition[, ...]]
```

```
host-definition:
    host_name[:port_number]
```
node_id is a positive integer which identifies a node in config.ini. host_name is a string representing a valid Internet host name or IP address. port_number is an integer referring to a TCP/IP port number.

| example 1 (long): | "nodeid=2,myhost1:1100,myhost2:1100,198.51.100.3:1200" |
| example 2 (short): | "myhost1" |

localhost:1186 is used as the default connection string value if none is provided. If port_num is omitted from the connection string, the default port is 1186. This port should always be available on the network because it has been assigned by IANA for this purpose (see http://www.iana.org/assignments/port-numbers for details).

By listing multiple host definitions, it is possible to designate several redundant management servers. An NDB Cluster data or API node attempts to contact successive management servers on each host in the order specified, until a successful connection has been established.

It is also possible to specify in a connection string one or more bind addresses to be used by nodes having multiple network interfaces for connecting to management servers. A bind address consists of a hostname or network address and an optional port number. This enhanced syntax for connection strings is shown here:

```
[nodeid=node_id, ]
[bind-address=host-definition, ]
 host-definition[; bind-address=host-definition]
 host-definition[; bind-address=host-definition]
[, ...]
```

host-definition:

```
 host_name[:port_number]
```

If a single bind address is used in the connection string prior to specifying any management hosts, then this address is used as the default for connecting to any of them (unless overridden for a given management server; see later in this section for an example). For example, the following connection string causes the node to use 198.51.100.242 regardless of the management server to which it connects:

```
bind-address=198.51.100.242, poseidon:1186, perch:1186
```

If a bind address is specified following a management host definition, then it is used only for connecting to that management node. Consider the following connection string:

```
poseidon:1186;bind-address=localhost, perch:1186;bind-address=198.51.100.242
```

In this case, the node uses localhost to connect to the management server running on the host named poseidon and 198.51.100.242 to connect to the management server running on the host named perch.

You can specify a default bind address and then override this default for one or more specific management hosts. In the following example, localhost is used for connecting to the management server running on host poseidon; since 198.51.100.242 is specified first (before any management server definitions), it is the default bind address and so is used for connecting to the management servers on hosts perch and orca:

```
bind-address=198.51.100.242,poseidon:1186;bind-address=localhost, perch:1186, orca:2200
```

There are a number of different ways to specify the connection string:

- Each executable has its own command-line option which enables specifying the management server at startup. (See the documentation for the respective executable.)
• It is also possible to set the connection string for all nodes in the cluster at once by placing it in a `[mysql_cluster]` section in the management server’s `my.cnf` file.

• For backward compatibility, two other options are available, using the same syntax:
  1. Set the `NDB_CONNECTSTRING` environment variable to contain the connection string.
  2. Write the connection string for each executable into a text file named `Ndb.cfg` and place this file in the executable’s startup directory.

However, these are now deprecated and should not be used for new installations.

The recommended method for specifying the connection string is to set it on the command line or in the `my.cnf` file for each executable.

### 18.3.3.4 Defining Computers in an NDB Cluster

The `[computer]` section has no real significance other than serving as a way to avoid the need of defining host names for each node in the system. All parameters mentioned here are required.

**Restart types.** Information about the restart types used by the parameter descriptions in this section is shown in the following table:

**Table 18.6 NDB Cluster restart types**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the <code>--initial</code> option</td>
</tr>
</tbody>
</table>

• **Id**

**Table 18.7 This table provides type and value information for the Id computer configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>IS</td>
</tr>
</tbody>
</table>

This is a unique identifier, used to refer to the host computer elsewhere in the configuration file.

**Important**

The computer ID is *not* the same as the node ID used for a management, API, or data node. Unlike the case with node IDs, you cannot use `Node_id` in place of `Id` in the `[computer]` section of the `config.ini` file.

• **HostName**
Table 18.8 This table provides type and value information for the HostName computer configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This is the computer’s hostname or IP address.

18.3.3.5 Defining an NDB Cluster Management Server

The [ndb_mgmd] section is used to configure the behavior of the management server. If multiple management servers are employed, you can specify parameters common to all of them in an [ndb_mgmd default] section. [mgm] and [mgm default] are older aliases for these, supported for backward compatibility.

All parameters in the following list are optional and assume their default values if omitted.

![Note]

If neither the ExecuteOnComputer nor the HostName parameter is present, the default value localhost will be assumed for both.

Restart types. Information about the restart types used by the parameter descriptions in this section is shown in the following table:

Table 18.9 NDB Cluster restart types

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the --initial option</td>
</tr>
</tbody>
</table>

- **Id**

Table 18.10 This table provides type and value information for the Id management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>
Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 255, inclusive. This ID is used by all internal cluster messages for addressing the node, and so must be unique for each NDB Cluster node, regardless of the type of node.

**Note**

Data node IDs must be less than 49. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

The use of the `Id` parameter for identifying management nodes is deprecated in favor of `NodeId`. Although `Id` continues to be supported for backward compatibility, it now generates a warning and is subject to removal in a future version of NDB Cluster.

- **NodeId**

**Table 18.11** This table provides type and value information for the `NodeId` management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 255 inclusive. This ID is used by all internal cluster messages for addressing the node, and so must be unique for each NDB Cluster node, regardless of the type of node.

**Note**

Data node IDs must be less than 49. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes. Although the older `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used; it is also subject to removal in a future NDB Cluster release.

- **ExecuteOnComputer**

**Table 18.12** This table provides type and value information for the `ExecuteOnComputer` management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This refers to the `Id` set for one of the computers defined in a `[computer]` section of the `config.ini` file.

- **PortNumber**

Table 18.13 This table provides type and value information for the PortNumber management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>1186</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 64K</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This is the port number on which the management server listens for configuration requests and management commands.

- **HostName**

Table 18.14 This table provides type and value information for the HostName management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specifying this parameter defines the hostname of the computer on which the management node is to reside. To specify a hostname other than `localhost`, either this parameter or `ExecuteOnComputer` is required.

- **LogDestination**

Table 18.15 This table provides type and value information for the LogDestination management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>{CONSOLE</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
</tbody>
</table>
This parameter specifies where to send cluster logging information. There are three options in this regard—CONSOLE, SYSLOG, and FILE—with FILE being the default:

- **CONSOLE** outputs the log to stdout:

  ```
  CONSOLE
  ```

- **SYSLOG** sends the log to a syslog facility, possible values being one of auth, authpriv, cron, daemon, ftp, kern, lpr, mail, news, syslog, user, uucp, local0, local1, local2, local3, local4, local5, local6, or local7.

  ```
  SYSLOG:facility=syslog
  ```

- **FILE** pipes the cluster log output to a regular file on the same machine. The following values can be specified:

  - **filename**: The name of the log file.

    In NDB 7.2.6 and earlier, the log file's default name, used if FILE was specified without also setting filename, was logger.log. Beginning with NDB 7.2.7, the default log file name used in such cases is ndb_nodeid_cluster.log.

  - **maxsize**: The maximum size (in bytes) to which the file can grow before logging rolls over to a new file. When this occurs, the old log file is renamed by appending .N to the file name, where N is the next number not yet used with this name.

  - **maxfiles**: The maximum number of log files.

    ```
    FILE:filename=cluster.log,maxsize=1000000,maxfiles=6
    ```

    The default value for the FILE parameter is

    ```
    FILE:filename=ndb_node_id_cluster.log,maxsize=1000000,maxfiles=6, where node_id is the ID of the node.
    ```

    It is possible to specify multiple log destinations separated by semicolons as shown here:

    ```
    CONSOLE;SYSLOG:facility=local0;FILE:filename=/var/log/mgmd
    ```

### ArbitrationRank

**Table 18.16** This table provides type and value information for the ArbitrationRank management node configuration parameter.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>0-2</td>
</tr>
<tr>
<td>Default</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 2</td>
</tr>
</tbody>
</table>
This parameter is used to define which nodes can act as arbitrators. Only management nodes and SQL nodes can be arbitrators. *ArbitrationRank* can take one of the following values:

- **0**: The node will never be used as an arbitrator.
- **1**: The node has high priority; that is, it will be preferred as an arbitrator over low-priority nodes.
- **2**: Indicates a low-priority node which be used as an arbitrator only if a node with a higher priority is not available for that purpose.

Normally, the management server should be configured as an arbitrator by setting its *ArbitrationRank* to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

You can disable arbitration completely either by setting *ArbitrationRank* to 0 on all management and SQL nodes, or by setting the *Arbitration* parameter in the `[ndbd default]` section of the `config.ini` global configuration file. Setting *Arbitration* causes any settings for *ArbitrationRank* to be disregarded.

### ArbitrationDelay

Table 18.17 This table provides type and value information for the ArbitrationDelay management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

An integer value which causes the management server's responses to arbitration requests to be delayed by that number of milliseconds. By default, this value is 0; it is normally not necessary to change it.

### DataDir

Table 18.18 This table provides type and value information for the DataDir management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>path</td>
</tr>
<tr>
<td>Default</td>
<td>.</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This specifies the directory where output files from the management server will be placed. These files include cluster log files, process output files, and the daemon's process ID (PID) file. (For log files,
this location can be overridden by setting the FILE parameter for LogDestination as discussed previously in this section.)

The default value for this parameter is the directory in which ndb_mgmd is located.

• PortNumberStats

Table 18.19 This table provides type and value information for the PortNumberStats management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 64K</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the port number used to obtain statistical information from an NDB Cluster management server. It has no default value.

• Wan

Table 18.20 This table provides type and value information for the wan management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Use WAN TCP setting as default.

• HeartbeatThreadPriority

Table 18.21 This table provides type and value information for the HeartbeatThreadPriority management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

Set the scheduling policy and priority of heartbeat threads for management and API nodes.

The syntax for setting this parameter is shown here:

HeartbeatThreadPriority = policy[, priority]
When setting this parameter, you must specify a policy. This is one of FIFO (first in, first out) or RR (round robin). The policy value is followed optionally by the priority (an integer).

- **ExtraSendBufferMemory**

  Table 18.22 This table provides type and value information for the ExtraSendBufferMemory management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.14</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 32G</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using TotalSendBufferMemory, SendBufferMemory, or both.

This parameter was added in NDB 7.2.14. (Bug #14555359)

- **TotalSendBufferMemory**

  Table 18.23 This table provides type and value information for the TotalSendBufferMemory management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>256K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

- **HeartbeatIntervalMgmdMgmd**

  Table 18.24 This table provides type and value information for the HeartbeatIntervalMgmdMgmd management node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.12</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>1500</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>100 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specify the interval between heartbeat messages used to determine whether another management node is on contact with this one. The management node waits after 3 of these intervals to declare the connection dead; thus, the default setting of 1500 milliseconds causes the management node to wait for approximately 1600 ms before timing out.

This parameter was added in NDB 7.2.12. (Bug #16426805, Bug #17807768)

**Note**

After making changes in a management node's configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect.

To add new management servers to a running NDB Cluster, it is also necessary to perform a rolling restart of all cluster nodes after modifying any existing config.ini files. For more information about issues arising when using multiple management nodes, see Section 18.1.7.10, “Limitations Relating to Multiple NDB Cluster Nodes”.

### 18.3.3.6 Defining NDB Cluster Data Nodes

The [ndbd] and [ndbd default] sections are used to configure the behavior of the cluster's data nodes.

[ndbd] and [ndbd default] are always used as the section names whether you are using ndbd or ndbmtd binaries for the data node processes.

There are many parameters which control buffer sizes, pool sizes, timeouts, and so forth. The only mandatory parameter is either one of ExecuteOnComputer or HostName; this must be defined in the local [ndbd] section.

The parameter NoOfReplicas should be defined in the [ndbd default] section, as it is common to all Cluster data nodes. It is not strictly necessary to set NoOfReplicas, but it is good practice to set it explicitly.

Most data node parameters are set in the [ndbd default] section. Only those parameters explicitly stated as being able to set local values are permitted to be changed in the [ndbd] section. Where present, HostName, NodeId and ExecuteOnComputer must be defined in the local [ndbd] section, and not in any other section of config.ini. In other words, settings for these parameters are specific to one data node.

For those parameters affecting memory usage or buffer sizes, it is possible to use K, M, or G as a suffix to indicate units of 1024, 1024×1024, or 1024×1024×1024. (For example, 100K means 100 × 1024 = 102400.)

Parameter names and values are case-insensitive, unless used in a MySQL Server my.cnf or my.ini file, in which case they are case-sensitive.

Information about configuration parameters specific to NDB Cluster Disk Data tables can be found later in this section (see Disk Data Configuration Parameters).

All of these parameters also apply to ndbmtd (the multithreaded version of ndbd). Three additional data node configuration parameters—MaxNoOfExecutionThreads, ThreadConfig, and NoOfFragmentLogParts—apply to ndbmtd only; these have no effect when used with ndbd. For more
information, see Multi-Threading Configuration Parameters (ndbmtd). See also Section 18.4.3, “ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)”.

**Restart types.** Information about the restart types used by the parameter descriptions in this section is shown in the following table:

**Table 18.25 NDB Cluster restart types**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the <code>--initial</code> option</td>
</tr>
</tbody>
</table>

**Identifying data nodes.** The `NodeId` or `Id` value (that is, the data node identifier) can be allocated on the command line when the node is started or in the configuration file.

- **Id**

**Table 18.26 This table provides type and value information for the Id data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Version (or later)</code></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><code>Type or units</code></td>
<td>unsigned</td>
</tr>
<tr>
<td><code>Default</code></td>
<td>[none]</td>
</tr>
<tr>
<td><code>Range</code></td>
<td>1 - 48</td>
</tr>
<tr>
<td><code>Restart Type</code></td>
<td>IS</td>
</tr>
</tbody>
</table>

A unique node ID is used as the node’s address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.

`NodeId` is the preferred parameter name to use when identifying data nodes. Although the older `Id` is still supported for backward compatibility, it is now deprecated, and generates a warning when used. `Id` is also subject to removal in a future NDB Cluster release.

- **NodeId**

**Table 18.27 This table provides type and value information for the NodeId data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Version (or later)</code></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><code>Type or units</code></td>
<td>unsigned</td>
</tr>
<tr>
<td><code>Default</code></td>
<td>[none]</td>
</tr>
<tr>
<td><code>Range</code></td>
<td>1 - 48</td>
</tr>
<tr>
<td><code>Restart Type</code></td>
<td>IS</td>
</tr>
</tbody>
</table>

A unique node ID is used as the node’s address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.
**NodeId** is the preferred parameter name to use when identifying data nodes. Although **Id** continues to be supported for backward compatibility, it is now deprecated, generates a warning when used, and is subject to removal in a future version of NDB Cluster.

- **ExecuteOnComputer**

  **Table 18.28 This table provides type and value information for the ExecuteOnComputer data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>S</td>
</tr>
</tbody>
</table>

  This refers to the **Id** set for one of the computers defined in a [computer] section.

- **HostName**

  **Table 18.29 This table provides type and value information for the HostName data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>localhost</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

  Specifying this parameter defines the hostname of the computer on which the data node is to reside. To specify a hostname other than **localhost**, either this parameter or **ExecuteOnComputer** is required.

- **ServerPort**

  **Table 18.30 This table provides type and value information for the ServerPort data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 64K</td>
</tr>
</tbody>
</table>
Each node in the cluster uses a port to connect to other nodes. By default, this port is allocated dynamically in such a way as to ensure that no two nodes on the same host computer receive the same port number, so it should normally not be necessary to specify a value for this parameter.

However, if you need to be able to open specific ports in a firewall to permit communication between data nodes and API nodes (including SQL nodes), you can set this parameter to the number of the desired port in an [ndbd] section or (if you need to do this for multiple data nodes) the [ndbd default] section of the config.ini file, and then open the port having that number for incoming connections from SQL nodes, API nodes, or both.

Note
Connections from data nodes to management nodes is done using the ndb_mgmd management port (the management server's PortNumber; see Section 18.3.3.5, "Defining an NDB Cluster Management Server") so outgoing connections to that port from any data nodes should always be permitted.

- **TcpBind_INADDR_ANY**

  Setting this parameter to *TRUE* or 1 binds *IP_ADDR_ANY* so that connections can be made from anywhere (for autogenerated connections). The default is *FALSE* (0).

- **NodeGroup**

Table 18.31 This table provides type and value information for the NodeGroup data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>[none]</td>
</tr>
<tr>
<td>Default</td>
<td>0 - 65536</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

This parameter can be used to assign a data node to a specific node group. It is read only when the cluster is started for the first time, and cannot be used to reassign a data node to a different node group online. It is generally not desirable to use this parameter in the [ndbd default] section of the config.ini file, and care must be taken not to assign nodes to node groups in such a way that an invalid numbers of nodes are assigned to any node groups.

The **NodeGroup** parameter is chiefly intended for use in adding a new node group to a running NDB Cluster without having to perform a rolling restart. For this purpose, you should set it to 65536 (the maximum value). You are not required to set a **NodeGroup** value for all cluster data nodes, only for those nodes which are to be started and added to the cluster as a new node group at a later time. For more information, see Section 18.5.14.3, "Adding NDB Cluster Data Nodes Online: Detailed Example".

---

2212
Table 18.32 This table provides type and value information for the NoOfReplicas data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>2</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

This global parameter can be set only in the `[ndbd default]` section, and defines the number of replicas for each table stored in the cluster. This parameter also specifies the size of node groups. A node group is a set of nodes all storing the same information.

Node groups are formed implicitly. The first node group is formed by the set of data nodes with the lowest node IDs, the next node group by the set of the next lowest node identities, and so on. By way of example, assume that we have 4 data nodes and that `NoOfReplicas` is set to 2. The four data nodes have node IDs 2, 3, 4 and 5. Then the first node group is formed from nodes 2 and 3, and the second node group by nodes 4 and 5. It is important to configure the cluster in such a manner that nodes in the same node groups are not placed on the same computer because a single hardware failure would cause the entire cluster to fail.

If no node IDs are provided, the order of the data nodes will be the determining factor for the node group. Whether or not explicit assignments are made, they can be viewed in the output of the management client's `SHOW` command.

The default and recommended maximum value for `NoOfReplicas` is 2. *This is the recommended value for most production environments.*

---

**Important**

While it is theoretically possible for the value of this parameter to be 3 or 4, NDB Cluster 7.2 does not support setting `NoOfReplicas` to a value greater than 2 in production.

**Warning**

Setting `NoOfReplicas` to 1 means that there is only a single copy of all Cluster data; in this case, the loss of a single data node causes the cluster to fail because there are no additional copies of the data stored by that node.

The value for this parameter must divide evenly into the number of data nodes in the cluster. For example, if there are two data nodes, then `NoOfReplicas` must be equal to either 1 or 2, since 2/3 and 2/4 both yield fractional values; if there are four data nodes, then `NoOfReplicas` must be equal to 1, 2, or 4.
• **DataDir**

Table 18.33 This table provides type and value information for the DataDir data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>path</td>
</tr>
<tr>
<td>Default</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>IN</td>
</tr>
</tbody>
</table>

This parameter specifies the directory where trace files, log files, pid files and error logs are placed.

The default is the data node process working directory.

• **FileSystemPath**

Table 18.34 This table provides type and value information for the FileSystemPath data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>path</td>
</tr>
<tr>
<td>Default</td>
<td>DataDir</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>IN</td>
</tr>
</tbody>
</table>

This parameter specifies the directory where all files created for metadata, REDO logs, UNDO logs (for Disk Data tables), and data files are placed. The default is the directory specified by **DataDir**.

Note

This directory must exist before the ndbd process is initiated.

The recommended directory hierarchy for NDB Cluster includes `/var/lib/mysql-cluster`, under which a directory for the node's file system is created. The name of this subdirectory contains the node ID. For example, if the node ID is 2, this subdirectory is named `ndb_2_fs`.

• **BackupDataDir**

Table 18.35 This table provides type and value information for the BackupDataDir data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>path</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
</tbody>
</table>
This parameter specifies the directory in which backups are placed.

Important

The string '/BACKUP' is always appended to this value. For example, if you set the value of `BackupDataDir` to `/var/lib/cluster-data`, then all backups are stored under `/var/lib/cluster-data/BACKUP`. This also means that the effective default backup location is the directory named `BACKUP` under the location specified by the `FileSystemPath` parameter.

Data Memory, Index Memory, and String Memory

`DataMemory` and `IndexMemory` are `[ndbd]` parameters specifying the size of memory segments used to store the actual records and their indexes. In setting values for these, it is important to understand how `DataMemory` and `IndexMemory` are used, as they usually need to be updated to reflect actual usage by the cluster:

- `DataMemory`

Table 18.36 This table provides type and value information for the `DataMemory` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>80M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 1T</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter defines the amount of space (in bytes) available for storing database records. The entire amount specified by this value is allocated in memory, so it is extremely important that the machine has sufficient physical memory to accommodate it.

The memory allocated by `DataMemory` is used to store both the actual records and indexes. There is a 16-byte overhead on each record; an additional amount for each record is incurred because it is stored in a 32KB page with 128 byte page overhead (see below). There is also a small amount wasted per page due to the fact that each record is stored in only one page.

For variable-size table attributes, the data is stored on separate data pages, allocated from `DataMemory`. Variable-length records use a fixed-size part with an extra overhead of 4 bytes to reference the variable-size part. The variable-size part has 2 bytes overhead plus 2 bytes per attribute.

The maximum record size is 14000 bytes.

The memory space defined by `DataMemory` is also used to store ordered indexes, which use about 10 bytes per record. Each table row is represented in the ordered index. A common error among users is to assume that all indexes are stored in the memory allocated by `IndexMemory`, but this is not the case: Only primary key and unique hash indexes use this memory; ordered indexes use the memory allocated by `DataMemory`. However, creating a primary key or unique hash index also creates an ordered index.
on the same keys, unless you specify `USING HASH` in the index creation statement. This can be verified by running `ndb_desc -d db_name table_name` in the management client.

NDB Cluster can use a maximum of 512 MB for hash indexes per partition, which means in some cases it is possible to get `Table is full` errors in MySQL client applications even when `ndb_mgm -e "ALL REPORT MEMORYUSAGE"` shows significant free `DataMemory`. This can also pose a problem with data node restarts on nodes that are heavily loaded with data.

You can force NDB to create extra partitions for NDB Cluster tables and thus have more memory available for hash indexes by using the `MAX_ROWS` option for `CREATE TABLE`. In general, setting `MAX_ROWS` to twice the number of rows that you expect to store in the table should be sufficient.

You can also use the `MinFreePct` configuration parameter to help avoid problems with node restarts. (NDB 7.2.3 and later; Bug #13436216.)

The memory space allocated by `DataMemory` consists of 32KB pages, which are allocated to table fragments. Each table is normally partitioned into the same number of fragments as there are data nodes in the cluster. Thus, for each node, there are the same number of fragments as are set in `NoOfReplicas`.

Once a page has been allocated, it is currently not possible to return it to the pool of free pages, except by deleting the table. (This also means that `DataMemory` pages, once allocated to a given table, cannot be used by other tables.) Performing a data node recovery also compresses the partition because all records are inserted into empty partitions from other live nodes.

The `DataMemory` memory space also contains UNDO information: For each update, a copy of the unaltered record is allocated in the `DataMemory`. There is also a reference to each copy in the ordered table indexes. Unique hash indexes are updated only when the unique index columns are updated, in which case a new entry in the index table is inserted and the old entry is deleted upon commit. For this reason, it is also necessary to allocate enough memory to handle the largest transactions performed by applications using the cluster. In any case, performing a few large transactions holds no advantage over using many smaller ones, for the following reasons:

- Large transactions are not any faster than smaller ones
- Large transactions increase the number of operations that are lost and must be repeated in event of transaction failure
- Large transactions use more memory

The default value for `DataMemory` is 80MB; the minimum is 1MB. There is no maximum size, but in reality the maximum size has to be adapted so that the process does not start swapping when the limit is reached. This limit is determined by the amount of physical RAM available on the machine and by the amount of memory that the operating system may commit to any one process. 32-bit operating systems are generally limited to 2–4GB per process; 64-bit operating systems can use more. For large databases, it may be preferable to use a 64-bit operating system for this reason.

- `IndexMemory`

Table 18.37 This table provides type and value information for the `IndexMemory` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Property</td>
<td>Value</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Default</td>
<td>18M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 1T</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter controls the amount of storage used for hash indexes in NDB Cluster. Hash indexes are always used for primary key indexes, unique indexes, and unique constraints. When defining a primary key or a unique index, two indexes are created, one of which is a hash index used for all tuple accesses as well as lock handling. This index is also used to enforce unique constraints.

You can estimate the size of a hash index using this formula:

\[
\text{size} = \left( \text{fragments} \times 32\text{K} \right) + \left( \text{rows} \times 18 \right) \times \text{replicas}
\]

`fragments` is the number of fragments, `replicas` is the number of replicas (normally 2), and `rows` is the number of rows. If a table has one million rows, 8 fragments, and 2 replicas, the expected index memory usage is calculated as shown here:

\[
\begin{align*}
\left( (8 \times 32\text{K}) + (1000000 \times 18) \right) \times 2 & = \left( (8 \times 32768) + (1000000 \times 18) \right) \times 2 \\
& = (262144 + 18000000) \times 2 \\
& = 18262144 \times 2 = 36524288 \text{ bytes} = \sim 35\text{MB}
\end{align*}
\]

In NDB Cluster 7.2 and later, index statistics (when enabled) for ordered indexes are stored in the `mysql.ndb_index_stat_sample` table. Since this table has a hash index, this adds to index memory usage. An upper bound to the number of rows for a given ordered index can be calculated as follows:

\[
\text{sample_size} = \text{key_size} + \left( (\text{key_attributes} + 1) \times 4 \right)
\]

\[
\text{sample_rows} = \frac{\text{IndexStatSaveSize} \times \left( (0.01 \times \text{IndexStatSaveScale} \times \log_2(\text{rows} \times \text{sample_size})) + 1 \right)}{\text{sample_size}}
\]

In the preceding formula, `key_size` is the size of the ordered index key in bytes, `key_attributes` is the number of attributes in the ordered index key, and `rows` is the number of rows in the base table.

Assume that table `t1` has 1 million rows and an ordered index named `ix1` on two four-byte integers. Assume in addition that `IndexStatSaveSize` and `IndexStatSaveScale` are set to their default values (32K and 100, respectively). Using the previous 2 formulas, we can calculate as follows:

\[
\text{sample_size} = 8 + ((1 + 2) \times 4) = 20 \text{ bytes}
\]

\[
\begin{align*}
\text{sample_rows} &= 32K \\
& \times \left( (0.01 \times 100 \times \log_2(10000000*20)) + 1 \right) \\
& \div 20 \\
& = 32768 \times (1 \times \sim 16.811) +1 \div 20 \\
& = 32768 \times \sim 17.811 \div 20 \\
& = \sim 29182 \text{ rows}
\end{align*}
\]

The expected index memory usage is thus \(2 \times 18 \times 29182 = \sim 1050550 \text{ bytes}\).

The default value for `IndexMemory` is 18MB. The minimum is 1MB.
Table 18.38 This table provides type and value information for the StringMemory data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>% or bytes</td>
</tr>
<tr>
<td>Default</td>
<td>25</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This parameter determines how much memory is allocated for strings such as table names, and is specified in an [ndbd] or [ndbd_default] section of the config.ini file. A value between 0 and 100 inclusive is interpreted as a percent of the maximum default value, which is calculated based on a number of factors including the number of tables, maximum table name size, maximum size of .FRM files, MaxNoOfTriggers, maximum column name size, and maximum default column value.

A value greater than 100 is interpreted as a number of bytes.

The default value is 25—that is, 25 percent of the default maximum.

Under most circumstances, the default value should be sufficient, but when you have a great many Cluster tables (1000 or more), it is possible to get Error 773 Out of string memory, please modify StringMemory config parameter: Permanent error: Schema error, in which case you should increase this value. 25 (25 percent) is not excessive, and should prevent this error from recurring in all but the most extreme conditions.

The following example illustrates how memory is used for a table. Consider this table definition:

```sql
CREATE TABLE example (  
a INT NOT NULL,  
b INT NOT NULL,  
c INT NOT NULL,  
PRIMARY KEY(a),  
UNIQUE(b)  
) ENGINE=NDBCLUSTER;
```

For each record, there are 12 bytes of data plus 12 bytes overhead. Having no nullable columns saves 4 bytes of overhead. In addition, we have two ordered indexes on columns a and b consuming roughly 10 bytes each per record. There is a primary key hash index on the base table using roughly 29 bytes per record. The unique constraint is implemented by a separate table with b as primary key and a as a column. This other table consumes an additional 29 bytes of index memory per record in the example table as well 8 bytes of record data plus 12 bytes of overhead.

Thus, for one million records, we need 58MB for index memory to handle the hash indexes for the primary key and the unique constraint. We also need 64MB for the records of the base table and the unique index table, plus the two ordered index tables.

You can see that hash indexes takes up a fair amount of memory space; however, they provide very fast access to the data in return. They are also used in NDB Cluster to handle uniqueness constraints.

The only partitioning algorithm is hashing and ordered indexes are local to each node. Thus, ordered indexes cannot be used to handle uniqueness constraints in the general case.
An important point for both `IndexMemory` and `DataMemory` is that the total database size is the sum of all data memory and all index memory for each node group. Each node group is used to store replicated information, so if there are four nodes with two replicas, there will be two node groups. Thus, the total data memory available is $2 \times \text{DataMemory}$ for each data node.

It is highly recommended that `DataMemory` and `IndexMemory` be set to the same values for all nodes. Data distribution is even over all nodes in the cluster, so the maximum amount of space available for any node can be no greater than that of the smallest node in the cluster.

`DataMemory` and `IndexMemory` can be changed, but decreasing either of these can be risky; doing so can easily lead to a node or even an entire NDB Cluster that is unable to restart due to there being insufficient memory space. Increasing these values should be acceptable, but it is recommended that such upgrades are performed in the same manner as a software upgrade, beginning with an update of the configuration file, and then restarting the management server followed by restarting each data node in turn.

**MinFreePct.** Beginning with NDB 7.2.3, a proportion (5% by default) of data node resources including `DataMemory` and `IndexMemory` is kept in reserve to insure that the data node does not exhaust its memory when performing a restart. This can be adjusted using the `MinFreePct` data node configuration parameter (default 5) introduced in the same version of NDB Cluster.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.3</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>5</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 100</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Updates do not increase the amount of index memory used. Inserts take effect immediately; however, rows are not actually deleted until the transaction is committed.

**Transaction parameters.** The next few `[ndbd]` parameters that we discuss are important because they affect the number of parallel transactions and the sizes of transactions that can be handled by the system. `MaxNoOfConcurrentTransactions` sets the number of parallel transactions possible in a node. `MaxNoOfConcurrentOperations` sets the number of records that can be in update phase or locked simultaneously.

Both of these parameters (especially `MaxNoOfConcurrentOperations`) are likely targets for users setting specific values and not using the default value. The default value is set for systems using small transactions, to ensure that these do not use excessive memory.

`MaxDMLOperationsPerTransaction` sets the maximum number of DML operations that can be performed in a given transaction.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MaxNoOfConcurrentTransactions</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 18.39 This table provides type and value information for the `MinFreePct` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
</tbody>
</table>
Each cluster data node requires a transaction record for each active transaction in the cluster. The task of coordinating transactions is distributed among all of the data nodes. The total number of transaction records in the cluster is the number of transactions in any given node times the number of nodes in the cluster.

Transaction records are allocated to individual MySQL servers. Each connection to a MySQL server requires at least one transaction record, plus an additional transaction object per table accessed by that connection. This means that a reasonable minimum for the total number of transactions in the cluster can be expressed as

\[
\text{TotalNoOfConcurrentTransactions} = (\text{maximum number of tables accessed in any single transaction} + 1) \times \text{number of SQL nodes}
\]

Suppose that there are 10 SQL nodes using the cluster. A single join involving 10 tables requires 11 transaction records; if there are 10 such joins in a transaction, then \(10 \times 11 = 110\) transaction records are required for this transaction, per MySQL server, or \(110 \times 10 = 1100\) transaction records total. Each data node can be expected to handle \(\text{TotalNoOfConcurrentTransactions} / \text{number of data nodes}\). For an NDB Cluster having 4 data nodes, this would mean setting \(\text{MaxNoOfConcurrentTransactions}\) on each data node to \(\frac{1100}{4} = 275\). In addition, you should provide for failure recovery by ensuring that a single node group can accommodate all concurrent transactions; in other words, that each data node’s \(\text{MaxNoOfConcurrentTransactions}\) is sufficient to cover a number of transactions equal to \(\text{TotalNoOfConcurrentTransactions} / \text{number of node groups}\). If this cluster has a single node group, then \(\text{MaxNoOfConcurrentTransactions}\) should be set to 1100 (the same as the total number of concurrent transactions for the entire cluster).

In addition, each transaction involves at least one operation; for this reason, the value set for \(\text{MaxNoOfConcurrentTransactions}\) should always be no more than the value of \(\text{MaxNoOfConcurrentOperations}\).

This parameter must be set to the same value for all cluster data nodes. This is due to the fact that, when a data node fails, the oldest surviving node re-creates the transaction state of all transactions that were ongoing in the failed node.

It is possible to change this value using a rolling restart, but the amount of traffic on the cluster must be such that no more transactions occur than the lower of the old and new levels while this is taking place.

The default value is 4096.

- \(\text{MaxNoOfConcurrentOperations}\)

### Table 18.41
This table provides type and value information for the \(\text{MaxNoOfConcurrentOperations}\) data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>32K</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>32 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

It is a good idea to adjust the value of this parameter according to the size and number of transactions. When performing transactions which involve only a few operations and records, the default value for this parameter is usually sufficient. Performing large transactions involving many records usually requires that you increase its value.

Records are kept for each transaction updating cluster data, both in the transaction coordinator and in the nodes where the actual updates are performed. These records contain state information needed to find UNDO records for rollback, lock queues, and other purposes.

This parameter should be set at a minimum to the number of records to be updated simultaneously in transactions, divided by the number of cluster data nodes. For example, in a cluster which has four data nodes and which is expected to handle one million concurrent updates using transactions, you should set this value to 1000000 / 4 = 250000. To help provide resiliency against failures, it is suggested that you set this parameter to a value that is high enough to permit an individual data node to handle the load for its node group. In other words, you should set the value equal to total number of concurrent operations / number of node groups. (In the case where there is a single node group, this is the same as the total number of concurrent operations for the entire cluster.)

Because each transaction always involves at least one operation, the value of MaxNoOfConcurrentOperations should always be greater than or equal to the value of MaxNoOfConcurrentTransactions.

Read queries which set locks also cause operation records to be created. Some extra space is allocated within individual nodes to accommodate cases where the distribution is not perfect over the nodes.

When queries make use of the unique hash index, there are actually two operation records used per record in the transaction. The first record represents the read in the index table and the second handles the operation on the base table.

The default value is 32768.

This parameter actually handles two values that can be configured separately. The first of these specifies how many operation records are to be placed with the transaction coordinator. The second part specifies how many operation records are to be local to the database.

A very large transaction performed on an eight-node cluster requires as many operation records in the transaction coordinator as there are reads, updates, and deletes involved in the transaction. However, the operation records of the are spread over all eight nodes. Thus, if it is necessary to configure the system for one very large transaction, it is a good idea to configure the two parts separately. MaxNoOfConcurrentOperations will always be used to calculate the number of operation records in the transaction coordinator portion of the node.

It is also important to have an idea of the memory requirements for operation records. These consume about 1KB per record.
• MaxNoOfLocalOperations

Table 18.42 This table provides type and value information for the MaxNoOfLocalOperations data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>UNDEFINED</td>
</tr>
<tr>
<td>Range</td>
<td>32 - 4294967039 (0xFFFFFFFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

By default, this parameter is calculated as 1.1 \( \times \) MaxNoOfConcurrentOperations. This fits systems with many simultaneous transactions, none of them being very large. If there is a need to handle one very large transaction at a time and there are many nodes, it is a good idea to override the default value by explicitly specifying this parameter.

• MaxDMLOperationsPerTransaction

Table 18.43 This table provides type and value information for the MaxDMLOperationsPerTransaction data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>operations (DML)</td>
</tr>
<tr>
<td>Default</td>
<td>4294967295</td>
</tr>
<tr>
<td>Range</td>
<td>32 - 4294967295</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter limits the size of a transaction. The transaction is aborted if it requires more than this many DML operations. The minimum number of operations per transaction is 32; however, you can set MaxDMLOperationsPerTransaction to 0 to disable any limitation on the number of DML operations per transaction. The maximum (and default) is 4294967295.

Transaction temporary storage. The next set of \([\text{ndbd}]\) parameters is used to determine temporary storage when executing a statement that is part of a Cluster transaction. All records are released when the statement is completed and the cluster is waiting for the commit or rollback.

The default values for these parameters are adequate for most situations. However, users with a need to support transactions involving large numbers of rows or operations may need to increase these values to enable better parallelism in the system, whereas users whose applications require relatively small transactions can decrease the values to save memory.

• MaxNoOfConcurrentIndexOperations

Table 18.44 This table provides type and value information for the MaxNoOfConcurrentIndexOperations data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
</tbody>
</table>
For queries using a unique hash index, another temporary set of operation records is used during a query's execution phase. This parameter sets the size of that pool of records. Thus, this record is allocated only while executing a part of a query. As soon as this part has been executed, the record is released. The state needed to handle aborts and commits is handled by the normal operation records, where the pool size is set by the parameter `MaxNoOfConcurrentOperations`.

The default value of this parameter is 8192. Only in rare cases of extremely high parallelism using unique hash indexes should it be necessary to increase this value. Using a smaller value is possible and can save memory if the DBA is certain that a high degree of parallelism is not required for the cluster.

- **MaxNoOfFiredTriggers**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>4000</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The default value of `MaxNoOfFiredTriggers` is 4000, which is sufficient for most situations. In some cases it can even be decreased if the DBA feels certain the need for parallelism in the cluster is not high.

A record is created when an operation is performed that affects a unique hash index. Inserting or deleting a record in a table with unique hash indexes or updating a column that is part of a unique hash index fires an insert or a delete in the index table. The resulting record is used to represent this index table operation while waiting for the original operation that fired it to complete. This operation is short-lived but can still require a large number of records in its pool for situations with many parallel write operations on a base table containing a set of unique hash indexes.

- **TransactionBufferMemory**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>1M</td>
</tr>
<tr>
<td>Range</td>
<td>1K - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
The memory affected by this parameter is used for tracking operations fired when updating index tables and reading unique indexes. This memory is used to store the key and column information for these operations. It is only very rarely that the value for this parameter needs to be altered from the default. The default value for `TransactionBufferMemory` is 1MB.

Normal read and write operations use a similar buffer, whose usage is even more short-lived. The compile-time parameter `ZATTRBUF_FILESIZE` (found in `ndb/src/kernel/blocks/Dbtc/Dbtc.hpp`) set to 4000 × 128 bytes (500KB). A similar buffer for key information, `ZDATABUF_FILESIZE` (also in `Dbtc.hpp`) contains 4000 × 16 = 62.5KB of buffer space. `Dbtc` is the module that handles transaction coordination.

Scans and buffering. There are additional [ndbd] parameters in the `Db1qh` module (in `ndb/src/kernel/blocks/Db1qh/Db1qh.hpp`) that affect reads and updates. These include `ZATTRINBUF_FILESIZE`, set by default to 10000 × 128 bytes (1250KB) and `ZDATABUF_FILENO_SIZE`, set by default to 10000*16 bytes (roughly 156KB) of buffer space. To date, there have been neither any reports from users nor any results from our own extensive tests suggesting that either of these compile-time limits should be increased.

**MaxNoOfConcurrentScans**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is used to control the number of parallel scans that can be performed in the cluster. Each transaction coordinator can handle the number of parallel scans defined for this parameter. Each scan query is performed by scanning all partitions in parallel. Each partition scan uses a scan record in the node where the partition is located, the number of records being the value of this parameter times the number of nodes. The cluster should be able to sustain `MaxNoOfConcurrentScans` scans concurrently from all nodes in the cluster.

Scans are actually performed in two cases. The first of these cases occurs when no hash or ordered indexes exists to handle the query, in which case the query is executed by performing a full table scan. The second case is encountered when there is no hash index to support the query but there is an ordered index. Using the ordered index means executing a parallel range scan. The order is kept on the local partitions only, so it is necessary to perform the index scan on all partitions.

The default value of `MaxNoOfConcurrentScans` is 256. The maximum value is 500.

**MaxNoOfLocalScans**
Table 18.48 This table provides type and value information for the MaxNoOfLocalScans data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>32 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specifies the number of local scan records if many scans are not fully parallelized. In NDB 7.2.0 and later, when the number of local scan records is not provided, it is calculated as shown here:

\[ 4 \times \text{MaxNoOfConcurrentScans} \times \# \text{data nodes} + 2 \]

The minimum value is 32.

- **BatchSizePerLocalScan**

Table 18.49 This table provides type and value information for the BatchSizePerLocalScan data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>256</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 992</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is used to calculate the number of lock records used to handle concurrent scan operations.

**BatchSizePerLocalScan** has a strong connection to the **BatchSize** defined in the SQL nodes.

- **LongMessageBuffer**

Table 18.50 This table provides type and value information for the LongMessageBuffer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.16</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>64M</td>
</tr>
<tr>
<td>Range</td>
<td>512K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This is an internal buffer used for passing messages within individual nodes and between nodes. The default is 64MB. (Prior to NDB 7.2.16, this was 4MB.)

This parameter seldom needs to be changed from the default.
- **MaxParallelScansPerFragment**

  Table 18.51 This table provides type and value information for the MaxParallelScansPerFragment data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>256</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

It is possible to configure the maximum number of parallel scans (TUP scans and TUX scans) allowed before they begin queuing for serial handling. You can increase this to take advantage of any unused CPU when performing large number of scans in parallel and improve their performance.

Beginning with NDB 7.2.0, the default value for this parameter was increased from 32 to 256.

**Memory Allocation**

- **MaxAllocate**

  Table 18.52 This table provides type and value information for the MaxAllocate data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>32M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 1G</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This is the maximum size of the memory unit to use when allocating memory for tables. In cases where NDB gives Out of memory errors, but it is evident by examining the cluster logs or the output of DUMP 1000 that all available memory has not yet been used, you can increase the value of this parameter (or MaxNoOfTables, or both) to cause NDB to make sufficient memory available.

**Hash Map Size**

- **DefaultHashMapSize**

  Table 18.53 This table provides type and value information for the DefaultHashMapSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.11</td>
</tr>
<tr>
<td>Type or units</td>
<td>LDM threads</td>
</tr>
<tr>
<td>Default</td>
<td>3840</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 3840</td>
</tr>
</tbody>
</table>
NDB 7.2.7 and later use a larger default table hash map size (3840) than in previous releases (240). Beginning with NDB 7.2.11, the size of the table hash maps used by NDB is configurable using this parameter; previously this value was hard-coded. DefaultHashMapSize can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table:

Table 18.54 DefaultHashMapSize parameters

<table>
<thead>
<tr>
<th>Value</th>
<th>Description / Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.</td>
</tr>
<tr>
<td>240</td>
<td>Original hash map size (used by default in all NDB Cluster releases prior to NDB 7.2.7)</td>
</tr>
<tr>
<td>3840</td>
<td>Larger hash map size (used by default beginning with NDB 7.2.7)</td>
</tr>
</tbody>
</table>

The primary intended use for this parameter is to facilitate upgrades and especially downgrades between NDB 7.2.7 and later NDB Cluster versions, in which the larger hash map size (3840) is the default, and earlier releases (in which the default was 240), due to the fact that this change is not otherwise backward compatible (Bug #14800539). By setting this parameter to 240 prior to performing an upgrade from an older version where this value is in use, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions following the upgrade. DefaultHashMapSize can be set for individual data nodes, API nodes, or both, but setting it once only, in the [ndbd default] section of the config.ini file, is the recommended practice.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run ALTER TABLE ... REORGANIZE PARTITION on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with DefaultHashMapSize equal to 3840 is not currently supported.

Logging and checkpointing. The following [ndbd] parameters control log and checkpoint behavior.

- NoOfFragmentLogFiles

Table 18.55 This table provides type and value information for the NoOfFragmentLogFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>16</td>
</tr>
<tr>
<td>Range</td>
<td>3 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

This parameter sets the number of REDO log files for the node, and thus the amount of space allocated to REDO logging. Because the REDO log files are organized in a ring, it is extremely important that the first and last log files in the set (sometimes referred to as the “head” and “tail” log files, respectively) do not meet. When these approach one another too closely, the node begins aborting all transactions encompassing updates due to a lack of room for new log records.
A REDO log record is not removed until the required number of local checkpoints has been completed since that log record was inserted. (In NDB Cluster 7.2, only 2 local checkpoints are necessary). Checkpointing frequency is determined by its own set of configuration parameters discussed elsewhere in this chapter.

The default parameter value is 16, which by default means 16 sets of 4 16MB files for a total of 1024MB. The size of the individual log files is configurable using the FragmentLogFileSize parameter. In scenarios requiring a great many updates, the value for NoOfFragmentLogFiles may need to be set as high as 300 or even higher to provide sufficient space for REDO logs.

If the checkpointing is slow and there are so many writes to the database that the log files are full and the log tail cannot be cut without jeopardizing recovery, all updating transactions are aborted with internal error code 410 (Out of log file space temporarily). This condition prevails until a checkpoint has completed and the log tail can be moved forward.

Important
This parameter cannot be changed “on the fly”; you must restart the node using --initial. If you wish to change this value for all data nodes in a running cluster, you can do so using a rolling node restart (using --initial when starting each data node).

- FragmentLogFileSize

Table 18.56 This table provides type and value information for the FragmentLogFileSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>16M</td>
</tr>
<tr>
<td>Range</td>
<td>4M - 1G</td>
</tr>
</tbody>
</table>

Setting this parameter enables you to control directly the size of redo log files. This can be useful in situations when NDB Cluster is operating under a high load and it is unable to close fragment log files quickly enough before attempting to open new ones (only 2 fragment log files can be open at one time); increasing the size of the fragment log files gives the cluster more time before having to open each new fragment log file. The default value for this parameter is 16M.

For more information about fragment log files, see the description for NoOfFragmentLogFiles.

- InitFragmentLogFiles

Table 18.57 This table provides type and value information for the InitFragmentLogFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>[see values]</td>
</tr>
<tr>
<td>Default</td>
<td>SPARSE</td>
</tr>
<tr>
<td>Range</td>
<td>SPARSE, FULL</td>
</tr>
</tbody>
</table>
By default, fragment log files are created sparsely when performing an initial start of a data node—that is, depending on the operating system and file system in use, not all bytes are necessarily written to disk. However, it is possible to override this behavior and force all bytes to be written, regardless of the platform and file system type being used, by means of this parameter. `InitFragmentLogFiles` takes either of two values:

- **SPARSE**. Fragment log files are created sparsely. This is the default value.
- **FULL**. Force all bytes of the fragment log file to be written to disk.

Depending on your operating system and file system, setting `InitFragmentLogFiles=FULL` may help eliminate I/O errors on writes to the REDO log.

- **MaxNoOfOpenFiles**

  **Table 18.58** This table provides type and value information for the MaxNoOfOpenFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>20 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets a ceiling on how many internal threads to allocate for open files. *Any situation requiring a change in this parameter should be reported as a bug.*

The default value is 0. However, the minimum value to which this parameter can be set is 20.

- **InitialNoOfOpenFiles**

  **Table 18.59** This table provides type and value information for the InitialNoOfOpenFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>files</td>
</tr>
<tr>
<td>Default</td>
<td>27</td>
</tr>
<tr>
<td>Range</td>
<td>20 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets the initial number of internal threads to allocate for open files.

The default value is 27.
• **MaxNoOfSavedMessages**

Table 18.60 This table provides type and value information for the MaxNoOfSavedMessages data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>25</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets the maximum number of errors written in the error log as well as the maximum number of trace files that are kept before overwriting the existing ones. Trace files are generated when, for whatever reason, the node crashes.

The default is 25, which sets these maximums to 25 error messages and 25 trace files.

• **MaxLCPStartDelay**

Table 18.61 This table provides type and value information for the MaxLCPStartDelay data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>seconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 600</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

In parallel data node recovery, only table data is actually copied and synchronized in parallel; synchronization of metadata such as dictionary and checkpoint information is done in a serial fashion. In addition, recovery of dictionary and checkpoint information cannot be executed in parallel with performing of local checkpoints. This means that, when starting or restarting many data nodes concurrently, data nodes may be forced to wait while a local checkpoint is performed, which can result in longer node recovery times.

It is possible to force a delay in the local checkpoint to permit more (and possibly all) data nodes to complete metadata synchronization; once each data node’s metadata synchronization is complete, all of the data nodes can recover table data in parallel, even while the local checkpoint is being executed. To force such a delay, set **MaxLCPStartDelay**, which determines the number of seconds the cluster can wait to begin a local checkpoint while data nodes continue to synchronize metadata. This parameter should be set in the `[ndbd default]` section of the `config.ini` file, so that it is the same for all data nodes. The maximum value is 600; the default is 0.

• **LcpScanProgressTimeout**

Table 18.62 This table provides type and value information for the LcpScanProgressTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.14</td>
</tr>
</tbody>
</table>
A local checkpoint fragment scan watchdog checks periodically for no progress in each fragment scan performed as part of a local checkpoint, and shuts down the node if there is no progress after a given amount of time has elapsed. Prior to NDB 7.2.14, this interval is always 60 seconds (Bug #16630410). In NDB 7.2.14 and later, this interval can be set using the `LcpScanProgressTimeout` data node configuration parameter, which sets the maximum time for which the local checkpoint can be stalled before the LCP fragment scan watchdog shuts down the node.

The default value is 60 seconds (providing compatibility with previous releases). Setting this parameter to 0 disables the LCP fragment scan watchdog altogether.

**Metadata objects.** The next set of `[ndbd]` parameters defines pool sizes for metadata objects, used to define the maximum number of attributes, tables, indexes, and trigger objects used by indexes, events, and replication between clusters. Note that these act merely as “suggestions” to the cluster, and any that are not specified revert to the default values shown.

- **MaxNoOfAttributes**

  This parameter sets a suggested maximum number of attributes that can be defined in the cluster; like `MaxNoOfTables`, it is not intended to function as a hard upper limit.

  (In older NDB Cluster releases, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with NDB Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible [or not possible, depending on the circumstances] to create more than `MaxNoOfAttributes` attributes.)

  The default value is 1000, with the minimum possible value being 32. The maximum is 4294967039. Each attribute consumes around 200 bytes of storage per node due to the fact that all metadata is fully replicated on the servers.

  When setting `MaxNoOfAttributes`, it is important to prepare in advance for any `ALTER TABLE` statements that you might want to perform in the future. This is due to the fact, during the execution of `ALTER TABLE` on a Cluster table, 3 times the number of attributes as in the original table are used, and a good practice is to permit double this amount. For example, if the NDB Cluster table having the greatest number of attributes (`greatest_number_of_attributes`) has 100 attributes, a good starting point for the value of `MaxNoOfAttributes` would be `6 * greatest_number_of_attributes = 600`.  

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>1000</td>
</tr>
<tr>
<td>Range</td>
<td>32 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>
You should also estimate the average number of attributes per table and multiply this by `MaxNoOfTables`. If this value is larger than the value obtained in the previous paragraph, you should use the larger value instead.

Assuming that you can create all desired tables without any problems, you should also verify that this number is sufficient by trying an actual `ALTER TABLE` after configuring the parameter. If this is not successful, increase `MaxNoOfAttributes` by another multiple of `MaxNoOfTables` and test it again.

- `MaxNoOfTables`

Table 18.64 This table provides type and value information for the `MaxNoOfTables` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>128</td>
</tr>
<tr>
<td>Range</td>
<td>8 - 20320</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>N</strong></td>
</tr>
</tbody>
</table>

A table object is allocated for each table and for each unique hash index in the cluster. This parameter sets a suggested maximum number of table objects for the cluster as a whole; like `MaxNoOfAttributes`, it is not intended to function as a hard upper limit.

(In older NDB Cluster releases, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with NDB Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible [or not possible, depending on the circumstances] to create more than `MaxNoOfTables` tables.)

For each attribute that has a `BLOB` data type an extra table is used to store most of the `BLOB` data. These tables also must be taken into account when defining the total number of tables.

The default value of this parameter is 128. The minimum is 8 and the maximum is 20320. Each table object consumes approximately 20KB per node.

**Note**

The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfOrderedIndexes`

Table 18.65 This table provides type and value information for the `MaxNoOfOrderedIndexes` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>128</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
For each ordered index in the cluster, an object is allocated describing what is being indexed and its storage segments. By default, each index so defined also defines an ordered index. Each unique index and primary key has both an ordered index and a hash index. MaxNoOfOrderedIndexes sets the total number of ordered indexes that can be in use in the system at any one time.

The default value of this parameter is 128. Each index object consumes approximately 10KB of data per node.

Note

The sum of MaxNoOfTables, MaxNoOfOrderedIndexes, and MaxNoOfUniqueHashIndexes must not exceed $2^{32} - 2$ (4294967294).

* MaxNoOfUniqueHashIndexes

Table 18.66 This table provides type and value information for the MaxNoOfUniqueHashIndexes data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>64</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

For each unique index that is not a primary key, a special table is allocated that maps the unique key to the primary key of the indexed table. By default, an ordered index is also defined for each unique index. To prevent this, you must specify the USING HASH option when defining the unique index.

The default value is 64. Each index consumes approximately 15KB per node.

Note

The sum of MaxNoOfTables, MaxNoOfOrderedIndexes, and MaxNoOfUniqueHashIndexes must not exceed $2^{32} - 2$ (4294967294).

* MaxNoOfTriggers

Table 18.67 This table provides type and value information for the MaxNoOfTriggers data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>768</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
Internal update, insert, and delete triggers are allocated for each unique hash index. (This means that three triggers are created for each unique hash index.) However, an ordered index requires only a single trigger object. Backups also use three trigger objects for each normal table in the cluster.

Replication between clusters also makes use of internal triggers.

This parameter sets the maximum number of trigger objects in the cluster.

The default value is 768.

- **MaxNoOfIndexes**

This parameter is deprecated and subject to removal in a future version of NDB Cluster. You should use MaxNoOfOrderedIndexes and MaxNoOfUniqueHashIndexes instead.

This parameter is used only by unique hash indexes. There needs to be one record in this pool for each unique hash index defined in the cluster.

The default value of this parameter is 128.

- **MaxNoOfSubscriptions**

Table 18.68 This table provides type and value information for the MaxNoOfSubscriptions data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Each NDB table in an NDB Cluster requires a subscription in the NDB kernel. For some NDB API applications, it may be necessary or desirable to change this parameter. However, for normal usage with MySQL servers acting as SQL nodes, there is not any need to do so.

The default value for MaxNoOfSubscriptions is 0, which is treated as equal to MaxNoOfTables. Each subscription consumes 108 bytes.

- **MaxNoOfSubscribers**

Table 18.69 This table provides type and value information for the MaxNoOfSubscribers data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
This parameter is of interest only when using NDB Cluster Replication. The default value is 0, which is treated as \(2 \times \text{MaxNoOfTables}\); that is, there is one subscription per NDB table for each of two MySQL servers (one acting as the replication master and the other as the slave). Each subscriber uses 16 bytes of memory.

When using circular replication, multi-master replication, and other replication setups involving more than 2 MySQL servers, you should increase this parameter to the number of \texttt{mysqld} processes included in replication (this is often, but not always, the same as the number of clusters). For example, if you have a circular replication setup using three NDB Clusters, with one \texttt{mysqld} attached to each cluster, and each of these \texttt{mysqld} processes acts as a master and as a slave, you should set \texttt{MaxNoOfSubscribers} equal to \(3 \times \text{MaxNoOfTables}\).

For more information, see Section 18.6, "NDB Cluster Replication".

• \textbf{MaxNoOfConcurrentSubOperations}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version (or later)</strong></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><strong>Type or units</strong></td>
<td>unsigned</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>256</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>0 - 4294967039 (0xFFFFFFFFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets a ceiling on the number of operations that can be performed by all API nodes in the cluster at one time. The default value (256) is sufficient for normal operations, and might need to be adjusted only in scenarios where there are a great many API nodes each performing a high volume of operations concurrently.

**Boolean parameters.** The behavior of data nodes is also affected by a set of \texttt{[ndbd]} parameters taking on boolean values. These parameters can each be specified as \texttt{TRUE} by setting them equal to \texttt{1} or \texttt{Y}, and as \texttt{FALSE} by setting them equal to \texttt{0} or \texttt{N}.

• \textbf{LateAlloc}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version (or later)</strong></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><strong>Type or units</strong></td>
<td>numeric</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>0 - 1</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>
Allocate memory for this data node after a connection to the management server has been established. Enabled by default.

- LockPagesInMainMemory

Table 18.72 This table provides type and value information for the LockPagesInMainMemory data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 2</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

For a number of operating systems, including Solaris and Linux, it is possible to lock a process into memory and so avoid any swapping to disk. This can be used to help guarantee the cluster’s real-time characteristics.

This parameter takes one of the integer values 0, 1, or 2, which act as shown in the following list:

- **0**: Disables locking. This is the default value.
- **1**: Performs the lock after allocating memory for the process.
- **2**: Performs the lock before memory for the process is allocated.

If the operating system is not configured to permit unprivileged users to lock pages, then the data node process making use of this parameter may have to be run as system root. (**LockPagesInMainMemory** uses the **mlockall** function. From Linux kernel 2.6.9, unprivileged users can lock memory as limited by **max locked memory**. For more information, see **ulimit -l** and [http://linux.die.net/man/2/mlock](http://linux.die.net/man/2/mlock).)

---

**Note**

In older NDB Cluster releases, this parameter was a Boolean. 0 or **false** was the default setting, and disabled locking. 1 or **true** enabled locking of the process after its memory was allocated. In NDB Cluster 7.2, using **true** or **false** as the value of this parameter causes an error.

---

**Important**

Beginning with **glibc** 2.10, **glibc** uses per-thread arenas to reduce lock contention on a shared pool, which consumes real memory. In general, a data node process does not need per-thread arenas, since it does not perform any memory allocation after startup. (This difference in allocators does not appear to affect performance significantly.)

The **glibc** behavior is intended to be configurable via the **MALLOC_ARENA_MAX** environment variable, but a bug in this mechanism prior to **glibc** 2.16 meant that this variable could not be set to less than 8, so that the wasted memory...
could not be reclaimed. (Bug #15907219; see also http://sourceware.org/bugzilla/show_bug.cgi?id=13137 for more information concerning this issue.)

One possible workaround for this problem is to use the `LD_PRELOAD` environment variable to preload a `jemalloc` memory allocation library to take the place of that supplied with `glibc`.

- **StopOnError**

  Table 18.73 This table provides type and value information for the StopOnError data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>0, 1</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies whether a data node process should exit or perform an automatic restart when an error condition is encountered.

This parameter's default value is 1; this means that, by default, an error causes the data node process to halt.

When an error is encountered and `StopOnError` is 0, the data node process is restarted.

**Important**

If the data node process exits in an uncontrolled fashion (due, for example, to performing `kill -9` on the data node process while performing a query, or to a segmentation fault), and `StopOnError` is set to 0, the angel process attempts to restart it in exactly the same way as it was started previously—that is, using the same startup options that were employed the last time the node was started. Thus, if the data node process was originally started using the `--initial` option, it is also restarted with `--initial`. This means that, in such cases, if the failure occurs on a sufficient number of data nodes in a very short interval, the effect is the same as if you had performed an initial restart of the entire cluster, leading to loss of all data. (Bug #24945638)

Users of MySQL Cluster Manager should note that, when `StopOnError` equals 1, this prevents the MySQL Cluster Manager agent from restarting any data nodes after it has performed its own restart and recovery. See Starting and Stopping the Agent on Linux, for more information.

- **CrashOnCorruptedTuple**

  Table 18.74 This table provides type and value information for the CrashOnCorruptedTuple data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>true</td>
</tr>
</tbody>
</table>
When this parameter is enabled, it forces a data node to shut down whenever it encounters a corrupted tuple. In NDB 7.2.1 and later, it is enabled by default. This is a change from NDB Cluster 7.0 and NDB Cluster 7.1, where it was disabled by default.

- **Diskless**

Table 18.75 This table provides type and value information for the Diskless data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>true</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

It is possible to specify NDB Cluster tables as *diskless*, meaning that tables are not checkpointed to disk and that no logging occurs. Such tables exist only in main memory. A consequence of using diskless tables is that neither the tables nor the records in those tables survive a crash. However, when operating in diskless mode, it is possible to run ndbd on a diskless computer.

⚠️ **Important**

This feature causes the *entire* cluster to operate in diskless mode.

When this feature is enabled, Cluster online backup is disabled. In addition, a partial start of the cluster is not possible.

**Diskless** is disabled by default.

- **ODirect**

Table 18.76 This table provides type and value information for the ODirect data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Enabling this parameter causes NDB to attempt using O_DIRECT writes for LCP, backups, and redo logs, often lowering kswapd and CPU usage. When using NDB Cluster on Linux, enable ODirect if you are using a 2.6 or later kernel.

**ODirect** is disabled by default.
• **RestartOnErrorInsert**

Table 18.77 This table provides type and value information for the RestartOnErrorInsert data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>error code</td>
</tr>
<tr>
<td>Default</td>
<td>2</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This feature is accessible only when building the debug version where it is possible to insert errors in the execution of individual blocks of code as part of testing.

This feature is disabled by default.

• **CompressedBackup**

Table 18.78 This table provides type and value information for the CompressedBackup data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Enabling this parameter causes backup files to be compressed. The compression used is equivalent to `gzip --fast`, and can save 50% or more of the space required on the data node to store uncompressed backup files. Compressed backups can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the `[ndbd default]` section of the `config.ini` file).

⚠️ **Important**

You cannot restore a compressed backup to a cluster running a MySQL version that does not support this feature.

The default value is 0 (disabled).

• **CompressedLCP**

Table 18.79 This table provides type and value information for the CompressedLCP data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Setting this parameter to 1 causes local checkpoint files to be compressed. The compression used is equivalent to gzip --fast, and can save 50% or more of the space required on the data node to store uncompressed checkpoint files. Compressed LCPs can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the [ndbd default] section of the config.ini file).

Important

You cannot restore a compressed local checkpoint to a cluster running a MySQL version that does not support this feature.

The default value is 0 (disabled).

Controlling Timeouts, Intervals, and Disk Paging

There are a number of [ndbd] parameters specifying timeouts and intervals between various actions in Cluster data nodes. Most of the timeout values are specified in milliseconds. Any exceptions to this are mentioned where applicable.

• TimeBetweenWatchDogCheck

Table 18.80 This table provides type and value information for the TimeBetweenWatchDogCheck data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>6000</td>
</tr>
<tr>
<td>Range</td>
<td>70 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>

To prevent the main thread from getting stuck in an endless loop at some point, a “watchdog” thread checks the main thread. This parameter specifies the number of milliseconds between checks. If the process remains in the same state after three checks, the watchdog thread terminates it.

This parameter can easily be changed for purposes of experimentation or to adapt to local conditions. It can be specified on a per-node basis although there seems to be little reason for doing so.

The default timeout is 6000 milliseconds (6 seconds).

• TimeBetweenWatchDogCheckInitial

Table 18.81 This table provides type and value information for the TimeBetweenWatchDogCheckInitial data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>6000</td>
</tr>
<tr>
<td>Range</td>
<td>70 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This is similar to the `TimeBetweenWatchDogCheck` parameter, except that `TimeBetweenWatchDogCheckInitial` controls the amount of time that passes between execution checks inside a storage node in the early start phases during which memory is allocated.

The default timeout is 6000 milliseconds (6 seconds).

- **StartPartialTimeout**

  **Table 18.82** This table provides type and value information for the `StartPartialTimeout` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>30000</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies how long the Cluster waits for all data nodes to come up before the cluster initialization routine is invoked. This timeout is used to avoid a partial Cluster startup whenever possible.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default value is 30000 milliseconds (30 seconds). 0 disables the timeout, in which case the cluster may start only if all nodes are available.

- **StartPartitionedTimeout**

  **Table 18.83** This table provides type and value information for the `StartPartitionedTimeout` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>60000</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

If the cluster is ready to start after waiting for `StartPartialTimeout` milliseconds but is still possibly in a partitioned state, the cluster waits until this timeout has also passed. If `StartPartitionedTimeout` is set to 0, the cluster waits indefinitely.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default timeout is 60000 milliseconds (60 seconds).
• **StartFailureTimeout**

Table 18.84 This table provides type and value information for the StartFailureTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

If a data node has not completed its startup sequence within the time specified by this parameter, the node startup fails. Setting this parameter to 0 (the default value) means that no data node timeout is applied.

For nonzero values, this parameter is measured in milliseconds. For data nodes containing extremely large amounts of data, this parameter should be increased. For example, in the case of a data node containing several gigabytes of data, a period as long as 10–15 minutes (that is, 600000 to 1000000 milliseconds) might be required to perform a node restart.

• **StartNoNodeGroupTimeout**

Table 18.85 This table provides type and value information for the StartNoNodeGroupTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>15000</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

When a data node is configured with `Nodegroup = 65536`, is regarded as not being assigned to any node group. When that is done, the cluster waits `StartNoNodegroupTimeout` milliseconds, then treats such nodes as though they had been added to the list passed to the `--nowait-nodes` option, and starts. The default value is **15000** (that is, the management server waits 15 seconds). Setting this parameter equal to 0 means that the cluster waits indefinitely.

`StartNoNodegroupTimeout` must be the same for all data nodes in the cluster; for this reason, you should always set it in the `[ndbd default]` section of the `config.ini` file, rather than for individual data nodes.

See Section 18.5.14, “Adding NDB Cluster Data Nodes Online”, for more information.

• **HeartbeatIntervalDbDb**

Table 18.86 This table provides type and value information for the HeartbeatIntervalDbDb data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
</tbody>
</table>
One of the primary methods of discovering failed nodes is by the use of heartbeats. This parameter states how often heartbeat signals are sent and how often to expect to receive them. Heartbeats cannot be disabled.

After missing four heartbeat intervals in a row, the node is declared dead. Thus, the maximum time for discovering a failure through the heartbeat mechanism is five times the heartbeat interval.

In NDB 7.2.0 and later, the default heartbeat interval is 5000 milliseconds (5 seconds). (Previously, the default was 1500 milliseconds [1.5 seconds]). This parameter must not be changed drastically and should not vary widely between nodes. If one node uses 5000 milliseconds and the node watching it uses 1000 milliseconds, obviously the node will be declared dead very quickly. This parameter can be changed during an online software upgrade, but only in small increments.

See also Network communication and latency, as well as the description of the ConnectCheckIntervalDelay configuration parameter.

HeartbeatIntervalDbApi

Table 18.87 This table provides type and value information for the HeartbeatIntervalDbApi data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>1500</td>
</tr>
<tr>
<td>Range</td>
<td>100 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Each data node sends heartbeat signals to each MySQL server (SQL node) to ensure that it remains in contact. If a MySQL server fails to send a heartbeat in time it is declared “dead,” in which case all ongoing transactions are completed and all resources released. The SQL node cannot reconnect until all activities initiated by the previous MySQL instance have been completed. The three-heartbeat criteria for this determination are the same as described for HeartbeatIntervalDbDb.

The default interval is 1500 milliseconds (1.5 seconds). This interval can vary between individual data nodes because each data node watches the MySQL servers connected to it, independently of all other data nodes.

For more information, see Network communication and latency.
HeartbeatOrder

Table 18.88 This table provides type and value information for the HeartbeatOrder data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 65535</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

Data nodes send heartbeats to one another in a circular fashion whereby each data node monitors the previous one. If a heartbeat is not detected by a given data node, this node declares the previous data node in the circle “dead” (that is, no longer accessible by the cluster). The determination that a data node is dead is done globally; in other words; once a data node is declared dead, it is regarded as such by all nodes in the cluster.

It is possible for heartbeats between data nodes residing on different hosts to be too slow compared to heartbeats between other pairs of nodes (for example, due to a very low heartbeat interval or temporary connection problem), such that a data node is declared dead, even though the node can still function as part of the cluster.

In this type of situation, it may be that the order in which heartbeats are transmitted between data nodes makes a difference as to whether or not a particular data node is declared dead. If this declaration occurs unnecessarily, this can in turn lead to the unnecessary loss of a node group and as thus to a failure of the cluster.

Consider a setup where there are 4 data nodes A, B, C, and D running on 2 host computers host1 and host2, and that these data nodes make up 2 node groups, as shown in the following table:

Table 18.89 Four data nodes A, B, C, D running on two host computers host1, host2; each data node belongs to one of two node groups.

<table>
<thead>
<tr>
<th>Node Group</th>
<th>Nodes Running on host1</th>
<th>Nodes Running on host2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node Group 0:</td>
<td>Node A</td>
<td>Node B</td>
</tr>
<tr>
<td>Node Group 1:</td>
<td>Node C</td>
<td>Node D</td>
</tr>
</tbody>
</table>

Suppose the heartbeats are transmitted in the order A->B->C->D->A. In this case, the loss of the heartbeat between the hosts causes node B to declare node A dead and node C to declare node B dead. This results in loss of Node Group 0, and so the cluster fails. On the other hand, if the order of transmission is A->B->D->C->A (and all other conditions remain as previously stated), the loss of the heartbeat causes nodes A and D to be declared dead; in this case, each node group has one surviving node, and the cluster survives.

The HeartbeatOrder configuration parameter makes the order of heartbeat transmission user-configurable. The default value for HeartbeatOrder is zero; allowing the default value to be used on all data nodes causes the order of heartbeat transmission to be determined by NDB. If this parameter is used, it must be set to a nonzero value (maximum 65535) for every data node in the cluster, and this value must be unique for each data node; this causes the heartbeat transmission to proceed from data node to data node in the order of their HeartbeatOrder values from lowest to highest (and then directly from the data node having the highest HeartbeatOrder to the data node having the
lowest value, to complete the circle). The values need not be consecutive. For example, to force the heartbeat transmission order A->B->D->C->A in the scenario outlined previously, you could set the HeartbeatOrder values as shown here:

Table 18.90 HeartbeatOrder values to force a heartbeat transition order of A->B->D->C->A.

<table>
<thead>
<tr>
<th>Node</th>
<th>HeartbeatOrder Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
</tr>
<tr>
<td>D</td>
<td>25</td>
</tr>
</tbody>
</table>

To use this parameter to change the heartbeat transmission order in a running NDB Cluster, you must first set HeartbeatOrder for each data node in the cluster in the global configuration (config.ini) file (or files). To cause the change to take effect, you must perform either of the following:

- A complete shutdown and restart of the entire cluster.
- 2 rolling restarts of the cluster in succession. All nodes must be restarted in the same order in both rolling restarts.

You can use DUMP 908 to observe the effect of this parameter in the data node logs.

Table 18.91 This table provides type and value information for the ConnectCheckIntervalDelay data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter enables connection checking between data nodes after one of them has failed heartbeat checks for 5 intervals of up to HeartbeatIntervalDbDb milliseconds.

Such a data node that further fails to respond within an interval of ConnectCheckIntervalDelay milliseconds is considered suspect, and is considered dead after two such intervals. This can be useful in setups with known latency issues.

The default value for this parameter is 0 (disabled); this represents a change from NDB Cluster 7.1.

Table 18.92 This table provides type and value information for the TimeBetweenLocalCheckpoints data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>number of 4-byte words, as a base-2 logarithm</td>
</tr>
</tbody>
</table>
This parameter is an exception in that it does not specify a time to wait before starting a new local checkpoint; rather, it is used to ensure that local checkpoints are not performed in a cluster where relatively few updates are taking place. In most clusters with high update rates, it is likely that a new local checkpoint is started immediately after the previous one has been completed.

The size of all write operations executed since the start of the previous local checkpoints is added. This parameter is also exceptional in that it is specified as the base-2 logarithm of the number of 4-byte words, so that the default value 20 means 4MB (4 × 2^20) of write operations, 21 would mean 8MB, and so on up to a maximum value of 31, which equates to 8GB of write operations.

All the write operations in the cluster are added together. Setting `TimeBetweenLocalCheckpoints` to 6 or less means that local checkpoints will be executed continuously without pause, independent of the cluster's workload.

- `TimeBetweenGlobalCheckpoints`

Table 18.93 This table provides type and value information for the `TimeBetweenGlobalCheckpoints` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>2000</td>
</tr>
<tr>
<td>Range</td>
<td>20 - 32000</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

When a transaction is committed, it is committed in main memory in all nodes on which the data is mirrored. However, transaction log records are not flushed to disk as part of the commit. The reasoning behind this behavior is that having the transaction safely committed on at least two autonomous host machines should meet reasonable standards for durability.

It is also important to ensure that even the worst of cases—a complete crash of the cluster—is handled properly. To guarantee that this happens, all transactions taking place within a given interval are put into a global checkpoint, which can be thought of as a set of committed transactions that has been flushed to disk. In other words, as part of the commit process, a transaction is placed in a global checkpoint group. Later, this group’s log records are flushed to disk, and then the entire group of transactions is safely committed to disk on all computers in the cluster.

This parameter defines the interval between global checkpoints. The default is 2000 milliseconds.

- `TimeBetweenGlobalCheckpointsTimeout`

Table 18.94 This table provides type and value information for the `TimeBetweenGlobalCheckpointsTimeout` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.20</td>
</tr>
</tbody>
</table>
This parameter defines the minimum timeout between global checkpoints. The default is 120000 milliseconds.

This parameter was added in NDB 7.2.20. (Bug #20069617)

- **TimeBetweenEpochs**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 32000</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter defines the interval between synchronization epochs for NDB Cluster Replication. The default value is 100 milliseconds.

**TimeBetweenEpochs** is part of the implementation of “micro-GCPs”, which can be used to improve the performance of NDB Cluster Replication.

- **TimeBetweenEpochsTimeout**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 256000</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter defines a timeout for synchronization epochs for NDB Cluster Replication. If a node fails to participate in a global checkpoint within the time determined by this parameter, the node is shut down. In NDB 7.2.0 and later, the default value is 0; in other words, the timeout is disabled. This represents
a change from previous versions of NDB Cluster, in which the default value was 4000 milliseconds (4 seconds).

`TimeBetweenEpochsTimeout` is part of the implementation of “micro-GCPs”, which can be used to improve the performance of NDB Cluster Replication.

The current value of this parameter and a warning are written to the cluster log whenever a GCP save takes longer than 1 minute or a GCP commit takes longer than 10 seconds.

Setting this parameter to zero has the effect of disabling GCP stops caused by save timeouts, commit timeouts, or both. The maximum possible value for this parameter is 256000 milliseconds.

- **MaxBufferedEpochs**

Table 18.97 This table provides type and value information for the MaxBufferedEpochs data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>epochs</td>
</tr>
<tr>
<td>Default</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 100000</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The number of unprocessed epochs by which a subscribing node can lag behind. Exceeding this number causes a lagging subscriber to be disconnected.

The default value of 100 is sufficient for most normal operations. If a subscribing node does lag enough to cause disconnections, it is usually due to network or scheduling issues with regard to processes or threads. (In rare circumstances, the problem may be due to a bug in the `NDDB` client.) It may be desirable to set the value lower than the default when epochs are longer.

Disconnection prevents client issues from affecting the data node service, running out of memory to buffer data, and eventually shutting down. Instead, only the client is affected as a result of the disconnect (by, for example gap events in the binary log), forcing the client to reconnect or restart the process.

- **MaxBufferedEpochBytes**

Table 18.98 This table provides type and value information for the MaxBufferedEpochBytes data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.13</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>26214400</td>
</tr>
<tr>
<td>Range</td>
<td>26214400 (0x01900000) - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The total number of bytes allocated for buffering epochs by this node.
• **TimeBetweenInactiveTransactionAbortCheck**

Table 18.99 This table provides type and value information for the TimeBetweenInactiveTransactionAbortCheck data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>1000</td>
</tr>
<tr>
<td>Range</td>
<td>1000 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Timeout handling is performed by checking a timer on each transaction once for every interval specified by this parameter. Thus, if this parameter is set to 1000 milliseconds, every transaction will be checked for timing out once per second.

The default value is 1000 milliseconds (1 second).

• **TransactionInactiveTimeout**

Table 18.100 This table provides type and value information for the TransactionInactiveTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter states the maximum time that is permitted to lapse between operations in the same transaction before the transaction is aborted.

The default for this parameter is 4G (also the maximum). For a real-time database that needs to ensure that no transaction keeps locks for too long, this parameter should be set to a relatively small value. Setting it to 0 means that the application never times out. The unit is milliseconds.

• **TransactionDeadlockDetectionTimeout**

Table 18.101 This table provides type and value information for the TransactionDeadlockDetectionTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>1200</td>
</tr>
<tr>
<td>Range</td>
<td>50 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
When a node executes a query involving a transaction, the node waits for the other nodes in the cluster to respond before continuing. This parameter sets the amount of time that the transaction can spend executing within a data node, that is, the time that the transaction coordinator waits for each data node participating in the transaction to execute a request.

A failure to respond can occur for any of the following reasons:

- The node is “dead”
- The operation has entered a lock queue
- The node requested to perform the action could be heavily overloaded.

This timeout parameter states how long the transaction coordinator waits for query execution by another node before aborting the transaction, and is important for both node failure handling and deadlock detection.

The default timeout value is 1200 milliseconds (1.2 seconds).

The minimum for this parameter is 50 milliseconds.

- **DiskSyncSize**

  **Table 18.102** This table provides type and value information for the DiskSyncSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>4M</td>
</tr>
<tr>
<td>Range</td>
<td>32K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This is the maximum number of bytes to store before flushing data to a local checkpoint file. This is done to prevent write buffering, which can impede performance significantly. This parameter is *not* intended to take the place of `TimeBetweenLocalCheckpoints`.

**Note**

When `ODirect` is enabled, it is not necessary to set `DiskSyncSize`; in fact, in such cases its value is simply ignored.

The default value is 4M (4 megabytes).

- **DiskCheckpointSpeed**

  **Table 18.103** This table provides type and value information for the DiskCheckpointSpeed data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
</tbody>
</table>
The amount of data, in bytes per second, that is sent to disk during a local checkpoint. This allocation is shared by DML operations and backups (but not backup logging), which means that backups started during times of intensive DML may be impaired by flooding of the redo log buffer and may fail altogether if the contention is sufficiently severe.

The default value is 10M (10 megabytes per second).

- **DiskCheckpointSpeedInRestart**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type or units</strong></td>
<td>bytes</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>10M</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>1M - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Table 18.104 This table provides type and value information for the DiskCheckpointSpeedInRestart data node configuration parameter

The amount of data, in bytes per second, that is sent to disk during a local checkpoint as part of a restart operation.

The default value is 100M (100 megabytes per second).

- **NoOfDiskPagesToDiskAfterRestartTUP**

  This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use DiskCheckpointSpeedInRestart and DiskSyncSize instead.

- **NoOfDiskPagesToDiskAfterRestartACC**

  This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use DiskCheckpointSpeedInRestart and DiskSyncSize instead.

- **NoOfDiskPagesToDiskDuringRestartTUP** (DEPRECATED)

  This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use DiskCheckpointSpeedInRestart and DiskSyncSize instead.

- **NoOfDiskPagesToDiskDuringRestartACC** (DEPRECATED)

  This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use DiskCheckpointSpeedInRestart and DiskSyncSize instead.
• **ArbitrationTimeout**

Table 18.105 This table provides type and value information for the ArbitrationTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>7500</td>
</tr>
<tr>
<td>Range</td>
<td>10 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies how long data nodes wait for a response from the arbitrator to an arbitration message. If this is exceeded, the network is assumed to have split.

In NDB 7.2.0 and later, the default value is 7500 milliseconds (7.5 seconds). Previously, this was 3000 milliseconds (3 seconds).

• **Arbitration**

Table 18.106 This table provides type and value information for the Arbitration data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>enumeration</td>
</tr>
<tr>
<td>Default</td>
<td>Default</td>
</tr>
<tr>
<td>Range</td>
<td>Default, Disabled, WaitExternal</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The **Arbitration** parameter enables a choice of arbitration schemes, corresponding to one of 3 possible values for this parameter:

• **Default.** This enables arbitration to proceed normally, as determined by the **ArbitrationRank** settings for the management and API nodes. This is the default value.

• **Disabled.** Setting **Arbitration = Disabled** in the [ndbd default] section of the config.ini file to accomplishes the same task as setting **ArbitrationRank** to 0 on all management and API nodes. When **Arbitration** is set in this way, any **ArbitrationRank** settings are ignored.

• **WaitExternal.** The **Arbitration** parameter also makes it possible to configure arbitration in such a way that the cluster waits until after the time determined by **ArbitrationTimeout** has passed for an external cluster manager application to perform arbitration instead of handling arbitration internally. This can be done by setting **Arbitration = WaitExternal** in the [ndbd default] section of the config.ini file. For best results with the **WaitExternal** setting, it is recommended that
ArbitrationTimeout be 2 times as long as the interval required by the external cluster manager to perform arbitration.

Important
This parameter should be used only in the [ndbd default] section of the cluster configuration file. The behavior of the cluster is unspecified when Arbitration is set to different values for individual data nodes.

• RestartSubscriberConnectTimeout

Table 18.107 This table provides type and value information for the RestartSubscriberConnectTimeout data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.17</td>
</tr>
<tr>
<td>Type or units</td>
<td>ms</td>
</tr>
<tr>
<td>Default</td>
<td>12000</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This parameter determines the time that a data node waits for subscribing API nodes to connect. Once this timeout expires, any “missing” API nodes are disconnected from the cluster. To disable this timeout, set RestartSubscriberConnectTimeout to 0.

While this parameter is specified in milliseconds, the timeout itself is resolved to the next-greatest whole second.

RestartSubscriberConnectTimeout was added in NDB 7.2.17.

Buffering and logging. Several [ndbd] configuration parameters enable the advanced user to have more control over the resources used by node processes and to adjust various buffer sizes at need.

These buffers are used as front ends to the file system when writing log records to disk. If the node is running in diskless mode, these parameters can be set to their minimum values without penalty due to the fact that disk writes are “faked” by the NDB storage engine’s file system abstraction layer.

• UndoIndexBuffer

Table 18.108 This table provides type and value information for the UndoIndexBuffer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>2M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The UNDO index buffer, whose size is set by this parameter, is used during local checkpoints. The NDB storage engine uses a recovery scheme based on checkpoint consistency in conjunction with an operational REDO log. To produce a consistent checkpoint without blocking the entire system for writes, UNDO logging is done while performing the local checkpoint. UNDO logging is activated on a
single table fragment at a time. This optimization is possible because tables are stored entirely in main memory.

The UNDO index buffer is used for the updates on the primary key hash index. Inserts and deletes rearrange the hash index; the NDB storage engine writes UNDO log records that map all physical changes to an index page so that they can be undone at system restart. It also logs all active insert operations for each fragment at the start of a local checkpoint.

Reads and updates set lock bits and update a header in the hash index entry. These changes are handled by the page-writing algorithm to ensure that these operations need no UNDO logging.

This buffer is 2MB by default. The minimum value is 1MB, which is sufficient for most applications. For applications doing extremely large or numerous inserts and deletes together with large transactions and large primary keys, it may be necessary to increase the size of this buffer. If this buffer is too small, the NDB storage engine issues internal error code 677 (Index UNDO buffers overloaded).

Important

It is not safe to decrease the value of this parameter during a rolling restart.

• UndoDataBuffer

Table 18.109 This table provides type and value information for the UndoDataBuffer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>16M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets the size of the UNDO data buffer, which performs a function similar to that of the UNDO index buffer, except the UNDO data buffer is used with regard to data memory rather than index memory. This buffer is used during the local checkpoint phase of a fragment for inserts, deletes, and updates.

Because UNDO log entries tend to grow larger as more operations are logged, this buffer is also larger than its index memory counterpart, with a default value of 16MB.

This amount of memory may be unnecessarily large for some applications. In such cases, it is possible to decrease this size to a minimum of 1MB.

It is rarely necessary to increase the size of this buffer. If there is such a need, it is a good idea to check whether the disks can actually handle the load caused by database update activity. A lack of sufficient disk space cannot be overcome by increasing the size of this buffer.

If this buffer is too small and gets congested, the NDB storage engine issues internal error code 891 (Data UNDO buffers overloaded).

Important

It is not safe to decrease the value of this parameter during a rolling restart.
• **RedoBuffer**

**Table 18.110** This table provides type and value information for the RedoBuffer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>32M</td>
</tr>
<tr>
<td>Range</td>
<td>1M - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

All update activities also need to be logged. The REDO log makes it possible to replay these updates whenever the system is restarted. The NDB recovery algorithm uses a “fuzzy” checkpoint of the data together with the UNDO log, and then applies the REDO log to play back all changes up to the restoration point.

**RedoBuffer** sets the size of the buffer in which the REDO log is written. The default value is 32MB; the minimum value is 1MB.

If this buffer is too small, the NDB storage engine issues error code 1221 (**REDO log buffers overloaded**). For this reason, you should exercise care if you attempt to decrease the value of **RedoBuffer** as part of an online change in the cluster's configuration.

**ndbmtd** allocates a separate buffer for each LDM thread (see **ThreadConfig**). For example, with 4 LDM threads, an **ndbmtd** data node actually has 4 buffers and allocates **RedoBuffer** bytes to each one, for a total of \(4 \times \text{RedoBuffer}\) bytes.

• **EventLogBufferSize**

**Table 18.111** This table provides type and value information for the EventLogBufferSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>8192</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 64K</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

Controls the size of the circular buffer used for NDB log events within data nodes.

**Controlling log messages.** In managing the cluster, it is very important to be able to control the number of log messages sent for various event types to **stdout**. For each event category, there are 16 possible event levels (numbered 0 through 15). Setting event reporting for a given event category to level 15 means all event reports in that category are sent to **stdout**; setting it to 0 means that there will be no event reports made in that category.

By default, only the startup message is sent to **stdout**, with the remaining event reporting level defaults being set to 0. The reason for this is that these messages are also sent to the management server's cluster log.
An analogous set of levels can be set for the management client to determine which event levels to record in the cluster log.

- **LogLevelStartup**

  Table 18.112 This table provides type and value information for the LogLevelStartup data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated during startup of the process.

The default level is 1.

- **LogLevelShutdown**

  Table 18.113 This table provides type and value information for the LogLevelShutdown data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated as part of graceful shutdown of a node.

The default level is 0.

- **LogLevelStatistic**

  Table 18.114 This table provides type and value information for the LogLevelStatistic data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for statistical events such as number of primary key reads, number of updates, number of inserts, information relating to buffer usage, and so on.

The default level is 0.
• **LogLevelCheckpoint**

Table 18.115 This table provides type and value information for the LogLevelCheckpoint data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>log level</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated by local and global checkpoints.

The default level is 0.

• **LogLevelNodeRestart**

Table 18.116 This table provides type and value information for the LogLevelNodeRestart data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated during node restart.

The default level is 0.

• **LogLevelConnection**

Table 18.117 This table provides type and value information for the LogLevelConnection data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated by connections between cluster nodes.

The default level is 0.
• **LogLevelError**

  Table 18.118 This table provides type and value information for the LogLevelError data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated by errors and warnings by the cluster as a whole. These errors do not cause any node failure but are still considered worth reporting.

The default level is 0.

• **LogLevelCongestion**

  Table 18.119 This table provides type and value information for the LogLevelCongestion data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>level</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated by congestion. These errors do not cause node failure but are still considered worth reporting.

The default level is 0.

• **LogLevelInfo**

  Table 18.120 This table provides type and value information for the LogLevelInfo data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The reporting level for events generated for information about the general state of the cluster.

The default level is 0.

• **MemReportFrequency**
Table 18.121 This table provides type and value information for the MemReportFrequency data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter controls how often data node memory usage reports are recorded in the cluster log; it is an integer value representing the number of seconds between reports.

Each data node’s data memory and index memory usage is logged as both a percentage and a number of 32 KB pages of the DataMemory and IndexMemory, respectively, set in the config.ini file. For example, if DataMemory is equal to 100 MB, and a given data node is using 50 MB for data memory storage, the corresponding line in the cluster log might look like this:

```
2006-12-24 01:18:16 [MgmSrvr] INFO -- Node 2: Data usage is 50%(1280 32K pages of total 2560)
```

MemReportFrequency is not a required parameter. If used, it can be set for all cluster data nodes in the [ndbd default] section of config.ini, and can also be set or overridden for individual data nodes in the corresponding [ndbd] sections of the configuration file. The minimum value—which is also the default value—is 0, in which case memory reports are logged only when memory usage reaches certain percentages (80%, 90%, and 100%), as mentioned in the discussion of statistics events in Section 18.5.6.2, “NDB Cluster Log Events”.

- StartupStatusReportFrequency

Table 18.122 This table provides type and value information for the StartupStatusReportFrequency data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>seconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

When a data node is started with the --initial option, it initializes the redo log file during Start Phase 4 (see Section 18.5.1, “Summary of NDB Cluster Start Phases”). When very large values are set for NoOffFragmentLogFile, FragmentLogFileSize, or both, this initialization can take a long time. You can force reports on the progress of this process to be logged periodically, by means of the StartupStatusReportFrequency configuration parameter. In this case, progress is reported in the cluster log, in terms of both the number of files and the amount of space that have been initialized, as shown here:

```
#Total files: 80, Completed: 60
#Total MBytes: 20480, Completed: 15557
#Total files: 80, Completed: 60
```
These reports are logged each **StartupStatusReportFrequency** seconds during Start Phase 4. If **StartupStatusReportFrequency** is 0 (the default), then reports are written to the cluster log only when at the beginning and at the completion of the redo log file initialization process.

**Debugging Parameters.** In NDB Cluster 7.2, it is possible to cause logging of traces for events generated by creating and dropping tables using **DictTrace**. This parameter is useful only in debugging NDB kernel code. **DictTrace** takes an integer value; currently, 0 (default - no logging) and 1 (logging enabled) are the only supported values.

**Backup parameters.** The **[ndbd]** parameters discussed in this section define memory buffers set aside for execution of online backups.

- **BackupDataBufferSize**

**Table 18.123** This table provides type and value information for the **BackupDataBufferSize** data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>16M</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

In creating a backup, there are two buffers used for sending data to the disk. The backup data buffer is used to fill in data recorded by scanning a node's tables. Once this buffer has been filled to the level specified as **BackupWriteSize**, the pages are sent to disk. While flushing data to disk, the backup process can continue filling this buffer until it runs out of space. When this happens, the backup process pauses the scan and waits until some disk writes have completed freeing up memory so that scanning may continue.

The default value for this parameter is 16MB.

- **BackupLogBufferSize**

**Table 18.124** This table provides type and value information for the **BackupLogBufferSize** data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>16M</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The backup log buffer fulfills a role similar to that played by the backup data buffer, except that it is used for generating a log of all table writes made during execution of the backup. The same principles apply for writing these pages as with the backup data buffer, except that when there is no more space in the backup log buffer, the backup fails. For that reason, the size of the backup log buffer must
be large enough to handle the load caused by write activities while the backup is being made. See Section 18.5.3.3, “Configuration for NDB Cluster Backups”.

The default value for this parameter should be sufficient for most applications. In fact, it is more likely for a backup failure to be caused by insufficient disk write speed than it is for the backup log buffer to become full. If the disk subsystem is not configured for the write load caused by applications, the cluster is unlikely to be able to perform the desired operations.

It is preferable to configure cluster nodes in such a manner that the processor becomes the bottleneck rather than the disks or the network connections.

The default value for this parameter is 16MB.

- **BackupMemory**

  Table 18.125 This table provides type and value information for the BackupMemory data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>32M</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is simply the sum of `BackupDataBufferSize` and `BackupLogBufferSize`.

The default value of this parameter in NDB Cluster 7.2 is 16MB + 16MB = 32MB.

- **BackupReportFrequency**

  Table 18.126 This table provides type and value information for the BackupReportFrequency data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>seconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter controls how often backup status reports are issued in the management client during a backup, as well as how often such reports are written to the cluster log (provided cluster event logging is configured to permit it—see Logging and checkpointing). `BackupReportFrequency` represents the time in seconds between backup status reports.

The default value is 0.
• **BackupWriteSize**

Table 18.127 This table provides type and value information for the BackupWriteSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>256K</td>
</tr>
<tr>
<td>Range</td>
<td>2K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the default size of messages written to disk by the backup log and backup data buffers.

The default value for this parameter is 256KB.

• **BackupMaxWriteSize**

Table 18.128 This table provides type and value information for the BackupMaxWriteSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>1M</td>
</tr>
<tr>
<td>Range</td>
<td>2K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the maximum size of messages written to disk by the backup log and backup data buffers.

The default value for this parameter is 1MB.

**Note**

The location of the backup files is determined by the `BackupDataDir` data node configuration parameter.

**Additional requirements.** When specifying these parameters, the following relationships must hold true. Otherwise, the data node will be unable to start.

- `BackupDataBufferSize >= BackupWriteSize + 188KB`
- `BackupLogBufferSize >= BackupWriteSize + 16KB`
- `BackupMaxWriteSize >= BackupWriteSize`

**NDB Cluster Realtime Performance Parameters**

The `[ndbd]` parameters discussed in this section are used in scheduling and locking of threads to specific CPUs on multiprocessor data node hosts.
To make use of these parameters, the data node process must be run as system root.

- **LockExecuteThreadToCPU**

  Table 18.129 This table provides type and value information for the LockExecuteThreadToCPU data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>set of CPU IDs</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

When used with `ndbd`, this parameter (now a string) specifies the ID of the CPU assigned to handle the `NDBCLUSTER` execution thread. When used with `ndbmtd`, the value of this parameter is a comma-separated list of CPU IDs assigned to handle execution threads. Each CPU ID in the list should be an integer in the range 0 to 65535 (inclusive).

The number of IDs specified should match the number of execution threads determined by `MaxNoOfExecutionThreads`. However, there is no guarantee that threads are assigned to CPUs in any given order when using this parameter; beginning with in NDB 7.2.5, you can obtain more finely-grained control of this type using `ThreadConfig`.

**LockExecuteThreadToCPU** has no default value.

- **LockMaintThreadsToCPU**

  Table 18.130 This table provides type and value information for the LockMaintThreadsToCPU data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>CPU ID</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 64K</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the ID of the CPU assigned to handle `NDBCLUSTER` maintenance threads.

The value of this parameter is an integer in the range 0 to 65535 (inclusive). In NDB Cluster 7.2, there is no default value.
• **RealtimeScheduler**

Table 18.131 This table provides type and value information for the RealtimeScheduler data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>N</strong></td>
</tr>
</tbody>
</table>

Setting this parameter to 1 enables real-time scheduling of data node threads.

Prior to NDB 7.2.14, this parameter did not work correctly with data nodes running ndbmtd. (Bug #16961971)

The default is 0 (scheduling disabled).

• **SchedulerExecutionTimer**

Table 18.132 This table provides type and value information for the SchedulerExecutionTimer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>µs</td>
</tr>
<tr>
<td>Default</td>
<td>50</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 11000</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>N</strong></td>
</tr>
</tbody>
</table>

This parameter specifies the time in microseconds for threads to be executed in the scheduler before being sent. Setting it to 0 minimizes the response time; to achieve higher throughput, you can increase the value at the expense of longer response times.

The default is 50 µsec, which our testing shows to increase throughput slightly in high-load cases without materially delaying requests.

• **SchedulerSpinTimer**

Table 18.133 This table provides type and value information for the SchedulerSpinTimer data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>µs</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 500</td>
</tr>
</tbody>
</table>
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the time in microseconds for threads to be executed in the scheduler before sleeping.

The default value is 0.

**BuildIndexThreads**

**Table 18.134** This table provides type and value information for the BuildIndexThreads data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 128</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This parameter determines the number of threads to create when rebuilding ordered indexes during a system or node start, as well as when running `ndb_restore --rebuild-indexes`. It is supported only when there is more than one fragment for the table per data node (for example, when the `MAX_ROWS` option has been used with `CREATE TABLE`).

Setting this parameter to 0 (the default) disables multithreaded building of ordered indexes.

This parameter is supported when using `ndbd` or `ndbmtd`.

You can enable multithreaded builds during data node initial restarts by setting the `TwoPassInitialNodeRestartCopy` data node configuration parameter to `TRUE`.

**TwoPassInitialNodeRestartCopy**

**Table 18.135** This table provides type and value information for the TwoPassInitialNodeRestartCopy data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Multithreaded building of ordered indexes can be enabled for initial restarts of data nodes by setting this configuration parameter to `TRUE`, which enables two-pass copying of data during initial node restarts.

You must also set `BuildIndexThreads` to a nonzero value.
NDB Cluster Configuration Files

- **Numa**

Table 18.136 This table provides type and value information for the Numa data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter determines whether Non-Uniform Memory Access (NUMA) is controlled by the operating system or by the data node process, whether the data node uses `ndbd` or `ndbmtd`. By default, NDB attempts to use an interleaved NUMA memory allocation policy on any data node where the host operating system provides NUMA support.

Setting `Numa = 0` means that the datanode process does not itself attempt to set a policy for memory allocation, and permits this behavior to be determined by the operating system, which may be further guided by the separate `numactl` tool. That is, `Numa = 0` yields the system default behavior, which can be customised by `numactl`. For many Linux systems, the system default behavior is to allocate socket-local memory to any given process at allocation time. This can be problematic when using `ndbmtd`; this is because `ndbmtd` allocates all memory at startup, leading to an imbalance, giving different access speeds for different sockets, especially when locking pages in main memory.

Setting `Numa = 1` means that the data node process uses `lib numa` to request interleaved memory allocation. (This can also be accomplished manually, on the operating system level, using `numactl`.) Using interleaved allocation in effect tells the data node process to ignore non-uniform memory access but does not attempt to take any advantage of fast local memory; instead, the data node process tries to avoid imbalances due to slow remote memory. If interleaved allocation is not desired, set `Numa` to 0 so that the desired behavior can be determined on the operating system level.

The `Numa` configuration parameter is supported only on Linux systems where `lib numa.so` is available.

**Multi-Threading Configuration Parameters (ndbmtd).** `ndbmtd` runs by default as a single-threaded process and must be configured to use multiple threads, using either of two methods, both of which require setting configuration parameters in the `config.ini` file. The first method is simply to set an appropriate value for the `MaxNoOfExecutionThreads` configuration parameter. In NDB 7.2.3 and later, a second method is also supported, whereby it is possible to set up more complex rules for `ndbmtd` multithreading using `ThreadConfig`. The next few paragraphs provide information about these parameters and their use with multithreaded data nodes.

- **MaxNoOfExecutionThreads**

Table 18.137 This table provides type and value information for the MaxNoOfExecutionThreads multi-threaded data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.5</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>2</td>
</tr>
<tr>
<td>Range</td>
<td>2 - 36</td>
</tr>
</tbody>
</table>
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restart Type</strong></td>
<td>IS</td>
</tr>
</tbody>
</table>

Starting with NDB 7.2.5, this parameter directly controls the number of execution threads used by `ndbmtd`, up to a maximum of 36. Although this parameter is set in `[ndbd]` or `[ndbd default]` sections of the `config.ini` file, it is exclusive to `ndbmtd` and does not apply to `ndbd`.

Setting `MaxNoOfExecutionThreads` sets the number of threads by type as determined in the following table:

**Table 18.138 MaxNoOfExecutionThreads values and the corresponding number of threads by thread type (LQH, TC, Send, Receive), NDB 7.4.2 and earlier**

<table>
<thead>
<tr>
<th><code>MaxNoOfExecutionThreads</code> Value</th>
<th>LDM Threads</th>
<th>TC Threads</th>
<th>Send Threads</th>
<th>Receive Threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 .. 3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4 .. 6</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7 .. 8</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
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<tr>
<td>10</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>3</td>
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<td>22</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>3</td>
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<tr>
<td>23</td>
<td>8</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>12</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td>12</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>28</td>
<td>12</td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29</td>
<td>12</td>
<td>8</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>31</td>
<td>12</td>
<td>9</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>8</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>33</td>
<td>16</td>
<td>8</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

2267
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>MaxNoOfExecutionThreads Value</th>
<th>LDM Threads</th>
<th>TC Threads</th>
<th>Send Threads</th>
<th>Receive Threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>16</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>35</td>
<td>16</td>
<td>9</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>36</td>
<td>16</td>
<td>10</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

NoOfFragmentLogParts should be set equal to the number of LDM threads used by ndbmtd as determined by the setting for MaxNoOfExecutionThreads; see the description of this parameter for more information.

There is always one SUMA (replication) thread. There was no separate send thread in NDB 7.2.4 and earlier, as well as no means of changing the number of TC threads.

The number of LDM threads also determines the number of partitions used by an NDB table that is not explicitly partitioned; this is the number of LDM threads times the number of data nodes in the cluster. (If ndbd is used on the data nodes rather than ndbmtd, then there is always a single LDM thread; in this case, the number of partitions created automatically is simply equal to the number of data nodes. See Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

Adding large tables for Disk Data tables when using more than the default number of LDM threads may cause issues with resource and CPU usage if the disk page buffer is insufficiently large; see the description of the DiskPageBufferMemory configuration parameter, for more information.

The thread types are described later in this section (see ThreadConfig).

Setting this parameter outside the permitted range of values causes the management server to abort on startup with the error Error line number: Illegal value value for parameter MaxNoOfExecutionThreads.

For MaxNoOfExecutionThreads, a value of 0 or 1 is rounded up internally by NDB to 2, so that 2 is considered this parameter's default and minimum value.

MaxNoOfExecutionThreads is generally intended to be set equal to the number of CPU threads available, and to allocate a number of threads of each type suitable to typical workloads. It does not assign particular threads to specified CPUs. For cases where it is desirable to vary from the settings provided, or to bind threads to CPUs, you should use ThreadConfig instead, which allows you to allocate each thread directly to a desired type, CPU, or both.

In NDB 7.2.5 and later, the multithreaded data node process always spawns, at a minimum, the threads listed here:

- 1 local query handler (LDM) thread
- 1 receive thread
- 1 subscription manager (SUMA or replication) thread

For a MaxNoOfExecutionThreads value of 8 or less, no TC threads are created, and TC handling is instead performed by the main thread.

Changing the number of LDM threads always requires a system restart, whether it is changed using this parameter or ThreadConfig. If the cluster's IndexMemory usage is greater than 50%, changing this requires an initial restart of the cluster. (A maximum of 30-35% IndexMemory usage is recommended in
such cases.) Otherwise, resource usage and LDM thread allocation cannot be balanced between nodes, which can result in underutilized and overutilized LDM threads, and ultimately data node failures.

In NDB 7.2.4 and earlier, there were only 4 thread types, with LDM threads being responsible for their own sends. In addition, it was not possible to cause `ndbmtd` to use more than 1 TC thread.

- **NoOfFragmentLogParts**

  **Table 18.139** This table provides type and value information for the NoOfFragmentLogParts multi-threaded data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.5</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>4</td>
</tr>
<tr>
<td>Range</td>
<td>4, 8, 12, 16</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

Set the number of log file groups for redo logs belonging to this `ndbmtd`. The value must be an even multiple of 4 between 4 and 16, inclusive.

**NoOfFragmentLogParts** should be set equal to the number of LDM threads used by `ndbmtd` as determined by the setting for `MaxNoOfExecutionThreads`; see the description of this parameter for more information.

- **ThreadConfig**

  **Table 18.140** This table provides type and value information for the ThreadConfig multi-threaded data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.3</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>&quot;</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

This parameter is used with `ndbmtd` to assign threads of different types to different CPUs. Its value is a string whose format has the following syntax:

```
ThreadConfig := entry[,entry, ...]
entry := type={param[,param, ...]}
type := ldm | main | recv | send | rep | io | tc | watchdog
param := count=number
         | cpubind=cpu_list
         | cpuset=cpu_list
         | spintime=number
```
The curly braces ( {... } ) surrounding the list of parameters are required, even if there is only one parameter in the list.

A `param` (parameter) specifies any or all of the following information:

- The number of threads of the given type (`count`).
- The set of CPUs to which the threads of the given type are to be nonexclusively bound. This is determined by either one of `cpubind` or `cpuset`. `cpubind` causes each thread to be bound (nonexclusively) to a CPU in the set; `cpuset` means that each thread is bound (nonexclusively) to the set of CPUs specified.

Only one of `cpubind` or `cpuset` can be provided in a single configuration.

- `spintime` determines the wait time in microseconds the thread spins before going to sleep.

The default value for `spintime` is the value of the `SchedulerSpinTimer` data node configuration parameter.

`spintime` does not apply to I/O threads or watchdog threads and so cannot be set for these thread types.

- `realtime` can be set to 0 or 1. If it is set to 1, the threads run with real-time priority. This also means that `thread_prio` cannot be set.

The `realtime` parameter is set by default to the value of the `RealtimeScheduler` data node configuration parameter.

The `type` attribute represents an NDB thread type. The thread types supported in NDB Cluster 7.2 and the range of permitted `count` values for each are provided in the following list:

- `ldm`: Local query handler (DBLQH kernel block) that handles data. The more LDM threads that are used, the more highly partitioned the data becomes. Each LDM thread maintains its own sets of data and index partitions, as well as its own redo log. The value set for `ldm` must be one of the values 1, 2, 4, 6, 8, 12, or 16.

Changing the number of LDM threads requires a system restart to be effective and safe for cluster operations. (This is also true when this is done using `MaxNoOfExecutionThreads`.) If `IndexMemory` usage is in excess of 50%, an initial restart of the cluster is required; a maximum of 30-35% `IndexMemory` usage is recommended in such cases. Otherwise, `IndexMemory` and `DataMemory` usage as well as the allocation of LDM threads cannot be balanced between nodes, which can ultimately lead to data node failures.

Adding large tablespaces (hundreds of gigabytes or more) for Disk Data tables when using more than the default number of LDMs may cause issues with resource and CPU usage if `DiskPageBufferMemory` is not sufficiently large.

- `tc`: Transaction coordinator thread (DBTC kernel block) containing the state of an ongoing transaction. In NDB 7.2.5 and later, the number of TC threads is configurable, with a total of 16 possible.

Optimally, every new transaction can be assigned to a new TC thread. In most cases 1 TC thread per 2 LDM threads is sufficient to guarantee that this can happen. In cases where the number of writes is relatively small when compared to the number of reads, it is possible that only 1 TC thread per 4 LQH threads is required to maintain transaction states. Conversely, in applications that perform a
NDB Cluster Configuration Files

great many updates, it may be necessary for the ratio of TC threads to LDM threads to approach 1 (for example, 3 TC threads to 4 LDM threads).

Range: (NDB 7.2.5 and later) 0 - 16; (prior to NDB 7.2.5) 1 (not settable).

• **main**: Data dictionary and transaction coordinator (DBDIH and DBTC kernel blocks), providing schema management. This is always handled by a single dedicated thread.

  Range: 1 only.

• **recv**: Receive thread (CMVMI kernel block). Each receive thread handles one or more sockets for communicating with other nodes in an NDB Cluster, with one socket per node. Previously, this was limited to a single thread, but NDB Cluster 7.2 implements multiple receive threads (up to 8).


• **send**: Send thread (CMVMI kernel block). Added in NDB 7.2.5. To increase throughput, it is possible in NDB 7.2.5 and later to perform sends from one or more separate, dedicated threads (maximum 8).

  Previously, all threads handled their own sending directly; this can still be made to happen by setting the number of send threads to 0 (this also happens when MaxNoOfExecutionThreads is set less than 10). While doing so can have an adverse impact on throughput, it can also in some cases provide decreased latency.

  Range: 0 - 8.

• **rep**: Replication thread (SUMA kernel block). Asynchronous replication operations are always handled by a single, dedicated thread.

  Range: 1 only.

• **io**: File system and other miscellaneous operations. These are not demanding tasks, and are always handled as a group by a single, dedicated I/O thread.

  Range: 1 only.

• **watchdog**: Settings to this parameter are actually applied to several threads of this type having specific uses. These threads include the SocketServer thread which receives connection setups from other nodes, the SocketClient thread which attempts to set up connections to other nodes, and the thread watchdog thread that checks that threads are progressing.

  Range: 1 only.

Simple examples:

```bash
# Example 1.
ThreadConfig=ldm={count=2,cpubind=1,2},main={cpubind=12},rep={cpubind=11}

# Example 2.
Threadconfig=main={cpubind=0},ldm={count=4,cpubind=1,2,5,6},io={cpubind=3}
```

It is usually desirable when configuring thread usage for a data node host to reserve one or more number of CPUs for operating system and other tasks. Thus, for a host machine with 24 CPUs, you might want to use 20 CPU threads (leaving 4 for other uses), with 8 LDM threads, 4 TC threads (half the number of LDM threads), 3 send threads, 3 receive threads, and 1 thread each for schema management, asynchronous replication, and I/O operations. (This is almost the same distribution of threads used when
MaxNoOfExecutionThreads is set equal to 20.) The following ThreadConfig setting performs these assignments, additionally binding all of these threads to specific CPUs:

```plaintext
ThreadConfig=ldm{count=8,cpubind=1,2,3,4,5,6,7,8},main={cpubind=9},io={cpubind=9}, 
rep={cpubind=10},tc{count=4,cpubind=11,12,13,14},recv={count=3,cpubind=15,16,17}, 
send{count=3,cpubind=18,19,20}
```

It should be possible in most cases to bind the main (schema management) thread and the I/O thread to the same CPU, as we have done in the example just shown.

In order to take advantage of the enhanced stability that the use of ThreadConfig offers, it is necessary to insure that CPUs are isolated, and that they not subject to interrupts, or to being scheduled for other tasks by the operating system. On many Linux systems, you can do this by setting IRQBALANCE_BANNED_CPUS in /etc/sysconfig/irqbalance to 0xFFFFF0, and by using the isolcpus boot option in grub.conf. For specific information, see your operating system or platform documentation.

**Disk Data Configuration Parameters.** Configuration parameters affecting Disk Data behavior include the following:

- **DiskPageBufferEntries**

  Table 18.141 This table provides type and value information for the DiskPageBufferEntries data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.19</td>
</tr>
<tr>
<td>Type or units</td>
<td>32K pages</td>
</tr>
<tr>
<td>Default</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 1000</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This is the number of page entries (page references) to allocate. It is specified as a number of 32K pages in DiskPageBufferMemory. The default is sufficient for most cases but you may need to increase the value of this parameter if you encounter problems with very large transactions on Disk Data tables. Each page entry requires approximately 100 bytes.

- **DiskPageBufferMemory**

  Table 18.142 This table provides type and value information for the DiskPageBufferMemory data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>64M</td>
</tr>
<tr>
<td>Range</td>
<td>4M - 1T</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This determines the amount of space used for caching pages on disk, and is set in the [ndbd] or [ndbd default] section of the config.ini file. It is measured in bytes. Each page takes up 32 KB. This means that NDB Cluster Disk Data storage always uses $N \times 32$ KB memory where $N$ is some nonnegative integer.
The default value for this parameter is 64M (2000 pages of 32 KB each).

If the value for DiskPageBufferMemory is set too low in conjunction with using more than the default number of LDM threads in ThreadConfig (for example \{ldm=6\}), problems can arise when trying to add a large (for example 500G) data file to a disk-based NDB table, wherein the process takes indefinitely long while occupying one of the CPU cores.

This is due to the fact that, as part of adding a data file to a tablespace, extent pages are locked into memory in an extra PGMAN worker thread, for quick metadata access. When adding a large file, this worker has insufficient memory for all of the data file metadata. In such cases, you should either increase DiskPageBufferMemory, or add smaller tablespace files. You may also need to adjust DiskPageBufferEntries.

You can query the ndbinfo.diskpagebuffer table to help determine whether the value for this parameter should be increased to minimize unnecessary disk seeks. See Section 18.5.10.8, “The ndbinfo diskpagebuffer Table”, for more information.

• SharedGlobalMemory

Table 18.143 This table provides type and value information for the SharedGlobalMemory data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>128M</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 64T</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter determines the amount of memory that is used for log buffers, disk operations (such as page requests and wait queues), and metadata for tablespaces, log file groups, UNDO files, and data files. The shared global memory pool also provides memory used for satisfying the memory requirements of the UNDO_BUFFER_SIZE option used with CREATE LOGFILE GROUP and ALTER LOGFILE GROUP statements, including any default value implied for this options by the setting of the InitialLogFileGroup data node configuration parameter. SharedGlobalMemory can be set in the [ndbd] or [ndbd default] section of the config.ini configuration file, and is measured in bytes.

As of NDB 7.2.0, the default value is 128M. (Previously, this was 20M.)

• DiskIOThreadPool

Table 18.144 This table provides type and value information for the DiskIOThreadPool data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>threads</td>
</tr>
<tr>
<td>Default</td>
<td>2</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
This parameter determines the number of unbound threads used for Disk Data file access. Before DiskIOThreadPool was introduced, exactly one thread was spawned for each Disk Data file, which could lead to performance issues, particularly when using very large data files. With DiskIOThreadPool, you can—for example—access a single large data file using several threads working in parallel.

This parameter applies to Disk Data I/O threads only.

The optimum value for this parameter depends on your hardware and configuration, and includes these factors:

- **Physical distribution of Disk Data files.** You can obtain better performance by placing data files, undo log files, and the data node file system on separate physical disks. If you do this with some or all of these sets of files, then you can set DiskIOThreadPool higher to enable separate threads to handle the files on each disk.

- **Disk performance and types.** The number of threads that can be accommodated for Disk Data file handling is also dependent on the speed and throughput of the disks. Faster disks and higher throughput allow for more disk I/O threads. Our test results indicate that solid-state disk drives can handle many more disk I/O threads than conventional disks, and thus higher values for DiskIOThreadPool.

In NDB Cluster 7.2, the default value for this parameter is 2.

- **Disk Data file system parameters.** The parameters in the following list make it possible to place NDB Cluster Disk Data files in specific directories without the need for using symbolic links.

  - **FileSystemPathDD**

  Table 18.145 This table provides type and value information for the FileSystemPathDD data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>filename</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>IN</strong></td>
</tr>
</tbody>
</table>

If this parameter is specified, then NDB Cluster Disk Data data files and undo log files are placed in the indicated directory. This can be overridden for data files, undo log files, or both, by specifying values for FileSystemPathDataFiles, FileSystemPathUndoFiles, or both, as explained for these parameters. It can also be overridden for data files by specifying a path in the ADD DATAFILE clause of a CREATE TABLESPACE or ALTER TABLESPACE statement, and for undo log files by specifying a path in the ADD UNDOFILE clause of a CREATE LOGFILE GROUP or ALTER LOGFILE GROUP statement. If FileSystemPathDD is not specified, then FileSystemPath is used.

If a FileSystemPathDD directory is specified for a given data node (including the case where the parameter is specified in the [ndbd default] section of the config.ini file), then starting that data node with --initial causes all files in the directory to be deleted.
• **FileSystemPathDataFiles**

Table 18.146 This table provides type and value information for the FileSystemPathDataFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>filename</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>IN</td>
</tr>
</tbody>
</table>

If this parameter is specified, then NDB Cluster Disk Data data files are placed in the indicated directory. This overrides any value set for `FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD DATAFILE` clause of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement used to create that data file. If `FileSystemPathDataFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

If a `FileSystemPathDataFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

• **FileSystemPathUndoFiles**

Table 18.147 This table provides type and value information for the FileSystemPathUndoFiles data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>filename</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>IN</td>
</tr>
</tbody>
</table>

If this parameter is specified, then NDB Cluster Disk Data undo log files are placed in the indicated directory. This overrides any value set for ` FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD UNDO` clause of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement used to create that data file. If `FileSystemPathUndoFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

If a `FileSystemPathUndoFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

For more information, see Section 18.5.12.1, "NDB Cluster Disk Data Objects".
- **Disk Data object creation parameters.** The next two parameters enable you—when starting the cluster for the first time—to cause a Disk Data log file group, tablespace, or both, to be created without the use of SQL statements.

  - *InitialLogFileGroup*

  **Table 18.148** This table provides type and value information for the InitialLogFileGroup data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This parameter can be used to specify a log file group that is created when performing an initial start of the cluster. *InitialLogFileGroup* is specified as shown here:

```
InitialLogFileGroup = [name=name;] [undo_buffer_size=size;] file-specification-list
```

```
file-specification-list:
  file-specification[; file-specification[; ...]]
```

```
file-specification:
  filename:size
```

The `name` of the log file group is optional and defaults to `DEFAULT-LG`. The `undo_buffer_size` is also optional; if omitted, it defaults to 64M. Each `file-specification` corresponds to an undo log file, and at least one must be specified in the `file-specification-list`. Undo log files are placed according to any values that have been set for `FileSystemPath`, `FileSystemPathDD`, and `FileSystemPathUndoFiles`, just as if they had been created as the result of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement.

Consider the following:

```
InitialLogFileGroup = name=LG1; undo_buffer_size=128M; undo1.log:250M; undo2.log:150M
```

This is equivalent to the following SQL statements:

```
CREATE LOGFILE GROUP LG1
  ADD UNDOFILE 'undo1.log'
  INITIAL_SIZE 250M
  UNDO BUFFER SIZE 128M
  ENGINE NDBCLUSTER;

ALTER LOGFILE GROUP LG1
  ADD UNDOFILE 'undo2.log'
  INITIAL_SIZE 150M
  ENGINE NDBCLUSTER;
```

This logfile group is created when the data nodes are started with `--initial`.

Resources for the initial log file group are taken from the global memory pool whose size is determined by the value of the **SharedGlobalMemory** data node configuration parameter; if this parameter is set too low and the values set in *InitialLogFileGroup* for the logfile group’s initial size or undo buffer
size are too high, the cluster may fail to create the default log file group when starting, or fail to start altogether.

This parameter, if used, should always be set in the [ndbd default] section of the config.ini file. The behavior of an NDB Cluster when different values are set on different data nodes is not defined.

• **InitialTablespace**

**Table 18.149 This table provides type and value information for the InitialTablespace data node configuration parameter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>S</td>
</tr>
</tbody>
</table>

This parameter can be used to specify an NDB Cluster Disk Data tablespace that is created when performing an initial start of the cluster. **InitialTablespace** is specified as shown here:

```
InitialTablespace = [name=name;] [extent_size=size;] file-specification-list
```

The name of the tablespace is optional and defaults to DEFAULT-TS. The extent_size is also optional; it defaults to 1M. The file-specification-list uses the same syntax as shown with the InitialLogfileGroup parameter, the only difference being that each file-specification used with InitialTablespace corresponds to a data file. At least one must be specified in the file-specification-list. Data files are placed according to any values that have been set for FileSystemPath, FileSystemPathDD, and FileSystemPathDataFiles, just as if they had been created as the result of a **CREATE TABLESPACE** or **ALTER TABLESPACE** statement.

For example, consider the following line specifying InitialTablespace in the [ndbd default] section of the config.ini file (as with InitialLogfileGroup, this parameter should always be set in the [ndbd default] section, as the behavior of an NDB Cluster when different values are set on different data nodes is not defined):

```
InitialTablespace = name=TS1; extent_size=8M; data1.dat:2G; data2.dat:4G
```

This is equivalent to the following SQL statements:

```
CREATE TABLESPACE TS1
   ADD DATAFILE 'data1.dat'
   EXTENT_SIZE 8M
   INITIAL_SIZE 2G
   ENGINE NDDBCLUSTER;

ALTER TABLESPACE TS1
   ADD DATAFILE 'data2.dat'
   INITIAL_SIZE 4G
   ENGINE NDDBCLUSTER;
```

This tablespace is created when the data nodes are started with ```--initial``` and can be used whenever creating NDB Cluster Disk Data tables thereafter.
Disk Data and GCP Stop errors. Errors encountered when using Disk Data tables such as `Node nodeid killed this node because GCP stop was detected` (error 2303) are often referred to as “GCP stop errors”. Such errors occur when the redo log is not flushed to disk quickly enough; this is usually due to slow disks and insufficient disk throughput.

You can help prevent these errors from occurring by using faster disks, and by placing Disk Data files on a separate disk from the data node file system. Reducing the value of `TimeBetweenGlobalCheckpoints` tends to decrease the amount of data to be written for each global checkpoint, and so may provide some protection against redo log buffer overflows when trying to write a global checkpoint; however, reducing this value also permits less time in which to write the GCP, so this must be done with caution.

In addition to the considerations given for `DiskPageBufferMemory` as explained previously, it is also very important that the `DiskIOThreadPool` configuration parameter be set correctly; having `DiskIOThreadPool` set too high is very likely to cause GCP stop errors (Bug #37227).

GCP stops can be caused by save or commit timeouts; the `TimeBetweenEpochsTimeout` data node configuration parameter determines the timeout for commits. However, it is possible to disable both types of timeouts by setting this parameter to 0.

Parameters for configuring send buffer memory allocation. Send buffer memory is allocated dynamically from a memory pool shared between all transporters, which means that the size of the send buffer can be adjusted as necessary. (Previously, the NDB kernel used a fixed-size send buffer for every node in the cluster, which was allocated when the node started and could not be changed while the node was running.) The `TotalSendBufferMemory` and `OverLoadLimit` data node configuration parameters permit the setting of limits on this memory allocation. For more information about the use of these parameters (as well as `SendBufferMemory`), see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

- **ExtraSendBufferMemory**

  This parameter specifies the amount of transporter send buffer memory to allocate in addition to any set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

  This parameter was added in NDB 7.2.5. (Bug #11760629, Bug #53053)

- **TotalSendBufferMemory**

  This parameter is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

  Prior to NDB 7.2.5, this parameter did not work correctly with `ndbmtd`. (Bug #13633845)

  If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

- **ReservedSendBufferMemory**

  This parameter is present in `NDBCLUSTER` source code beginning with NDB 6.4.0. However, it is not currently enabled.

  As of NDB 7.2.5, this parameter is deprecated, and is subject to removal in a future release of NDB Cluster (Bug #11760629, Bug #53053).

  For more detailed information about the behavior and use of `TotalSendBufferMemory` and `ReservedSendBufferMemory`, and about configuring send buffer memory parameters in NDB Cluster, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.


See also Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

**Redo log over-commit handling.** It is possible to control a data node’s handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than `RedoOverCommitLimit` seconds, more than `RedoOverCommitCounter` times, causing any pending transactions to be aborted. When this happens, the API node that sent the transaction can handle the operations that should have been committed either by queuing the operations and re-trying them, or by aborting them, as determined by `DefaultOperationRedoProblemAction`. The data node configuration parameters for setting the timeout and number of times it may be exceeded before the API node takes this action are described in the following list:

- **RedoOverCommitCounter**

  **Table 18.150** This table provides type and value information for the `RedoOverCommitCounter` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

When `RedoOverCommitLimit` is exceeded when trying to write a given redo log to disk this many times or more, any transactions that were not committed as a result are aborted, and an API node where any of these transactions originated handles the operations making up those transactions according to its value for `DefaultOperationRedoProblemAction` (by either queuing the operations to be re-triesd, or aborting them).

`RedoOverCommitCounter` defaults to 3. Set it to 0 to disable the limit.

- **RedoOverCommitLimit**

  **Table 18.151** This table provides type and value information for the `RedoOverCommitLimit` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>seconds</td>
</tr>
<tr>
<td>Default</td>
<td>20</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter sets an upper limit in seconds for trying to write a given redo log to disk before timing out. The number of times the data node tries to flush this redo log, but takes longer than `RedoOverCommitLimit`, is kept and compared with `RedoOverCommitCounter`, and when flushing takes too long more times than the value of that parameter, any transactions that were not committed as a result of the flush timeout are aborted. When this occurs, the API node where any of these transactions originated handles the operations making up those transactions according to its `DefaultOperationRedoProblemAction` setting (it either queues the operations to be re-triesd, or aborts them).
By default, `RedoOverCommitLimit` is 20 seconds. Set to 0 to disable checking for redo log flush timeouts. This parameter was added in NDB 7.1.10.

**Controlling restart attempts.** It is possible to exercise finely-grained control over restart attempts by data nodes when they fail to start using the `MaxStartFailRetries` and `StartFailRetryDelay` data node configuration parameters.

`MaxStartFailRetries` limits the total number of retries made before giving up on starting the data node, `StartFailRetryDelay` sets the number of seconds between retry attempts. These parameters are listed here:

- `StartFailRetryDelay`

**Table 18.152** This table provides type and value information for the `StartFailRetryDelay` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Use this parameter to set the number of seconds between restart attempts by the data node in the event on failure on startup. The default is 0 (no delay).

Both this parameter and `MaxStartFailRetries` are ignored unless `StopOnError` is equal to 0.

- `MaxStartFailRetries`

**Table 18.153** This table provides type and value information for the `MaxStartFailRetries` data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Use this parameter to limit the number restart attempts made by the data node in the event that it fails on startup. The default is 3 attempts.

Both this parameter and `StartFailRetryDelay` are ignored unless `StopOnError` is equal to 0.

**NDB index statistics parameters.** The parameters in the following list relate to NDB index statistics generation, which was introduced in NDB 7.2.1.

- `IndexStatAutoCreate`
Table 18.154 This table provides type and value information for the IndexStatAutoCreate data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0, 1</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

Enable (set equal to 1) or disable (set equal to 0) automatic statistics collection when indexes are created. Disabled by default.

This parameter was added in NDB 7.2.1.

- **IndexStatAutoUpdate**

Table 18.155 This table provides type and value information for the IndexStatAutoUpdate data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0, 1</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

Enable (set equal to 1) or disable (set equal to 0) monitoring of indexes for changes and trigger automatic statistics updates these are detected. The amount and degree of change needed to trigger the updates are determined by the settings for the IndexStatTriggerPct and IndexStatTriggerScale options.

This parameter was added in NDB 7.2.1.

- **IndexStatSaveSize**

Table 18.156 This table provides type and value information for the IndexStatSaveSize data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>32768</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
Maximum space in bytes allowed for the saved statistics of any given index in the NDB system tables and in the mysqld memory cache. This consumes IndexMemory.

At least one sample is always produced, regardless of any size limit. Note that this size is scaled by IndexStatSaveScale.

This parameter was added in NDB 7.2.1.

The size specified by IndexStatSaveSize is scaled by the value of IndexStatTriggerPct for a large index, times 0.01. Note that this is further multiplied by the logarithm to the base 2 of the index size. Setting IndexStatTriggerPct equal to 0 disables the scaling effect.

• IndexStatSaveScale

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

Table 18.157 This table provides type and value information for the IndexStatSaveScale data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>percentage</td>
</tr>
<tr>
<td>Default</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFFFFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

The size specified by IndexStatSaveSize is scaled by the value of IndexStatTriggerPct for a large index, times 0.01. Note that this is further multiplied by the logarithm to the base 2 of the index size. Setting IndexStatTriggerPct equal to 0 disables the scaling effect.

This parameter was added in NDB 7.2.1.

• IndexStatTriggerPct

Table 18.158 This table provides type and value information for the IndexStatTriggerPct data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>percentage</td>
</tr>
<tr>
<td>Default</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFFFFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

Percentage change in updates that triggers an index statistics update. The value is scaled by IndexStatTriggerScale. You can disable this trigger altogether by setting IndexStatTriggerPct to 0.

This parameter was added in NDB 7.2.1.

• IndexStatTriggerScale
### Table 18.159 This table provides type and value information for the IndexStatTriggerScale data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>percentage</td>
</tr>
<tr>
<td>Default</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

Scale `IndexStatTriggerPct` by this amount times 0.01 for a large index. A value of 0 disables scaling.

This parameter was added in NDB 7.2.1.

- **IndexStatUpdateDelay**

### Table 18.160 This table provides type and value information for the IndexStatUpdateDelay data node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>seconds</td>
</tr>
<tr>
<td>Default</td>
<td>60</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IN</td>
</tr>
</tbody>
</table>

Minimum delay in seconds between automatic index statistics updates for a given index. Setting this variable to 0 disables any delay. The default is 60 seconds.

This parameter was added in NDB 7.2.1.

### 18.3.3.7 Defining SQL and Other API Nodes in an NDB Cluster

The `[mysqld]` and `[api]` sections in the `config.ini` file define the behavior of the MySQL servers (SQL nodes) and other applications (API nodes) used to access cluster data. None of the parameters shown is required. If no computer or host name is provided, any host can use this SQL or API node.

Generally speaking, a `[mysqld]` section is used to indicate a MySQL server providing an SQL interface to the cluster, and an `[api]` section is used for applications other than `mysqld` processes accessing cluster data, but the two designations are actually synonymous; you can, for instance, list parameters for a MySQL server acting as an SQL node in an `[api]` section.

---

**Note**

For a discussion of MySQL server options for NDB Cluster, see MySQL Server Options for NDB Cluster. For information about MySQL server system variables relating to NDB Cluster, see NDB Cluster System Variables.

**Restart types.** Information about the restart types used by the parameter descriptions in this section is shown in the following table:
Table 18.161 NDB Cluster restart types

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the --initial option</td>
</tr>
</tbody>
</table>

- **Id**

Table 18.162 This table provides type and value information for the Id API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

The **Id** is an integer value used to identify the node in all cluster internal messages. The permitted range of values is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

**Note**

Data node IDs must be less than 49, regardless of the NDB Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

**NodeId** is the preferred parameter name to use when identifying API nodes. (**Id** continues to be supported for backward compatibility, but is now deprecated and generates a warning when used. It is also subject to future removal.)

- **ConnectionMap**

Table 18.163 This table provides type and value information for the ConnectionMap API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>string</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specifies which data nodes to connect.
Table 18.164 This table provides type and value information for the NodeId API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>IS</td>
</tr>
</tbody>
</table>

The **NodeId** is an integer value used to identify the node in all cluster internal messages. The permitted range of values is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

**Note**

Data node IDs must be less than 49, regardless of the NDB Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

**NodeId** is the preferred parameter name to use when identifying management nodes in NDB Cluster 7.2 and later. Previously, **Id** was used for this purpose and this continues to be supported for backward compatibility. **Id** is now deprecated and generates a warning when used; it is subject to removal in a future release of NDB Cluster.

• **ExecuteOnComputer**

Table 18.165 This table provides type and value information for the ExecuteOnComputer API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>S</td>
</tr>
</tbody>
</table>

This refers to the **Id** set for one of the computers (hosts) defined in a **[computer]** section of the configuration file.

• **HostName**

Table 18.166 This table provides type and value information for the HostName API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specifying this parameter defines the hostname of the computer on which the SQL node (API node) is to reside. To specify a hostname, either this parameter or ExecuteOnComputer is required.

If no HostName or ExecuteOnComputer is specified in a given [mysql] or [api] section of the config.ini file, then an SQL or API node may connect using the corresponding "slot" from any host which can establish a network connection to the management server host machine. This differs from the default behavior for data nodes, where localhost is assumed for HostName unless otherwise specified.

- ArbitrationRank

Table 18.167 This table provides type and value information for the ArbitrationRank API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>0-2</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 2</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter defines which nodes can act as arbitrators. Both management nodes and SQL nodes can be arbitrators. A value of 0 means that the given node is never used as an arbitrator, a value of 1 gives the node high priority as an arbitrator, and a value of 2 gives it low priority. A normal configuration uses the management server as arbitrator, setting its ArbitrationRank to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

By setting ArbitrationRank to 0 on all management and SQL nodes, you can disable arbitration completely. You can also control arbitration by overriding this parameter; to do so, set the Arbitration parameter in the [ndbd default] section of the config.ini global configuration file.

- ArbitrationDelay

Table 18.168 This table provides type and value information for the ArbitrationDelay API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Setting this parameter to any other value than 0 (the default) means that responses by the arbitrator to arbitration requests will be delayed by the stated number of milliseconds. It is usually not necessary to change this value.
• **BatchByteSize**

Table 18.169 This table provides type and value information for the BatchByteSize API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>16K</td>
</tr>
<tr>
<td>Range</td>
<td>1K - 1M</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

For queries that are translated into full table scans or range scans on indexes, it is important for best performance to fetch records in properly sized batches. It is possible to set the proper size both in terms of number of records (BatchSize) and in terms of bytes (BatchByteSize). The actual batch size is limited by both parameters.

The speed at which queries are performed can vary by more than 40% depending upon how this parameter is set.

This parameter is measured in bytes. The default value prior to NDB 7.2.1 was 32K; in NDB 7.2.1 and later, the default is 16K.

• **BatchSize**

Table 18.170 This table provides type and value information for the BatchSize API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>records</td>
</tr>
<tr>
<td>Default</td>
<td>256</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 992</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is measured in number of records and is by default set to 256 (NDB 7.2.1 and later; previously, the default was 64). The maximum size is 992.

• **ExtraSendBufferMemory**

Table 18.171 This table provides type and value information for the ExtraSendBufferMemory API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.14</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Property</td>
<td>Value</td>
</tr>
<tr>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

This parameter was added in NDB 7.2.14. (Bug #14555359)

- **HeartbeatThreadPriority**

**Table 18.172** This table provides type and value information for the HeartbeatThreadPriority API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version (or later)</strong></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><strong>Type or units</strong></td>
<td>string</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>[none]</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>S</td>
</tr>
</tbody>
</table>

Use this parameter to set the scheduling policy and priority of heartbeat threads for management and API nodes. The syntax for setting this parameter is shown here:

```
HeartbeatThreadPriority = policy[, priority]
```

- **policy**:
  - `{FIFO | RR}`

When setting this parameter, you must specify a policy. This is one of FIFO (first in, first in) or RR (round robin). This followed optionally by the priority (an integer).

- **MaxScanBatchSize**

**Table 18.173** This table provides type and value information for the MaxScanBatchSize API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version (or later)</strong></td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td><strong>Type or units</strong></td>
<td>bytes</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>256K</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>32K - 16M</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

The batch size is the size of each batch sent from each data node. Most scans are performed in parallel to protect the MySQL Server from receiving too much data from many nodes in parallel; this parameter sets a limit to the total batch size over all nodes.

The default value of this parameter is set to 256KB. Its maximum size is 16MB.
• TotalSendBufferMemory

Table 18.174 This table provides type and value information for the TotalSendBufferMemory API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>256K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is available beginning with NDB 6.4.0. It is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

• AutoReconnect

Table 18.175 This table provides type and value information for the AutoReconnect API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is false by default. This forces disconnected API nodes (including MySQL Servers acting as SQL nodes) to use a new connection to the cluster rather than attempting to re-use an existing one, as re-use of connections can cause problems when using dynamically-allocated node IDs. (Bug #45921)

Note

This parameter can be overridden using the NDB API. For more information, see Ndb_cluster_connection::set_auto_reconnect(), and Ndb_cluster_connection::get_auto_reconnect().

• DefaultOperationRedoProblemAction

Table 18.176 This table provides type and value information for the DefaultOperationRedoProblemAction API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.10</td>
</tr>
<tr>
<td>Type or units</td>
<td>enumeration</td>
</tr>
<tr>
<td>Default</td>
<td>QUEUE</td>
</tr>
</tbody>
</table>
This parameter (along with RedoOverCommitLimit and RedoOverCommitCounter) controls the data node's handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than RedoOverCommitLimit seconds, more than RedoOverCommitCounter times, causing any pending transactions to be aborted.

When this happens, the node can respond in either of two ways, according to the value of DefaultOperationRedoProblemAction, listed here:

- **ABORT**: Any pending operations from aborted transactions are also aborted.
- **QUEUE**: Pending operations from transactions that were aborted are queued up to be re-tried. This is the default in NDB Cluster 7.2 and later. In NDB 7.2.21 and later, pending operations are still aborted when the redo log runs out of space—that is, when _P_TAIL_PROBLEM_ errors occur. (Bug #20782580)

Prior to NDB 7.2.10, setting this parameter did not have any effect. (Bug #15855588)

- **DefaultHashMapSize**

Table 18.177 This table provides type and value information for the DefaultHashMapSize API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.11</td>
</tr>
<tr>
<td>Type or units</td>
<td>buckets</td>
</tr>
<tr>
<td>Default</td>
<td>3840</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 3840</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

NDB 7.2.7 and later use a larger default table hash map size (3840) than in previous releases (240). Beginning with NDB 7.2.11, the size of the table hash maps used by NDB is configurable using this parameter; previously this value was hard-coded. DefaultHashMapSize can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table.

Table 18.178 DefaultHashMapSize parameter values

<table>
<thead>
<tr>
<th>Value</th>
<th>Description / Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.</td>
</tr>
<tr>
<td>240</td>
<td>Original hash map size (used by default prior to NDB 7.2.7.</td>
</tr>
<tr>
<td>3840</td>
<td>Larger hash map size as (used by default in NDB 7.2.7 and later</td>
</tr>
</tbody>
</table>

The primary intended use for this parameter is to facilitate upgrades and especially downgrades between NDB 7.2.7 and later NDB Cluster versions, in which the larger hash map size (3840) is the default, and earlier releases (in which the default was 240), due to the fact that this change is not otherwise backward compatible (Bug #14800539). By setting this parameter to 240 prior to performing an upgrade from an older version where this value is in use, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions following the upgrade.
DefaultHashMapSize can be set for individual data nodes, API nodes, or both, but setting it once only, in the [ndbd default] section of the config.ini file, is the recommended practice.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run ALTER TABLE ... REORGANIZE PARTITION on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with DefaultHashMapSize equal to 3840 is not currently supported.

Table 18.179 This table provides type and value information for the wan API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Use WAN TCP setting as default.

Table 18.180 This table provides type and value information for the ConnectBackoffMaxTime API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.18</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Starting with NDB 7.2.18, in an NDB Cluster with many unstarted data nodes, the value of this parameter can be raised to circumvent connection attempts to data nodes which have not yet begun to function in the cluster, as well as moderate high traffic to management nodes. As long as the API node is not connected to any new data nodes, the value of the StartConnectBackoffMaxTime parameter is applied; otherwise, ConnectBackoffMaxTime is used to determine the length of time in milliseconds to wait between connection attempts.

Time elapsed during node connection attempts is not taken into account when calculating elapsed time for this parameter. The timeout is applied with approximately 100 ms resolution, starting with a 100 ms delay; for each subsequent attempt, the length of this period is doubled until it reaches ConnectBackoffMaxTime milliseconds, up to a maximum of 100000 ms (100s).

Once the API node is connected to a data node and that node reports (in a heartbeat message) that it has connected to other data nodes, connection attempts to those data nodes are no longer affected by this parameter, and are made every 100 ms thereafter until connected. Note that, once a data node
NDB Cluster Configuration Files

has started, it can take up HeartbeatIntervalDbApi for the API node to be notified that this has occurred.

- **StartConnectBackoffMaxTime**

**Table 18.181** This table provides type and value information for the StartConnectBackoffMaxTime API node configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.18</td>
</tr>
<tr>
<td>Type or units</td>
<td>integer</td>
</tr>
<tr>
<td>Default</td>
<td>1500</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Starting with NDB 7.2.18, in an NDB Cluster with many unstarted data nodes, the value of this parameter can be raised to circumvent connection attempts to data nodes which have not yet begun to function in the cluster, as well as moderate high traffic to management nodes. As long as the API node is not connected to any new data nodes, the value of the StartConnectBackoffMaxTime parameter is applied; otherwise, ConnectBackoffMaxTime is used to determine the length of time in milliseconds to wait between connection attempts.

Time elapsed during node connection attempts is not taken into account when calculating elapsed time for this parameter. The timeout is applied with approximately 100 ms resolution, starting with a 100 ms delay; for each subsequent attempt, the length of this period is doubled until it reaches StartConnectBackoffMaxTime milliseconds, up to a maximum of 100000 ms (100s).

Once the API node is connected to a data node and that node reports (in a heartbeat message) that it has connected to other data nodes, connection attempts to those data nodes are no longer affected by this parameter, and are made every 100 ms thereafter until connected. Note that, once a data node has started, it can take up HeartbeatIntervalDbApi for the API node to be notified that this has occurred.

You can also obtain information from a MySQL server running as an NDB Cluster SQL node using SHOW STATUS in the mysql client, as shown here:

```sql
mysql> SHOW STATUS LIKE 'ndb\';
+-----------------------------+----------------+
| Variable_name               | Value          |
|-----------------------------+----------------+
| Ndb_cluster_node_id         | 5              |
| Ndb_config_from_host        | 198.51.100.112 |
| Ndb_config_from_port        | 1186           |
| Ndb_number_of_storage_nodes | 4              |
+-----------------------------+----------------+
4 rows in set (0.02 sec)
```

For information about the status variables appearing in the output from this statement, see NDB Cluster Status Variables.

**Note**

To add new SQL or API nodes to the configuration of a running NDB Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new [mysqld] or [api] sections to the config.ini file (or files, if you are using
more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

It is not necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

18.3.3.8 MySQL Server Options and Variables for NDB Cluster

This section provides information about MySQL server options, server and status variables that are specific to NDB Cluster. For general information on using these, and for other options and variables not specific to NDB Cluster, see Section 5.1, “The MySQL Server”.

For NDB Cluster configuration parameters used in the cluster configuration file (usually named `config.ini`), see Section 18.3, “Configuration of NDB Cluster”.

MySQL Server Options for NDB Cluster

This section provides descriptions of `mysqld` server options relating to NDB Cluster. For information about `mysqld` options not specific to NDB Cluster, and for general information about the use of options with `mysqld`, see Section 5.1.6, “Server Command Options”.

For information about command-line options used with other NDB Cluster processes (`ndbd`, `ndb_mgmd`, and `ndb_mgm`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”. For information about command-line options used with NDB utility programs (such as `ndb_desc`, `ndb_size.pl`, and `ndb_show_tables`), see Section 18.4, “NDB Cluster Programs”.

- **--ndbcluster**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndbcluster [=value]</code></td>
</tr>
<tr>
<td>Disabled by</td>
<td><code>skip-ndbcluster</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

The NDBCLUSTER storage engine is necessary for using NDB Cluster. If a `mysqld` binary includes support for the NDBCLUSTER storage engine, the engine is disabled by default. Use the `--ndbcluster` option to enable it. Use `--skip-ndbcluster` to explicitly disable the engine.

- **--ndb-batch-size=#**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-batch-size</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_batch_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32768</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>31536000</td>
</tr>
</tbody>
</table>
This sets the size in bytes that is used for NDB transaction batches.

- `--ndb-cluster-connection-pool=#`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--ndb-cluster-connection-pool</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>ndb_cluster_connection_pool</code></td>
</tr>
<tr>
<td><strong>System Variable</strong></td>
<td><code>ndb_cluster_connection_pool</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Minimum Value</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>63</td>
</tr>
</tbody>
</table>

By setting this option to a value greater than 1 (the default), a `mysqld` process can use multiple connections to the cluster, effectively mimicking several SQL nodes. Each connection requires its own `[api]` or `[mysqld]` section in the cluster configuration (`config.ini`) file, and counts against the maximum number of API connections supported by the cluster.

Suppose that you have 2 cluster host computers, each running an SQL node whose `mysqld` process was started with `--ndb-cluster-connection-pool=4`; this means that the cluster must have 8 API slots available for these connections (instead of 2). All of these connections are set up when the SQL node connects to the cluster, and are allocated to threads in a round-robin fashion.

This option is useful only when running `mysqld` on host machines having multiple CPUs, multiple cores, or both. For best results, the value should be smaller than the total number of cores available on the host machine. Setting it to a value greater than this is likely to degrade performance severely.

**Important**

Because each SQL node using connection pooling occupies multiple API node slots—each slot having its own node ID in the cluster—you must not use a node ID as part of the cluster connection string when starting any `mysqld` process that employs connection pooling.

Setting a node ID in the connection string when using the `--ndb-cluster-connection-pool` option causes node ID allocation errors when the SQL node attempts to connect to the cluster.

**Note**

In some older releases of NDB Cluster prior to NDB Cluster 7.2, there was also a separate status variable corresponding to this option; however, the status variable was removed as redundant as of these versions. (Bug #60119)
• `--ndb-blob-read-batch-bytes=bytes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-blob-read-batch-bytes</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_blob_read_batch_bytes</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>65536</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This option can be used to set the size (in bytes) for batching of BLOB data reads in NDB Cluster applications. When this batch size is exceeded by the amount of BLOB data to be read within the current transaction, any pending BLOB read operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling BLOB read batching.

**Note**

In NDB API applications, you can control BLOB write batching with the `setMaxPendingBlobReadBytes()` and `getMaxPendingBlobReadBytes()` methods.

• `--ndb-blob-write-batch-bytes=bytes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-blob-write-batch-bytes</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_blob_write_batch_bytes</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>65536</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

This option can be used to set the size (in bytes) for batching of BLOB data writes in NDB Cluster applications. When this batch size is exceeded by the amount of BLOB data to be written within the current transaction, any pending BLOB write operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling BLOB write batching.

**Note**

In NDB API applications, you can control BLOB write batching with the `setMaxPendingBlobWriteBytes()` and `getMaxPendingBlobWriteBytes()` methods.
### NDB Cluster Configuration Files

- **--ndb-connectstring=connection_string**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-connectstring</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>

When using the NDBCLUSTER storage engine, this option specifies the management server that distributes cluster configuration data. See Section 18.3.3.3, “NDB Cluster Connection Strings”, for syntax.

- **--ndb-deferred-constraints=[0|1]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-deferred-constraints</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_deferred_constraints</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

Controls whether or not constraint checks on unique indexes are deferred until commit time, where such checks are supported. 0 is the default.

This option is not normally needed for operation of NDB Cluster or NDB Cluster Replication, and is intended primarily for use in testing.

- **--ndb-distribution=[KEYHASH|LINHASH]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-distribution={KEYHASH</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_distribution</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>KEYHASH</td>
</tr>
<tr>
<td>Valid Values</td>
<td>LINHASH, KEYHASH</td>
</tr>
</tbody>
</table>

Controls the default distribution method for NDB tables. Can be set to either of KEYHASH (key hashing) or LINHASH (linear hashing). KEYHASH is the default.

- **--ndb-log-apply-status**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-log-apply-status={OFF</td>
</tr>
</tbody>
</table>
Causes a slave `mysqld` to log any updates received from its immediate master to the `mysql.ndb_apply_status` table in its own binary log using its own server ID rather than the server ID of the master. In a circular or chain replication setting, this allows such updates to propagate to the `mysql.ndb_apply_status` tables of any MySQL servers configured as slaves of the current `mysqld`.

In a chain replication setup, using this option allows downstream (slave) clusters to be aware of their positions relative to all of their upstream contributors (masters).

In a circular replication setup, this option causes changes to `ndb_apply_status` tables to complete the entire circuit, eventually propagating back to the originating NDB Cluster. This also allows a cluster acting as a master to see when its changes (epochs) have been applied to the other clusters in the circle.

This option has no effect unless the MySQL server is started with the `--ndbcluster` option.

- `--ndb-log-empty-epochs=[ON|OFF]`

Causes epochs during which there were no changes to be written to the `ndb_apply_status` and `ndb_binlog_index` tables, even when `log_slave_updates` is enabled.

By default this option is disabled. Disabling `--ndb-log-empty-epochs` causes epoch transactions with no changes not to be written to the binary log, although a row is still written even for an empty epoch in `ndb_binlog_index`.

Because `--ndb-log-empty-epochs=1` causes the size of the `ndb_binlog_index` table to increase independently of the size of the binary log, users should be prepared to manage the growth of this table, even if they expect the cluster to be idle a large part of the time.

- `--ndb-log-empty-update=[ON|OFF]`
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Causes updates that produced no changes to be written to the `ndb_apply_status` and `ndb_binlog_index` tables, when `log_slave_updates` is enabled.

By default this option is disabled (OFF). Disabling `--ndb-log-empty-update` causes updates with no changes not to be written to the binary log.

• `--ndb-log-orig`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-orig=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_orig</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Log the originating server ID and epoch in the `ndb_binlog_index` table.

Note that this makes it possible for a given epoch to have multiple rows in `ndb_binlog_index`, one for each originating epoch.

For more information, see Section 18.6.4, "NDB Cluster Replication Schema and Tables".

• `--ndb-log-transaction-id`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-transaction-id=[OFF</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.15-ndb-7.2.1</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_transaction_id</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

2298
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>log_bin_use_v1_row_events</code></td>
<td><strong>FALSE</strong></td>
</tr>
</tbody>
</table>

Causes a slave `mysqld` to write the NDB transaction ID in each row of the binary log. Such logging requires the use of the Version 2 event format for the binary log; thus, the `log_bin_use_v1_row_events` system variable must be disabled to use this option.

This option is available beginning with NDB 7.2.1 (and is not supported in mainline MySQL Server 5.5). It is required to enable NDB Cluster Replication conflict detection and resolution using the `NDB $EPOCH_TRANS()` function introduced in the same NDB Cluster release.

The default value is **FALSE**.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• `--ndb-mgmd-host=host[:port]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--ndb-mgmd-host=host_name[:port_num]</code></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>String</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td><code>localhost:1186</code></td>
</tr>
</tbody>
</table>

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

• `--ndb-nodeid=#`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--ndb-nodeid=#</code></td>
</tr>
<tr>
<td><strong>Status Variable</strong></td>
<td><code>Ndb_cluster_node_id</code></td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Global</td>
</tr>
<tr>
<td><strong>Dynamic</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Minimum Value</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>255</td>
</tr>
<tr>
<td><strong>Maximum Value</strong></td>
<td>63</td>
</tr>
</tbody>
</table>

Set this MySQL server’s node ID in an NDB Cluster.

The `--ndb-nodeid` option overrides any node ID set with `--ndb-connectstring`, regardless of the order in which the two options are used.

In addition, if `--ndb-nodeid` is used, then either a matching node ID must be found in a `[mysqld]` or `[api]` section of `config.ini`, or there must be an “open” `[mysqld]` or `[api]` section in the file (that
is, a section without a `NodeId` or `Id` parameter specified). This is also true if the node ID is specified as part of the connection string.

Regardless of how the node ID is determined, its is shown as the value of the global status variable `Ndb_cluster_node_id` in the output of `SHOW STATUS`, and as `cluster_node_id` in the connection row of the output of `SHOW ENGINE NDBCLUSTER STATUS`.

For more information about node IDs for NDB Cluster SQL nodes, see Section 18.3.3.7, "Defining SQL and Other API Nodes in an NDB Cluster".

- `--ndb-optimization-delay=milliseconds`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-optimization-delay=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_optimization_delay</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100000</td>
</tr>
</tbody>
</table>

Set the number of milliseconds to wait between sets of rows by `OPTIMIZE TABLE` statements on NDB tables. The default is 10.

- `ndb-transid-mysql-connection-map=state`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-transid-mysql-connection-map=[=state]</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.16-ndb-7.2.2</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ON, OFF, FORCE</td>
</tr>
</tbody>
</table>

Enables or disables the plugin that handles the `ndb_transid_mysql_connection_map` table in the `INFORMATION_SCHEMA` database. Takes one of the values ON, OFF, or FORCE. ON (the default) enables the plugin. OFF disables the plugin, which makes `ndb_transid_mysql_connection_map` inaccessible. FORCE keeps the MySQL Server from starting if the plugin fails to load and start.

You can see whether the `ndb_transid_mysql_connection_map` table plugin is running by checking the output of `SHOW PLUGINS`.

This option was added in NDB 7.2.2.
### --ndb-wait-connected=seconds

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-wait-connected=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_wait_connected</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>31536000</td>
</tr>
</tbody>
</table>

This option sets the period of time that the MySQL server waits for connections to NDB Cluster management and data nodes to be established before accepting MySQL client connections. The time is specified in seconds. The default value is 30.

### --ndb-wait-setup=seconds

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-wait-setup=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_wait_setup</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
<tr>
<td>Default Value</td>
<td>15</td>
</tr>
<tr>
<td>Default Value</td>
<td>15</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>31536000</td>
</tr>
</tbody>
</table>

This variable shows the period of time that the MySQL server waits for the NDB storage engine to complete setup before timing out and treating NDB as unavailable. The time is specified in seconds. The default value is 30.

### --server-id-bits=

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--server-id-bits=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>server_id_bits</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32</td>
</tr>
</tbody>
</table>
This option indicates the number of least significant bits within the 32-bit `server_id` which actually identify the server. Indicating that the server is actually identified by fewer than 32 bits makes it possible for some of the remaining bits to be used for other purposes, such as storing user data generated by applications using the NDB API's Event API within the `AnyValue` of an `OperationOptions` structure (NDB Cluster uses the `AnyValue` to store the server ID).

When extracting the effective server ID from `server_id` for purposes such as detection of replication loops, the server ignores the remaining bits. The `--server-id-bits` option is used to mask out any irrelevant bits of `server_id` in the IO and SQL threads when deciding whether an event should be ignored based on the server ID.

This data can be read from the binary log by `mysqlbinlog`, provided that it is run with its own `--server-id-bits` option set to 32 (the default).

The value of `server_id` must be less than $2^{server_id_bits}$; otherwise, `mysqld` refuses to start.

This system variable is supported only by NDB Cluster. It is not supported in the standard MySQL 5.5 Server.

- `--skip-ndbcluster`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--skip-ndbcluster</code></td>
</tr>
</tbody>
</table>

Disable the `NDBCLUSTER` storage engine. This is the default for binaries that were built with `NDBCLUSTER` storage engine support; the server allocates memory and other resources for this storage engine only if the `--ndbcluster` option is given explicitly. See Section 18.3.1, “Quick Test Setup of NDB Cluster”, for an example.

**NDB Cluster System Variables**

This section provides detailed information about MySQL server system variables that are specific to NDB Cluster and the `NDB` storage engine. For system variables not specific to NDB Cluster, see Section 5.1.7, “Server System Variables”. For general information on using system variables, see Section 5.1.8, “Using System Variables”.

- `have_ndbcluster`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>have_ndbcluster</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>

*YES* if `mysqld` supports `NDBCLUSTER` tables. *DISABLED* if `--skip-ndbcluster` is used.

This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `ndb_autoincrement_prefetch_sz`
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Command-Line Format</th>
<th>System Variable</th>
<th>Scope</th>
<th>Dynamic</th>
<th>Type</th>
<th>Default Value</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Value</td>
<td>Command-Line Format</td>
<td>System Variable</td>
<td>Scope</td>
<td>Dynamic</td>
<td>Type</td>
<td>Default Value</td>
<td>Minimum Value</td>
<td>Maximum Value</td>
</tr>
<tr>
<td>Command-Line Format</td>
<td>--ndb-autoincrement-prefetch-sz=#</td>
<td></td>
<td>ndb_autoincrement_prefetch_sz</td>
<td>Global, Session</td>
<td>Yes</td>
<td>Integer</td>
<td>1</td>
<td>1</td>
<td>65536</td>
</tr>
</tbody>
</table>

Determines the probability of gaps in an autoincremented column. Set it to 1 to minimize this. Setting it to a high value for optimization makes inserts faster, but decreases the likelihood that consecutive autoincrement numbers will be used in a batch of inserts.

This variable affects only the number of AUTO_INCREMENT IDs that are fetched between statements; within a given statement, at least 32 IDs are obtained at a time.

Important

This variable does not affect inserts performed using INSERT ... SELECT.

• ndb_cache_check_time

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Command-Line Format</th>
<th>System Variable</th>
<th>Scope</th>
<th>Dynamic</th>
<th>Type</th>
<th>Default Value</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Value</td>
<td>Command-Line Format</td>
<td>System Variable</td>
<td>Scope</td>
<td>Dynamic</td>
<td>Type</td>
<td>Default Value</td>
<td>Minimum Value</td>
<td>Maximum Value</td>
</tr>
<tr>
<td>Command-Line Format</td>
<td>--ndb-cache-check-time=#</td>
<td></td>
<td>ndb_cache_check_time</td>
<td>Global</td>
<td>Yes</td>
<td>Integer</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The number of milliseconds that elapse between checks of NDB Cluster SQL nodes by the MySQL query cache. Setting this to 0 (the default and minimum value) means that the query cache checks for validation on every query.

The recommended maximum value for this variable is 1000, which means that the check is performed once per second. A larger value means that the check is performed and possibly invalidated due to updates on different SQL nodes less often. It is generally not desirable to set this to a value greater than 2000.

• ndb_deferred_constraints

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Command-Line Format</th>
<th>System Variable</th>
<th>Scope</th>
<th>Dynamic</th>
<th>Type</th>
<th>Default Value</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Value</td>
<td>Command-Line Format</td>
<td>System Variable</td>
<td>Scope</td>
<td>Dynamic</td>
<td>Type</td>
<td>Default Value</td>
<td>Minimum Value</td>
<td>Maximum Value</td>
</tr>
<tr>
<td>Command-Line Format</td>
<td>--ndb-deferred-constraints=#</td>
<td></td>
<td>ndb_deferred_constraints</td>
<td>Global, Session</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2303
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1</td>
</tr>
</tbody>
</table>

Controls whether or not constraint checks are deferred, where these are supported. 0 is the default.

This variable is not normally needed for operation of NDB Cluster or NDB Cluster Replication, and is intended primarily for use in testing.

- **ndb_distribution**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-distribution={KEYHASH</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_distribution</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>KEYHASH</code></td>
</tr>
<tr>
<td>Valid Values</td>
<td><code>LINHASH</code> <code>KEYHASH</code></td>
</tr>
</tbody>
</table>

Controls the default distribution method for NDB tables. Can be set to either of `KEYHASH` (key hashing) or `LINHASH` (linear hashing). `KEYHASH` is the default.

- **ndb_eventbuffer_max_alloc**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-eventbuffer-max-alloc=#</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.34-ndb-7.2.14</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_eventbuffer_max_alloc</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

Sets the maximum amount memory (in bytes) that can be allocated for buffering events by the NDB API. 0 means that no limit is imposed, and is the default.

This variable was added in NDB 7.2.14.

- **ndb_extra_logging**
This variable enables recording in the MySQL error log of information specific to the **NDB** storage engine.

When this variable is set to 0, the only information specific to **NDB** that is written to the MySQL error log relates to transaction handling. If it set to a value greater than 0 but less than 10, **NDB** table schema and connection events are also logged, as well as whether or not conflict resolution is in use, and other **NDB** errors and information. If the value is set to 10 or more, information about **NDB** internals, such as the progress of data distribution among cluster nodes, is also written to the MySQL error log. The default is 1.

* **ndb_force_send**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>(--ndb-force-send[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_force_send</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Forces sending of buffers to **NDB** immediately, without waiting for other threads. Defaults to **ON**.

* **ndb_index_stat_cache_entries**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>(--ndb-index-stat-cache-entries=#)</td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes (removed in 5.5.36-ndb-7.2.16)</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndb_index_stat_cache_entries</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
</tbody>
</table>
Sets the granularity of the statistics by determining the number of starting and ending keys to store in the statistics memory cache. Zero means no caching takes place; in this case, the data nodes are always queried directly. Default value: 32.

Note

If `ndb_index_stat_enable` is OFF, then setting this variable has no effect.

This variable was deprecated in MySQL 5.1, and is removed from NDB 7.2.16 and later.

- **ndb_index_stat_enable**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-index-stat-enable=[OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_index_stat_enable</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Use NDB index statistics in query optimization. ON is the default in NDB Cluster 7.2 and later.

- **ndb_index_stat_option**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-index-stat-option=value</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.15-ndb-7.2.1</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_index_stat_option</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>loop_checkon=1000ms,loop_idle=1000ms,loop_busy=100ms,update_batch=1,read_batch=4,idle_batch=32,check_batch=32,check_delay=1m,delete_batch=8,clean_delay=0,error_batch=4,</code></td>
</tr>
</tbody>
</table>
This variable is used for providing tuning options for NDB index statistics generation. The list consists of comma-separated name-value pairs of option names and values. Note that this list must not contain any space characters.

Options not used when setting `ndb_index_stat_option` are not changed from their default values. For example, you can set `ndb_index_stat_option = 'loop_idle=1000ms,cache_limit=32M'`.

Time values can be optionally suffixed with `h` (hours), `m` (minutes), or `s` (seconds). Millisecond values can optionally be specified using `ms`; millisecond values cannot be specified using `h`, `m`, or `s`). Integer values can be suffixed with `K`, `M`, or `G`.

The names of the options that can be set using this variable are shown in the table that follows. The table also provides brief descriptions of the options, their default values, and (where applicable) their minimum and maximum values.

### Table 18.182 ndb_index_stat_option options and values

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Default/Units</th>
<th>Minimum/Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>loop_enable</code></td>
<td>Time to sleep when idle</td>
<td>1000 ms</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>loop_idle</code></td>
<td>Time to sleep when idle</td>
<td>1000 ms</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>loop_busy</code></td>
<td>Time to sleep when more work is waiting</td>
<td>100 ms</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>update_batch</code></td>
<td></td>
<td>1</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>read_batch</code></td>
<td></td>
<td>4</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>idle_batch</code></td>
<td></td>
<td>32</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>check_batch</code></td>
<td></td>
<td>8</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>check_delay</code></td>
<td>How often to check for new statistics</td>
<td>10 m</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>delete_batch</code></td>
<td></td>
<td>8</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>clean_delay</code></td>
<td></td>
<td>1 m</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>error_batch</code></td>
<td></td>
<td>4</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>error_delay</code></td>
<td></td>
<td>1 m</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>evict_batch</code></td>
<td>Clean LRU cache, from read time</td>
<td>8</td>
<td>1/4G</td>
</tr>
<tr>
<td><code>evict_delay</code></td>
<td></td>
<td>1 m</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>cache_limit</code></td>
<td>Maximum amount of memory in bytes used for cached index statistics by this <code>mysqld</code>; clean up the cache when this is exceeded.</td>
<td>32 M</td>
<td>0/4G</td>
</tr>
<tr>
<td><code>cache_lowpct</code></td>
<td></td>
<td>90</td>
<td>0/100</td>
</tr>
</tbody>
</table>
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Default/Units</th>
<th>Minimum/Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>zero_total</td>
<td>Setting this to 1 resets all accumulating counters in <code>ndb_index_stat_status</code> to 0. This option value is also reset to 0 when this is done.</td>
<td>0</td>
<td>0/1</td>
</tr>
</tbody>
</table>

- **ndb_index_stat_update_freq**
  
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-index-stat-update-freq=#</code></td>
</tr>
<tr>
<td>Deprecated</td>
<td>Yes (removed in 5.5.36-ndb-7.2.16)</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_index_stat_update_freq</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>20</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

How often to query data nodes instead of the statistics cache. For example, a value of 20 (the default) means to direct every 20th query to the data nodes.

**Note**

If `ndb_index_stat_cache_entries` is 0, then setting this variable has no effect; in this case, every query is sent directly to the data nodes.

This variable was deprecated in MySQL 5.1, and is removed from NDB 7.2.16 and later.

- **ndb_log_apply_status**
  
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-apply-status[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_apply_status</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

A read-only variable which shows whether the server was started with the `--ndb-log-apply-status` option.
### ndb_log_bin

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-bin[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_bin</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Causes updates to NDB tables to be written to the binary log. Setting this variable has no effect if binary logging is not already enabled for the server using `log_bin`. `ndb_log_bin` defaults to 1 (ON); normally, there is never any need to change this value in a production environment.

### ndb_log_binlog_index

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-binlog-index[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_binlog_index</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

Causes a mapping of epochs to positions in the binary log to be inserted into the `ndb_binlog_index` table. Setting this variable has no effect if binary logging is not already enabled for the server using `log_bin`. (In addition, `ndb_log_bin` must not be disabled.) `ndb_log_binlog_index` defaults to 1 (ON); normally, there is never any need to change this value in a production environment.

### ndb_log_empty_epochs

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-empty-epochs[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_empty_epochs</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When this variable is set to 0, epoch transactions with no changes are not written to the binary log, although a row is still written even for an empty epoch in `ndb_binlog_index`.

### ndb_log_empty_update

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-empty-update[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_empty_update</code></td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When this variable is set to **ON** (1), update transactions with no changes are written to the binary log, even when `log_slave_updates` is enabled.

- **ndb_log_orig**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-orig[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_orig</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Shows whether the originating server ID and epoch are logged in the `ndb_binlog_index` table. Set using the `--ndb-log-orig` server option.

- **ndb_log_transaction_id**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduced</td>
<td>5.5.15-ndb-7.2.1</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_transaction_id</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

This read-only, Boolean system variable shows whether a slave `mysqld` writes NDB transaction IDs in the binary log (required to use “active-active” NDB Cluster Replication with `NDB$EPOCH_TRANS()` conflict detection). To change the setting, use the `--ndb-log-transaction-id` option.

`ndb_log_transaction_id` is available in NDB 7.2.1 and later. It is not supported in mainline MySQL Server 5.5.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- **ndb_optimized_node_selection**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-optimized-node-selection=</code></td>
</tr>
</tbody>
</table>
There are two forms of optimized node selection, described here:

1. The SQL node uses *proximity* to determine the transaction coordinator; that is, the “closest” data node to the SQL node is chosen as the transaction coordinator. For this purpose, a data node having a shared memory connection with the SQL node is considered to be “closest” to the SQL node; the next closest (in order of decreasing proximity) are: TCP connection to `localhost`; SCI connection; TCP connection from a host other than `localhost`.

2. The SQL thread uses *distribution awareness* to select the data node. That is, the data node housing the cluster partition accessed by the first statement of a given transaction is used as the transaction coordinator for the entire transaction. (This is effective only if the first statement of the transaction accesses no more than one cluster partition.)

This option takes one of the integer values 0, 1, 2, or 3. 3 is the default. These values affect node selection as follows:

- **0**: Node selection is not optimized. Each data node is employed as the transaction coordinator 8 times before the SQL thread proceeds to the next data node.
- **1**: Proximity to the SQL node is used to determine the transaction coordinator.
- **2**: Distribution awareness is used to select the transaction coordinator. However, if the first statement of the transaction accesses more than one cluster partition, the SQL node reverts to the round-robin behavior seen when this option is set to 0.
- **3**: If distribution awareness can be employed to determine the transaction coordinator, then it is used; otherwise proximity is used to select the transaction coordinator. (This is the default behavior.)

Proximity is determined as follows:

1. Start with the value set for the `Group` parameter (default 55).
2. For an API node sharing the same host with other API nodes, decrement the value by 1. Assuming the default value for `Group`, the effective value for data nodes on same host as the API node is 54, and for remote data nodes 55.

- **ndb_report_thresh_binlog_epoch_slip**
This is a threshold on the number of epochs to be behind before reporting binary log status. For example, a value of 3 (the default) means that if the difference between which epoch has been received from the storage nodes and which epoch has been applied to the binary log is 3 or more, a status message is sent to the cluster log.

```
  ndb_report_thresh_binlog_mem_usage
```

This is a threshold on the percentage of free memory remaining before reporting binary log status. For example, a value of 10 (the default) means that if the amount of available memory for receiving binary log data from the data nodes falls below 10%, a status message is sent to the cluster log.

```
  ndb_table_no_logging
```

When this variable is set to ON or 1, it causes NDB tables not to be checkpointed to disk. More specifically, this setting applies to tables which are created or altered using ENGINE NDB when ndb_table_no_logging is enabled, and continues to apply for the lifetime of the table, even if ndb_table_no_logging is later changed. Suppose that A, B, C, and D are tables that we create (and perhaps also alter), and that we also change the setting for ndb_table_no_logging as shown here:

```
SET @@ndb_table_no_logging = 1;
CREATE TABLE A ... ENGINE NDB;
CREATE TABLE B ... ENGINE MYISAM;
CREATE TABLE C ... ENGINE MYISAM;
ALTER TABLE B ENGINE NDB;
```
After the previous sequence of events, tables A and B are not checkpointed; A was created with \texttt{ENGINE NDB} and B was altered to use \texttt{NDB}, both while \texttt{ndb_table_no_logging} was enabled. However, tables C and D are logged; C was altered to use \texttt{NDB} and D was created using \texttt{ENGINE NDB}, both while \texttt{ndb_table_no_logging} was disabled. Setting \texttt{ndb_table_no_logging} back to 1 or \texttt{ON} does \textit{not} cause table C or D to be checkpointed.

\textbf{Note}

\texttt{ndb_table_no_logging} has no effect on the creation of \texttt{NDB} table schema files; to suppress these, use \texttt{ndb_table_temporary} instead.

\begin{tabular}{|l|l|}
\hline
\textbf{Property}       & \textbf{Value} \\
\hline
\texttt{System Variable} & \texttt{ndb_table_temporary} \\
\hline
\texttt{Scope}          & Session \\
\hline
\texttt{Dynamic}        & Yes \\
\hline
\texttt{Type}           & Boolean \\
\hline
\texttt{Default Value}  & \texttt{OFF} \\
\hline
\end{tabular}

When set to \texttt{ON} or \texttt{1}, this variable causes \texttt{NDB} tables not to be written to disk: This means that no table schema files are created, and that the tables are not logged.

\textbf{Note}

Setting this variable currently has no effect in \texttt{NDB Cluster 7.0} and later. This is a known issue; see Bug \#34036.

\begin{tabular}{|l|l|}
\hline
\textbf{Property}       & \textbf{Value} \\
\hline
\texttt{System Variable} & \texttt{ndb_use_copying_alter_table} \\
\hline
\texttt{Scope}          & Global, Session \\
\hline
\texttt{Dynamic}        & No \\
\hline
\end{tabular}

Forces \texttt{NDB} to use copying of tables in the event of problems with online \texttt{ALTER TABLE} operations. The default value is \texttt{OFF}.

\begin{tabular}{|l|l|}
\hline
\textbf{Property}       & \textbf{Value} \\
\hline
\texttt{System Variable} & \texttt{ndb_use_exact_count} \\
\hline
\texttt{Scope}          & Global, Session \\
\hline
\texttt{Dynamic}        & Yes \\
\hline
\texttt{Type}           & Boolean \\
\hline
\end{tabular}
## NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Forces NDB to use a count of records during `SELECT COUNT(*)` query planning to speed up this type of query. The default value is `OFF`, which allows for faster queries overall.

- **ndb_use_transactions**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-use-transactions=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_use_transactions</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

You can disable NDB transaction support by setting this variable's values to `OFF` (not recommended). The default is `ON`.

- **ndb_version**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>ndb_version</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

NDB engine version, as a composite integer.

- **ndb_version_string**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>ndb_version_string</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

NDB engine version in `ndb-x.y.z` format.

- **server_id_bits**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--server-id-bits=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>server_id_bits</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
</tbody>
</table>
The effective value of `server_id` if the server was started with the `--server-id-bits` option set to a nondefault value.

If the value of `server_id` greater than or equal to 2 to the power of `server_id_bits`, `mysqld` refuses to start.

This system variable is supported only by NDB Cluster. `server_id_bits` is not supported by the standard MySQL Server.

- `slave_allow_batching`

  Whether or not batched updates are enabled on NDB Cluster replication slaves.

  This variable is available for `mysqld` only as supplied with NDB Cluster or built from the NDB Cluster sources. For more information, see Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”.

  Setting this variable had no effect in NDB Cluster 7.2 prior to NDB 7.2.10. (Bug #15953730)

- `transaction_allow_batching`

  Whether or not batched updates are enabled on NDB Cluster replication slaves.

  This variable is available for `mysqld` only as supplied with NDB Cluster or built from the NDB Cluster sources. For more information, see Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”.

  Setting this variable had no effect in NDB Cluster 7.2 prior to NDB 7.2.10. (Bug #15953730)
### NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

When set to 1 or ON, this variable enables batching of statements within the same transaction. To use this variable, `autocommit` must first be disabled by setting it to 0 or OFF; otherwise, setting `transaction_allow_batching` has no effect.

It is safe to use this variable with transactions that performs writes only, as having it enabled can lead to reads from the “before” image. You should ensure that any pending transactions are committed (using an explicit COMMIT if desired) before issuing a SELECT.

---

**Important**

`transaction_allow_batching` should not be used whenever there is the possibility that the effects of a given statement depend on the outcome of a previous statement within the same transaction.

This variable is currently supported for NDB Cluster only.

---

**Important**

Due an issue in the NDB Cluster 7.2 codebase (Bug #64697) prior to General Availability, this variable is not available prior to NDB 7.2.6.

The system variables in the following list all relate to the `ndbinfo` information database.

- **ndbinfo_database**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>ndbinfo_database</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>ndbinfo</code></td>
</tr>
</tbody>
</table>

Shows the name used for the NDB information database; the default is `ndbinfo`. This is a read-only variable whose value is determined at compile time; you can set it by starting the server using `--ndbinfo-database=name`, which sets the value shown for this variable but does not actually change the name used for the NDB information database.

- **ndbinfo_max_bytes**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndbinfo-max-bytes=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndbinfo_max_bytes</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

Used in testing and debugging only.
• **ndbinfo_max_rows**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndbinfo-max-rows=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndbinfo_max_rows</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
</tbody>
</table>

Used in testing and debugging only.

• **ndbinfo_offline**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>ndbinfo_offline</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Place the `ndbinfo` database into offline mode, in which tables and views can be opened even when they do not actually exist, or when they exist but have different definitions in NDB. No rows are returned from such tables (or views).

• **ndbinfo_show_hidden**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndbinfo-show-hidden[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndbinfo_show_hidden</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Whether or not the `ndbinfo` database's underlying internal tables are shown in the `mysql` client. The default is OFF.

• **ndbinfo_table_prefix**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndbinfo-table-prefix=name</td>
</tr>
<tr>
<td>System Variable</td>
<td>ndbinfo_table_prefix</td>
</tr>
<tr>
<td>Scope</td>
<td>Global, Session</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>ndb$</td>
</tr>
</tbody>
</table>

The prefix used in naming the ndbinfo database's base tables (normally hidden, unless exposed by setting ndbinfo_show_hidden). This is a read-only variable whose default value is ndb$. You can start the server with the --ndbinfo-table-prefix option, but this merely sets the variable and does not change the actual prefix used to name the hidden base tables; the prefix itself is determined at compile time.

- **ndbinfo_version**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td>ndbinfo_version</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Shows the version of the ndbinfo engine in use; read-only.

**NDB Cluster Status Variables**

This section provides detailed information about MySQL server status variables that relate to NDB Cluster and the NDB storage engine. For status variables not specific to NDB Cluster, and for general information on using status variables, see Section 5.1.9, "Server Status Variables".

- **Handler_discover**

  The MySQL server can ask the NDBCLUSTER storage engine if it knows about a table with a given name. This is called discovery. Handler_discover indicates the number of times that tables have been discovered using this mechanism.

- **Ndb_api_bytes_sent_count_session**

  Amount of data (in bytes) sent to the data nodes in this client session.

  Although this variable can be read using either SHOW GLOBAL STATUS or SHOW SESSION STATUS, it relates to the current session only, and is not affected by any other clients of this mysqld.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_bytes_sent_count_slave**

  Amount of data (in bytes) sent to the data nodes by this slave.

  Although this variable can be read using either SHOW GLOBAL STATUS or SHOW SESSION STATUS, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_bytes_sent_count**

  Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).
Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_bytes_received_count_session**

  Amount of data (in bytes) received from the data nodes in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_bytes_received_count_slave**

  Amount of data (in bytes) received from the data nodes by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_bytes_received_count**

  Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_event_data_count.Injector**

  The number of row change events received by the NDB binlog injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_event_data_count**

  The number of row change events received by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.
NDB Cluster Configuration Files

- **Ndb_api_event_nondata_count_injector**
  
  The number of events received, other than row change events, by the NDB binary log injector thread.
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_event_nondata_count**
  
  The number of events received, other than row change events, by this MySQL Server (SQL node).
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_event_bytes_count_injector**
  
  The number of bytes of events received by the NDB binlog injector thread.
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_event_bytes_count**
  
  The number of bytes of events received by this MySQL Server (SQL node).
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_pk_op_count_session**
  
  The number of operations in this client session based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_pk_op_count_slave**
  
  The number of operations by this slave based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.
  
  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.
  
  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **2320**
- **Ndb_api_pk_op_count**

  The number of operations by this MySQL Server (SQL node) based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_pruned_scan_count_session**

  The number of scans in this client session that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_pruned_scan_count_slave**

  The number of scans by this slave that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_pruned_scan_count**

  The number of scans by this MySQL Server (SQL node) that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_range_scan_count_session**

  The number of range scans that have been started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_range_scan_count_slave**

  The number of range scans that have been started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_range_scan_count**

  The number of range scans that have been started by this slave.
The number of range scans that have been started by this MySQL Server (SQL node).

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_read_row_count_session**

The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_read_row_count_slave**

The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_read_row_count**

The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

You should be aware that this value may not be completely accurate with regard to rows read by `SELECT COUNT(*)` queries, due to the fact that, in this case, the MySQL server actually reads pseudo-rows in the form `[table fragment ID]:[number of rows in fragment]` and sums the rows per fragment for all fragments in the table to derive an estimated count for all rows. `Ndb_api_read_row_count` uses this estimate and not the actual number of rows in the table.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_scan_batch_count_session**

The number of batches of rows received in this client session. 1 batch is defined as 1 set of scan results from a single fragment.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.
NDB Cluster Configuration Files

- **Ndb_api_scan_batch_count_slave**
  
The number of batches of rows received by this slave. 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_scan_batch_count**
  
The number of batches of rows received by this MySQL Server (SQL node). 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_table_scan_count_session**
  
The number of table scans that have been started in this client session, including scans of internal tables.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_table_scan_count_slave**
  
The number of table scans that have been started by this slave, including scans of internal tables.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

- **Ndb_api_table_scan_count**
  
The number of table scans that have been started by this MySQL Server (SQL node), including scans of internal tables.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

2323
• **Ndb_api_trans_abort_count_session**

  The number of transactions aborted in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_abort_count_slave**

  The number of transactions aborted by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_abort_count**

  The number of transactions aborted by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_close_count_session**

  The number of transactions closed in this client session. This value may be greater than the sum of `Ndb_api_trans_commit_count_session` and `Ndb_api_trans_abort_count_session`, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_close_count_slave**

  The number of transactions closed by this slave. This value may be greater than the sum of `Ndb_api_trans_commit_count_slave` and `Ndb_api_trans_abort_count_slave`, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.
• **Ndb_api_trans_close_count**

  The number of transactions closed by this MySQL Server (SQL node). This value may be greater than the sum of **Ndb_api_trans_commit_count** and **Ndb_api_trans_abort_count**, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_commit_count_session**

  The number of transactions committed in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_commit_count_slave**

  The number of transactions committed by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_commit_count**

  The number of transactions committed by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_local_read_row_count_session**

  The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.
• **Ndb_api_trans_local_read_row_count_slave**

  The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_local_read_row_count**

  The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_start_count_session**

  The number of transactions started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_start_count_slave**

  The number of transactions started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_trans_start_count**

  The number of transactions started by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_uk_op_count_session**

  The number of operations in this client session based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_uk_op_count_slave**

  2326
The number of operations by this slave based on or using unique keys.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• `Ndb_api_uk_op_count`

The number of operations by this MySQL Server (SQL node) based on or using unique keys.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• `Ndb_api_wait_exec_complete_count_session`

The number of times a thread has been blocked in this client session while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit executes for blob and auto-increment operations not visible to clients.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• `Ndb_api_wait_exec_complete_count_slave`

The number of times a thread has been blocked by this slave while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit executes for blob and auto-increment operations not visible to clients.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• `Ndb_api_wait_exec_complete_count`

The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit executes for blob and auto-increment operations not visible to clients.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.
• **Ndb_api_wait_meta_request_count_session**

  The number of times a thread has been blocked in this client session waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_meta_request_count_slave**

  The number of times a thread has been blocked by this slave waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_meta_request_count**

  The number of times a thread has been blocked by this MySQL Server (SQL node) waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_nanos_count_session**

  Total time (in nanoseconds) spent in this client session waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_nanos_count_slave**

  Total time (in nanoseconds) spent by this slave waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

2328
• **Ndb_api_wait_nanos_count**

  Total time (in nanoseconds) spent by this MySQL Server (SQL node) waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_scan_result_count_session**

  The number of times a thread has been blocked in this client session while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_scan_result_count_slave**

  The number of times a thread has been blocked by this slave while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_api_wait_scan_result_count**

  The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.16, “NDB API Statistics Counters and Variables”.

• **Ndb_cluster_node_id**

  If the server is acting as an NDB Cluster node, then the value of this variable its node ID in the cluster.

  If the server is not part of an NDB Cluster, then the value of this variable is 0.

• **Ndb_config_from_host**

  If the server is part of an NDB Cluster, the value of this variable is the host name or IP address of the Cluster management server from which it gets its configuration data.

  If the server is not part of an NDB Cluster, then the value of this variable is an empty string.
• **Ndb_config_from_port**

If the server is part of an NDB Cluster, the value of this variable is the number of the port through which it is connected to the Cluster management server from which it gets its configuration data.

If the server is not part of an NDB Cluster, then the value of this variable is 0.

• **Ndb_conflict_fn_max**

Used in NDB Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied on the current SQL node due to “greatest timestamp wins” conflict resolution since the last time that this *mysqld* was started.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• **Ndb_conflict_fn_old**

Used in NDB Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied as the result of “same timestamp wins” conflict resolution on a given *mysqld* since the last time it was restarted.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• **Ndb_conflict_fn_epoch**

Used in NDB Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using *NDB$EPOCH()* conflict resolution on a given *mysqld* since the last time it was restarted.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• **Ndb_conflict_fn_epoch_trans**

Used in NDB Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using *NDB$EPOCH_TRANS()* conflict resolution on a given *mysqld* since the last time it was restarted.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• **Ndb_conflict_trans_row_conflict_count**

Used in NDB Cluster Replication conflict resolution, this status variable shows the number of rows found to be directly in-conflict by a transactional conflict function on a given *mysqld* since the last time it was restarted.

Currently, the only transactional conflict detection function supported by NDB Cluster is *NDB$EPOCH_TRANS()*(), so this status variable is effectively the same as *Ndb_conflict_fn_epoch_trans*.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

• **Ndb_conflict_trans_row_reject_count**

Used in NDB Cluster Replication conflict resolution, this status variable shows the total number of rows realigned due to being determined as conflicting by a transactional conflict detection function. This includes not only *Ndb_conflict_trans_row_conflict_count*, but any rows in or dependent on conflicting transactions.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.
• **Ndb_conflict_trans_reject_count**

  Used in NDB Cluster Replication conflict resolution, this status variable shows the number of transactions found to be in conflict by a transactional conflict detection function.

  For more information, see Section 18.6.11, "NDB Cluster Replication Conflict Resolution".

• **Ndb_conflict_trans_detect_iter_count**

  Used in NDB Cluster Replication conflict resolution, this shows the number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to **Ndb_conflict_trans_conflict_commit_count**.

  For more information, see Section 18.6.11, "NDB Cluster Replication Conflict Resolution".

• **Ndb_conflict_trans_conflict_commit_count**

  Used in NDB Cluster Replication conflict resolution, this shows the number of epoch transactions committed after they required transactional conflict handling.

  For more information, see Section 18.6.11, "NDB Cluster Replication Conflict Resolution".

• **Ndb_execute_count**

  Provides the number of round trips to the NDB kernel made by operations.

• **Ndb_number_of_data_nodes**

  If the server is part of an NDB Cluster, the value of this variable is the number of data nodes in the cluster.

  If the server is not part of an NDB Cluster, then the value of this variable is 0.

• **Ndb_pushed_queries_defined**

  The total number of joins pushed down to the NDB kernel for distributed handling on the data nodes. Note that joins tested using `EXPLAIN` that can be pushed down contribute to this number. Added in NDB 7.2.0.

• **Ndb_pushed_queries_dropped**

  The number of joins that were pushed down to the NDB kernel but that could not be handled there. Added in NDB 7.2.0.

• **Ndb_pushed_queries_executed**

  The number of joins successfully pushed down to NDB and executed there. Added in NDB 7.2.0.

• **Ndb_pushed_reads**

  The number of rows returned to mysql from the NDB kernel by joins that were pushed down. Note that executing `EXPLAIN` on joins that can be pushed down to NDB does not add to this number. Added in NDB 7.2.0.

• **Ndb_pruned_scan_count**

  This variable holds a count of the number of scans executed by NDBCLUSTER since the NDB Cluster was last started where NDBCLUSTER was able to use partition pruning.
Using this variable together with \texttt{Ndb\_scan\_count} can be helpful in schema design to maximize the ability of the server to prune scans to a single table partition, thereby involving only a single data node.

- \texttt{Ndb\_scan\_count}

  This variable holds a count of the total number of scans executed by \texttt{NDBCLUSTER} since the NDB Cluster was last started.

### 18.3.3.9 NDB Cluster TCP/IP Connections

TCP/IP is the default transport mechanism for all connections between nodes in an NDB Cluster. Normally it is not necessary to define TCP/IP connections; NDB Cluster automatically sets up such connections for all data nodes, management nodes, and SQL or API nodes.

\textbf{Note}

For an exception to this rule, see \textit{Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections”}.

To override the default connection parameters, it is necessary to define a connection using one or more \texttt{[tcp]} sections in the \texttt{config.ini} file. Each \texttt{[tcp]} section explicitly defines a TCP/IP connection between two NDB Cluster nodes, and must contain at a minimum the parameters \texttt{NodeId1} and \texttt{NodeId2}, as well as any connection parameters to override.

It is also possible to change the default values for these parameters by setting them in the \texttt{[tcp default]} section.

\textbf{Important}

Any \texttt{[tcp]} sections in the \texttt{config.ini} file should be listed \emph{last}, following all other sections in the file. However, this is not required for a \texttt{[tcp default]} section. This requirement is a known issue with the way in which the \texttt{config.ini} file is read by the NDB Cluster management server.

Connection parameters which can be set in \texttt{[tcp]} and \texttt{[tcp default]} sections of the \texttt{config.ini} file are listed here:

\textbf{Restart types.} Information about the restart types used by the parameter descriptions in this section is shown in the following table:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see \textit{Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”})</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the \texttt{--initial} option</td>
</tr>
</tbody>
</table>

- \texttt{NodeId1}
Table 18.184 This table provides type and value information for the NodeId1 TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide their node IDs in the [tcp] section of the configuration file as the values of NodeId1 and NodeId2. These are the same unique Id values for each of these nodes as described in Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”.

- **NodeId2**

Table 18.185 This table provides type and value information for the NodeId2 TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide their node IDs in the [tcp] section of the configuration file as the values of NodeId1 and NodeId2. These are the same unique Id values for each of these nodes as described in Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”.

- **HostName1**

Table 18.186 This table provides type and value information for the HostName1 TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The HostName1 and HostName2 parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.
• HostName2

Table 18.187 This table provides type and value information for the HostName1 TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>N</strong></td>
</tr>
</tbody>
</table>

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.

• OverloadLimit

Table 18.188 This table provides type and value information for the OverloadLimit TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td><strong>N</strong></td>
</tr>
</tbody>
</table>

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded.

This parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”, and Section 18.5.10.19, “The ndbinfo transporters Table”, for more information.

In some older releases, the effective value of this parameter was limited by the size of `SendBufferMemory`; in NDB Cluster 7.2, the actual value for `OverloadLimit` (up to the stated maximum of 4G) is used instead.

• SendBufferMemory

Table 18.189 This table provides type and value information for the SendBufferMemory TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>2M</td>
</tr>
<tr>
<td>Range</td>
<td>256K - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
TCP transporters use a buffer to store all messages before performing the send call to the operating system. When this buffer reaches 64KB its contents are sent; these are also sent when a round of messages have been executed. To handle temporary overload situations it is also possible to define a bigger send buffer.

If this parameter is set explicitly, then the memory is not dedicated to each transporter; instead, the value used denotes the hard limit for how much memory (out of the total available memory—that is, TotalSendBufferMemory) that may be used by a single transporter. For more information about configuring dynamic transporter send buffer memory allocation in NDB Cluster, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

The default size of the send buffer in NDB Cluster 7.2 is 2MB, which is the size recommended in most situations. The minimum size is 64 KB; the theoretical maximum is 4 GB.

- **SendSignalId**

  Table 18.190 This table provides type and value information for the SendSignalId TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>[see text]</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

  To be able to retrace a distributed message datagram, it is necessary to identify each message. When this parameter is set to \texttt{Y}, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in \texttt{–debug} builds.

- **Checksum**

  Table 18.191 This table provides type and value information for the Checksum TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

  This parameter is a boolean parameter (enabled by setting it to \texttt{Y} or \texttt{1}, disabled by setting it to \texttt{N} or \texttt{0}). It is disabled by default. When it is enabled, checksums for all messages are calculated before they placed in the send buffer. This feature ensures that messages are not corrupted while waiting in the send buffer, or by the transport mechanism.
• **PortNumber (OBSOLETE)**

This formerly specified the port number to be used for listening for connections from other nodes. This parameter is deprecated and should no longer be used; use the `ServerPort` data node configuration parameter for this purpose instead.

• **ReceiveBufferMemory**

Table 18.192 This table provides type and value information for the ReceiveBufferMemory TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>2M</td>
</tr>
<tr>
<td>Range</td>
<td>16K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Specifies the size of the buffer used when receiving data from the TCP/IP socket.

The default value of this parameter is 2MB. The minimum possible value is 16KB; the theoretical maximum is 4GB.

• **TCP_RCV_BUF_SIZE**

Table 18.193 This table provides type and value information for the TCP_RCV_BUF_SIZE TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>70080</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 2G</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Determines the size of the receive buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

• **TCP_SND_BUF_SIZE**

Table 18.194 This table provides type and value information for the TCP_SND_BUF_SIZE TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>71540</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 2G</td>
</tr>
</tbody>
</table>
Table 18.195 This table provides type and value information for the TCP_MAXSEG_SIZE TCP configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 2G</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Determines the size of the send buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

- **TCP_MAXSEG_SIZE**

18.3.3.10 NDB Cluster TCP/IP Connections Using Direct Connections

Setting up a cluster using direct connections between data nodes requires specifying explicitly the crossover IP addresses of the data nodes so connected in the [tcp] section of the cluster config.ini file.

In the following example, we envision a cluster with at least four hosts, one each for a management server, an SQL node, and two data nodes. The cluster as a whole resides on the 172.23.72.* subnet of a LAN. In addition to the usual network connections, the two data nodes are connected directly using a standard crossover cable, and communicate with one another directly using IP addresses in the 1.1.0.* address range as shown:

```plaintext
# Management Server
[ndb_mgmd]
Id=1
HostName=172.23.72.20

# SQL Node
[mysqld]
Id=2
HostName=172.23.72.21

# Data Nodes
```
NDB Cluster Configuration Files

```
[ndbd]
Id=3
HostName=172.23.72.22

[ndbd]
Id=4
HostName=172.23.72.23

# TCP/IP Connections
[tcp]
NodeId1=3
NodeId2=4
HostName1=1.1.0.1
HostName2=1.1.0.2
```

The `HostName1` and `HostName2` parameters are used only when specifying direct connections.

The use of direct TCP connections between data nodes can improve the cluster's overall efficiency by enabling the data nodes to bypass an Ethernet device such as a switch, hub, or router, thus cutting down on the cluster's latency. It is important to note that to take the best advantage of direct connections in this fashion with more than two data nodes, you must have a direct connection between each data node and every other data node in the same node group.

### 18.3.3.11 NDB Cluster Shared-Memory Connections

NDB Cluster attempts to use the shared memory transporter and configure it automatically where possible. `[shm]` sections in the `config.ini` file explicitly define shared-memory connections between nodes in the cluster. When explicitly defining shared memory as the connection method, it is necessary to define at least `NodeId1`, `NodeId2`, and `ShmKey`. All other parameters have default values that should work well in most cases.

**Important**

*SHM functionality is considered experimental only.* It is not officially supported in any current NDB Cluster release, and testing results indicate that SHM performance is not appreciably greater than when using TCP/IP for the transporter.

For these reasons, you must determine for yourself or by using our free resources (forums, mailing lists) whether SHM can be made to work correctly in your specific case.

**Restart types.** Information about the restart types used by the parameter descriptions in this section is shown in the following table:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the <code>--initial</code> option</td>
</tr>
</tbody>
</table>

• Checksum

2338
Table 18.197 This table provides type and value information for the Checksum shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>true</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is a boolean (Y/N) parameter which is disabled by default. When it is enabled, checksums for all messages are calculated before being placed in the send buffer. This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

- HostName1

Table 18.198 This table provides type and value information for the HostName1 shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The HostName1 and HostName2 parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.

- HostName2

Table 18.199 This table provides type and value information for the HostName1 shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

The HostName1 and HostName2 parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.
### NodeId1

Table 18.200 This table provides type and value information for the NodeId1 shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as NodeId1 and NodeId2.

### NodeId2

Table 18.201 This table provides type and value information for the NodeId2 shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as NodeId1 and NodeId2.

### NodeIdServer

Table 18.202 This table provides type and value information for the NodeIdServer shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 63</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

Identify the server end of a shared memory connection.
NDB Cluster Configuration Files

- **OverloadLimit**

Table 18.203 This table provides type and value information for the OverloadLimit shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded.

This parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”, for more information.

In some older releases, the effective value of this parameter was limited by the size of `SendBufferMemory`; in NDB Cluster 7.2, the actual value for `OverloadLimit` (up to the stated maximum of 4G) is used instead.

- **SendSignalId**

Table 18.204 This table provides type and value information for the SendSignalId shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

To retrace the path of a distributed message, it is necessary to provide each message with a unique identifier. Setting this parameter to `Y` causes these message IDs to be transported over the network as well. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- **ShmKey**

Table 18.205 This table provides type and value information for the ShmKey shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>
When setting up shared memory segments, a node ID, expressed as an integer, is used to identify uniquely the shared memory segment to use for the communication. There is no default value.

- **ShmSize**

  Table 18.206 This table provides type and value information for the ShmSize shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>1M</td>
</tr>
<tr>
<td>Range</td>
<td>64K - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>

Each SHM connection has a shared memory segment where messages between nodes are placed by the sender and read by the reader. The size of this segment is defined by `ShmSize`. The default value is 1MB.

- **SigNum**

  Table 18.207 This table provides type and value information for the Signum shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
</tbody>
</table>

When using the shared memory transporter, a process sends an operating system signal to the other process when there is new data available in the shared memory. Should that signal conflict with an existing signal, this parameter can be used to change it. This is a possibility when using SHM due to the fact that different operating systems use different signal numbers.

The default value of `SigNum` is 0; therefore, it must be set to avoid errors in the cluster log when using the shared memory transporter. Typically, this parameter is set to 10 in the `[shm default]` section of the `config.ini` file.

**18.3.3.12 SCI Transport Connections in NDB Cluster**

[sci] sections in the `config.ini` file explicitly define SCI (Scalable Coherent Interface) connections between cluster nodes. Using SCI transporters in NDB Cluster requires specialized hardware as well as specially-built MySQL binaries; compiling such binaries is not supported using an NDB 7.2 or later distribution.

**Restart types.** Information about the restart types used by the parameter descriptions in this section is shown in the following table:
Table 18.208 NDB Cluster restart types

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Restart Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Node</td>
<td>The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”)</td>
</tr>
<tr>
<td>S</td>
<td>System</td>
<td>All cluster nodes must be shut down completely, then restarted, to effect a change in this parameter</td>
</tr>
<tr>
<td>I</td>
<td>Initial</td>
<td>Data nodes must be restarted using the --initial option</td>
</tr>
</tbody>
</table>

The following parameters are present in NDB source code as well as the output of ndb_config and other NDB programs, but are nonfunctional in NDB 7.2 and later.

- **NodeId1**

  Table 18.209 This table provides type and value information for the NodeId1 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as NodeId1 and NodeId2.

- **NodeId2**

  Table 18.210 This table provides type and value information for the NodeId2 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>numeric</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>1 - 255</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as NodeId1 and NodeId2.

- **Group**

  Table 18.211 This table provides type and value information for the Group shared memory configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
</tbody>
</table>
NDB Cluster Configuration Files

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>35</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 200</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Determines the group proximity; a smaller value is interpreted as being closer. The default value is sufficient for most conditions.

- **Host1SciId0**

  Table 18.212 This table provides type and value information for the Host1SciId0 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

This identifies the SCI node ID on the first Cluster node (identified by NodeId1).

- **Host1SciId1**

  Table 18.213 This table provides type and value information for the Host1SciId1 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

It is possible to set up SCI Transporters for failover between two SCI cards which then should use separate networks between the nodes. This identifies the node ID and the second SCI card to be used on the first node.

- **Host2SciId0**

  Table 18.214 This table provides type and value information for the Host2SciId0 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>
This identifies the SCI node ID on the second Cluster node (identified by \texttt{NodeId2}).

- \textbf{Host2SciId1}

  \textbf{Table 18.215} This table provides type and value information for the Host2SciId1 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>\textbf{Restart Type}</td>
<td>N</td>
</tr>
</tbody>
</table>

When using two SCI cards to provide failover, this parameter identifies the second SCI card to be used on the second node.

- \textbf{HostName1}

  \textbf{Table 18.216} This table provides type and value information for the HostName1 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>\textbf{Restart Type}</td>
<td>N</td>
</tr>
</tbody>
</table>

The \texttt{HostName1} and \texttt{HostName2} parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

- \textbf{HostName2}

  \textbf{Table 18.217} This table provides type and value information for the HostName1 SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>name or IP address</td>
</tr>
<tr>
<td>Default</td>
<td>[none]</td>
</tr>
<tr>
<td>Range</td>
<td>...</td>
</tr>
<tr>
<td>\textbf{Restart Type}</td>
<td>N</td>
</tr>
</tbody>
</table>

The \texttt{HostName1} and \texttt{HostName2} parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

- \textbf{SharedBufferSize}

  \texttt{SharedBufferSize} 2345
Table 18.218 This table provides type and value information for the SharedBufferSize SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>10M</td>
</tr>
<tr>
<td>Range</td>
<td>64K - 4294967039 (0xFFFFFEFF)</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

Each SCI transporter has a shared memory segment used for communication between the two nodes. Setting the size of this segment to the default value of 1MB should be sufficient for most applications. Using a smaller value can lead to problems when performing many parallel inserts; if the shared buffer is too small, this can also result in a crash of the ndbd process.

- **SendLimit**

Table 18.219 This table provides type and value information for the SendLimit SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>unsigned</td>
</tr>
<tr>
<td>Default</td>
<td>8K</td>
</tr>
<tr>
<td>Range</td>
<td>128 - 32K</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

A small buffer in front of the SCI media stores messages before transmitting them over the SCI network. By default, this is set to 8KB. Our benchmarks show that performance is best at 64KB but 16KB reaches within a few percent of this, and there was little if any advantage to increasing it beyond 8KB.

- **SendSignalId**

Table 18.220 This table provides type and value information for the SendSignalId SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>true</td>
</tr>
<tr>
<td>Range</td>
<td>true, false</td>
</tr>
<tr>
<td>Restart Type</td>
<td>N</td>
</tr>
</tbody>
</table>

To trace a distributed message it is necessary to identify each message uniquely. When this parameter is set to \texttt{Y}, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in \texttt{-debug} builds.
• Checksum

Table 18.221 This table provides type and value information for the Checksum SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>boolean</td>
</tr>
<tr>
<td>Default</td>
<td>false</td>
</tr>
<tr>
<td>Range</td>
<td>true,false</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

This parameter is a boolean value, and is disabled by default. When Checksum is enabled, checksums are calculated for all messages before they are placed in the send buffer. This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

• OverloadLimit

Table 18.222 This table provides type and value information for the OverloadLimit SCI configuration parameter

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version (or later)</td>
<td>NDB 7.2.1</td>
</tr>
<tr>
<td>Type or units</td>
<td>bytes</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 4294967039</td>
</tr>
<tr>
<td><strong>Restart Type</strong></td>
<td>N</td>
</tr>
</tbody>
</table>

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded. See Section 18.3.3.13, "Configuring NDB Cluster Send Buffer Parameters", for more information.

18.3.3.13 Configuring NDB Cluster Send Buffer Parameters

Formerly, the NDB kernel employed a send buffer whose size was fixed at 2MB for each node in the cluster, this buffer being allocated when the node started. Because the size of this buffer could not be changed after the cluster was started, it was necessary to make it large enough in advance to accommodate the maximum possible load on any transporter socket. However, this was an inefficient use of memory, since much of it often went unused, and could result in large amounts of resources being wasted when scaling up to many API nodes.

This problem was eventually solved (in NDB Cluster 7.0) by employing a unified send buffer whose memory is allocated dynamically from a pool shared by all transporters. This means that the size of the send buffer can be adjusted as necessary. Configuration of the unified send buffer can accomplished by setting the following parameters:

• **TotalSendBufferMemory.** This parameter can be set for all types of NDB Cluster nodes—that is, it can be set in the [ndbd], [mgm], and [api] (or [mysql]) sections of the config.ini file. It represents the total amount of memory (in bytes) to be allocated by each node for which it is set for use among all configured transporters. If set, its minimum is 256KB; the maximum is 4294967039.
To be backward-compatible with existing configurations, this parameter takes as its default value the sum of the maximum send buffer sizes of all configured transporters, plus an additional 32KB (one page) per transporter. The maximum depends on the type of transporter, as shown in the following table:

<table>
<thead>
<tr>
<th>Transporter</th>
<th>Maximum Send Buffer Size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>SendBufferMemory (default = 2M)</td>
</tr>
<tr>
<td>SCI</td>
<td>SendLimit (default = 8K) plus 16K</td>
</tr>
<tr>
<td>SHM</td>
<td>20K</td>
</tr>
</tbody>
</table>

This enables existing configurations to function in close to the same way as they did with NDB Cluster 6.3 and earlier, with the same amount of memory and send buffer space available to each transporter. However, memory that is unused by one transporter is not available to other transporters.

- **OverloadLimit.** This parameter is used in the `config.ini` file `[tcp]` section, and denotes the amount of unsent data (in bytes) that must be present in the send buffer before the connection is considered overloaded. When such an overload condition occurs, transactions that affect the overloaded connection fail with NDB API Error 1218 (*Send Buffers overloaded in NDB kernel*) until the overload status passes. The default value is 0, in which case the effective overload limit is calculated as `SendBufferMemory * 0.8` for a given connection. The maximum value for this parameter is 4G.

- **SendBufferMemory.** This value denotes a hard limit for the amount of memory that may be used by a single transporter out of the entire pool specified by `TotalSendBufferMemory`. However, the sum of `SendBufferMemory` for all configured transporters may be greater than the `TotalSendBufferMemory` that is set for a given node. This is a way to save memory when many nodes are in use, as long as the maximum amount of memory is never required by all transporters at the same time.

- **ReservedSendBufferMemory.** This optional data node parameter, if set, gives an amount of memory (in bytes) that is reserved for connections between data nodes; this memory is not allocated to send buffers used for communications with management servers or API nodes. This provides a way to protect the cluster against misbehaving API nodes that use excess send memory and thus cause failures in communications internally in the NDB kernel. If set, its the minimum permitted value for this parameters is 256KB; the maximum is 4294967039.

You can use the `ndbinfo.transporters` table to monitor send buffer memory usage, and to detect slowdown and overload conditions that can adversely affect performance.

### 18.3.4 Using High-Speed Interconnects with NDB Cluster

Even before design of `NDBCLUSTER` began in 1996, it was evident that one of the major problems to be encountered in building parallel databases would be communication between the nodes in the network. For this reason, `NDBCLUSTER` was designed from the very beginning to permit the use of a number of different data transport mechanisms. In this Manual, we use the term `transporter` for these.

The NDB Cluster codebase provides for four different transporters:

- **TCP/IP using 100 Mbps or gigabit Ethernet**, as discussed in Section 18.3.3.9, “NDB Cluster TCP/IP Connections”.
- **Direct (machine-to-machine) TCP/IP**; although this transporter uses the same TCP/IP protocol as mentioned in the previous item, it requires setting up the hardware differently and is configured
NDB Cluster Programs

NDB Cluster Programs
differently as well. For this reason, it is considered a separate transport mechanism for NDB Cluster. See Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections”, for details.

- **Shared memory (SHM).** For more information about SHM, see Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”.

  ![Note]

  SHM is considered experimental only, and is not officially supported.

- **Scalable Coherent Interface (SCI).** For more information about SHM, see Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”.

  ![Note]

  Using SCI transporters in NDB Cluster requires specialized hardware, software, and MySQL binaries not available using an NDB 7.2 or later distribution.

Most users today employ TCP/IP over Ethernet because it is ubiquitous. TCP/IP is also by far the best-tested transporter for use with NDB Cluster.

We are working to make sure that communication with the ndbd process is made in “chunks” that are as large as possible because this benefits all types of data transmission.

### 18.4 NDB Cluster Programs

Using and managing an NDB Cluster requires several specialized programs, which we describe in this chapter. We discuss the purposes of these programs in an NDB Cluster, how to use the programs, and what startup options are available for each of them.

These programs include the NDB Cluster data, management, and SQL node processes (ndbd, ndbmxtd, ndb_mgmd, and mysqld) and the management client (ndb_mgm).

For information about using mysqld as an NDB Cluster process, see Section 18.5.4, “MySQL Server Usage for NDB Cluster”.

Other NDB utility, diagnostic, and example programs are included with the NDB Cluster distribution. These include ndb_restore, ndb_show_tables, and ndb_config. These programs are also covered in this section.

The final portion of this section contains tables of options that are common to all the various NDB Cluster programs.

#### 18.4.1 ndbd — The NDB Cluster Data Node Daemon

*ndbd* is the process that is used to handle all the data in tables using the NDB Cluster storage engine. This is the process that empowers a data node to accomplish distributed transaction handling, node recovery, checkpointing to disk, online backup, and related tasks.

In an NDB Cluster, a set of *ndbd* processes cooperate in handling data. These processes can execute on the same computer (host) or on different computers. The correspondences between data nodes and Cluster hosts is completely configurable.

The following table includes command options specific to the NDB Cluster data node program *ndbd*. Additional descriptions follow the table. For options common to most NDB Cluster programs (including
**ndbd** — The NDB Cluster Data Node Daemon

*ndbd*, see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

### Table 18.224 Command-line options for the ndbd program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--bind-address=name</code></td>
<td>Local bind address</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--connect-delay=#</code></td>
<td>Time to wait between attempts to contact a management server, in seconds; 0 means do not wait between attempts</td>
<td>ADDED: NDB 7.2.9</td>
</tr>
<tr>
<td><code>--connect-retries=#</code></td>
<td>Set the number of times to retry a connection before giving up; 0 means 1 attempt only (and no retries)</td>
<td>ADDED: NDB 7.2.9</td>
</tr>
<tr>
<td><code>--daemon</code>, <code>-d</code></td>
<td>Start ndbd as daemon (default); override with <code>--nodaemon</code></td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--foreground</code></td>
<td>Run ndbd in foreground, provided for debugging purposes (implies <code>--nodaemon</code>)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--initial</code></td>
<td>Perform initial start of ndbd, including cleaning the file system. Consult the documentation before using this option</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--initial-start</code></td>
<td>Perform partial initial start (requires <code>--nowait-nodes</code>)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--install[=name]</code></td>
<td>Used to install the data node process as a Windows service. Does not apply on non-Windows platforms</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nodaemon</code></td>
<td>Do not start ndbd as daemon; provided for testing purposes</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nostart</code>, <code>-n</code></td>
<td>Do not start ndbd immediately; ndbd waits for command to start from ndb_mgmd</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nowait-nodes=list</code></td>
<td>Do not wait for these data nodes to start (takes comma-separated list of node IDs). Also requires <code>--ndb-nodeid</code> to be used</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--remove[=name]</code></td>
<td>Used to remove a data node process that was previously installed as a Windows service. Does not apply on non-Windows platforms</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--verbose</code>, <code>-v</code></td>
<td>Causes the data log to write extra debugging information to the node log</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
ndbd — The NDB Cluster Data Node Daemon

Note
All of these options also apply to the multithreaded version of this program (ndbmtd) and you may substitute “ndbmtd” for “ndbd” wherever the latter occurs in this section.

• --bind-address

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--bind-address=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Causes ndbd to bind to a specific network interface (host name or IP address). This option has no default value.

• --daemon, -d

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--daemon</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

Instructs ndbd or ndbmtd to execute as a daemon process. This is the default behavior. --nodaemon can be used to prevent the process from running as a daemon.

This option has no effect when running ndbd or ndbmtd on Windows platforms.

• --connect-delay=#

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--connect-delay=#</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28-ndb-7.2.9</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>5</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>3600</td>
</tr>
</tbody>
</table>

Determines the time to wait between attempts to contact a management server when starting (the time between attempts is controlled by the --connect-retries option). The default is 5 attempts.

This option was added in NDB 7.2.9.

• --connect-retries=#

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--connect-retries=#</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.28-ndb-7.2.9</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td></td>
<td>2351</td>
</tr>
</tbody>
</table>
### ndbd — The NDB Cluster Data Node Daemon

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>12</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

Determines the number of times that the data node attempts to contact a management server when starting. Setting this option to -1 causes the data node to keep trying to make contact indefinitely. The default is 12 attempts. The time to wait between attempts is controlled by the `--connect-delay` option.

This option was added in NDB 7.2.9.

- **--foreground**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--foreground</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Causes `ndbd` or `ndbmtd` to execute as a foreground process, primarily for debugging purposes. This option implies the `--nodaemon` option.

This option has no effect when running `ndbd` or `ndbmtd` on Windows platforms.

- **--initial**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--initial</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Instructs `ndbd` to perform an initial start. An initial start erases any files created for recovery purposes by earlier instances of `ndbd`. It also re-creates recovery log files. On some operating systems, this process can take a substantial amount of time.

An `--initial` start is to be used only when starting the `ndbd` process under very special circumstances; this is because this option causes all files to be removed from the NDB Cluster file system and all redo log files to be re-created. These circumstances are listed here:

- When performing a software upgrade which has changed the contents of any files.
- When restarting the node with a new version of `ndbd`.
- As a measure of last resort when for some reason the node restart or system restart repeatedly fails. In this case, be aware that this node can no longer be used to restore data due to the destruction of the data files.

**Warning**

To avoid the possibility of eventual data loss, it is recommended that you *not* use the `--initial` option together with `StopOnError = 0`. Instead, set `StopOnError` to 0 in `config.ini` only after the cluster has been started, then...
restart the data nodes normally—that is, without the `--initial` option. See the description of the `StopOnError` parameter for a detailed explanation of this issue. (Bug #24945638)

Use of this option prevents the `StartPartialTimeout` and `StartPartitionedTimeout` configuration parameters from having any effect.

**Important**

This option does *not* affect either of the following types of files:

- Backup files that have already been created by the affected node
- NDB Cluster Disk Data files (see Section 18.5.12, “NDB Cluster Disk Data Tables”).

This option also has no effect on recovery of data by a data node that is just starting (or restarting) from data nodes that are already running. This recovery of data occurs automatically, and requires no user intervention in an NDB Cluster that is running normally.

It is permissible to use this option when starting the cluster for the very first time (that is, before any data node files have been created); however, it is *not* necessary to do so.

- **--initial-start**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--initial-start</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

This option is used when performing a partial initial start of the cluster. Each node should be started with this option, as well as `--nowait-nodes`.

Suppose that you have a 4-node cluster whose data nodes have the IDs 2, 3, 4, and 5, and you wish to perform a partial initial start using only nodes 2, 4, and 5—that is, omitting node 3:

```shell
shell> ndbd --ndb-nodeid=2 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=4 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=5 --nowait-nodes=3 --initial-start
```

When using this option, you must also specify the node ID for the data node being started with the `--ndb-nodeid` option.

**Important**

Do not confuse this option with the `--nowait-nodes` option for `ndb_mgmd`, which can be used to enable a cluster configured with multiple management servers to be started without all management servers being online.

- **--install[=name]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--install[=name]</code></td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
</tbody>
</table>
Causes `ndbd` to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to `ndbd`. Although it is preferable to specify other `ndbd` program options in a `my.ini` or `my.cnf` configuration file, it is possible to use together with `--install`. However, in such cases, the `--install` option must be specified first, before any other options are given, for the Windows service installation to succeed.

It is generally not advisable to use this option together with the `--initial` option, since this causes the data node file system to be wiped and rebuilt every time the service is stopped and started. Extreme care should also be taken if you intend to use any of the other `ndbd` options that affect the starting of data nodes—including `--initial-start`, `--nostart`, and `--nowait-nodes`—together with `--install`, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

The `--install` option has no effect on non-Windows platforms.

- `--nodaemon`

Prevents `ndbd` or `ndbmtd` from executing as a daemon process. This option overrides the `--daemon` option. This is useful for redirecting output to the screen when debugging the binary.

The default behavior for `ndbd` and `ndbmtd` on Windows is to run in the foreground, making this option unnecessary on Windows platforms, where it has no effect.

- `--nostart,-n`

Instructs `ndbd` not to start automatically. When this option is used, `ndbd` connects to the management server, obtains configuration data from it, and initializes communication objects. However, it does not actually start the execution engine until specifically requested to do so by the management server. This can be accomplished by issuing the proper `START` command in the management client (see Section 18.5.2, “Commands in the NDB Cluster Management Client”).

- `--nowait-nodes=node_id_1[, node_id_2[, ...]]`
This option takes a list of data nodes which for which the cluster will not wait for before starting.

This can be used to start the cluster in a partitioned state. For example, to start the cluster with only half of the data nodes (nodes 2, 3, 4, and 5) running in a 4-node cluster, you can start each ndbd process with `--nowait-nodes=3,5`. In this case, the cluster starts as soon as nodes 2 and 4 connect, and does not wait `StartPartitionedTimeout` milliseconds for nodes 3 and 5 to connect as it would otherwise.

If you wanted to start up the same cluster as in the previous example without one ndbd (say, for example, that the host machine for node 3 has suffered a hardware failure) then start nodes 2, 4, and 5 with `--nowait-nodes=3`. Then the cluster will start as soon as nodes 2, 4, and 5 connect and will not wait for node 3 to start.

```
• --remove [=name]
```

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--remove [=name]</code></td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>ndbd</td>
</tr>
</tbody>
</table>

Causes an ndbd process that was previously installed as a Windows service to be removed. Optionally, you can specify a name for the service to be uninstalled; if not set, the service name defaults to ndbd.

The `--remove` option has no effect on non-Windows platforms.

```
• --verbose, -v
```

Causes extra debug output to be written to the node log.

In NDB 7.6.4 and later, you can also use `NODELOG DEBUG ON` and `NODELOG DEBUG OFF` to enable and disable this extra logging while the data node is running.

ndbd generates a set of log files which are placed in the directory specified by `DataDir` in the `config.ini` configuration file.

These log files are listed below. `node_id` is the node's unique identifier. Note that `node_id` represents the node's unique identifier. For example, `ndb_2_error.log` is the error log generated by the data node whose node ID is 2.

```
• ndb_node_id_error.log is a file containing records of all crashes which the referenced ndbd process has encountered. Each record in this file contains a brief error string and a reference to a trace file for this crash. A typical entry in this file might appear as shown here:
```

```
Date/Time: Saturday 30 July 2004 - 00:20:01
Type of error: error
Message: Internal program error (failed ndbrequire)
Fault ID: 2341
Problem data: DbtpFixAlloc.cpp
Object of reference: DBTUP (Line: 173)
ProgramName: NDB Kernel
ProcessID: 14909
```
Lists of possible ndbd exit codes and messages generated when a data node process shuts down prematurely can be found in Data Node Error Messages.

Important

The last entry in the error log file is not necessarily the newest one (nor is it likely to be). Entries in the error log are *not* listed in chronological order; rather, they correspond to the order of the trace files as determined in the ndb_node_id_trace.log.next file (see below). Error log entries are thus overwritten in a cyclical and not sequential fashion.

- ndb_node_id_trace.log.trace_id is a trace file describing exactly what happened just before the error occurred. This information is useful for analysis by the NDB Cluster development team.

  It is possible to configure the number of these trace files that will be created before old files are overwritten. trace_id is a number which is incremented for each successive trace file.

- ndb_node_id_trace.log.next is the file that keeps track of the next trace file number to be assigned.

- ndb_node_id_out.log is a file containing any data output by the ndbd process. This file is created only if ndbd is started as a daemon, which is the default behavior.

- ndb_node_id.pid is a file containing the process ID of the ndbd process when started as a daemon. It also functions as a lock file to avoid the starting of nodes with the same identifier.

- ndb_node_id_signal.log is a file used only in debug versions of ndbd, where it is possible to trace all incoming, outgoing, and internal messages with their data in the ndbd process.

It is recommended not to use a directory mounted through NFS because in some environments this can cause problems whereby the lock on the .pid file remains in effect even after the process has terminated.

To start ndbd, it may also be necessary to specify the host name of the management server and the port on which it is listening. Optionally, one may also specify the node ID that the process is to use.

```
shell> ndbd --connect-string="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

See Section 18.3.3.3, “NDB Cluster Connection Strings”, for additional information about this issue. Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”, describes other command-line options which can be used with ndbd. For information about data node configuration parameters, see Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.

When ndbd starts, it actually initiates two processes. The first of these is called the “angel process”; its only job is to discover when the execution process has been completed, and then to restart the ndbd process if it is configured to do so. Thus, if you attempt to kill ndbd using the Unix kill command, it is necessary to kill both processes, beginning with the angel process. The preferred method of terminating an ndbd process is to use the management client and stop the process from there.

The execution process uses one thread for reading, writing, and scanning data, as well as all other activities. This thread is implemented asynchronously so that it can easily handle thousands of concurrent actions. In addition, a watch-dog thread supervises the execution thread to make sure that it does not hang in an endless loop. A pool of threads handles file I/O, with each thread able to handle one open file. Threads can also be used for transporter connections by the transporters in the ndbd process. In a multi-processor system performing a large number of operations (including updates), the ndbd process can consume up to 2 CPUs if permitted to do so.
For a machine with many CPUs it is possible to use several ndbd processes which belong to different node groups; however, such a configuration is still considered experimental and is not supported for MySQL 5.5 in a production setting. See Section 18.1.7, “Known Limitations of NDB Cluster”.

### 18.4.2 ndbinfo_select_all — Select From ndbinfo Tables

ndbinfo_select_all is a client program that selects all rows and columns from one or more tables in the ndbinfo database. It is included with the NDB Cluster distribution beginning with NDB 7.2.2.

Not all ndbinfo tables available in the mysql client can be read by this program. In addition, ndbinfo_select_all can show information about some tables internal to ndbinfo which cannot be accessed using SQL, including the tables and columns metadata tables.

To select from one or more ndbinfo tables using ndbinfo_select_all, it is necessary to supply the names of the tables when invoking the program as shown here:

```
shell> ndbinfo_select_all table_name1 [table_name2] [...]
```

For example:

```
shell> ndbinfo_select_all logbuffers logspaces
== logbuffers ==
node_id log_type log_id log_part total used high
5 0 0 0 33554432 262144 0
6 0 0 0 33554432 262144 0
7 0 0 0 33554432 262144 0
8 0 0 0 33554432 262144 0

== logspaces ==
node_id log_type log_id log_part total used high
5 0 0 0 268435456 0 0
5 0 0 1 268435456 0 0
5 0 0 2 268435456 0 0
5 0 0 3 268435456 0 0
6 0 0 0 268435456 0 0
6 0 0 1 268435456 0 0
6 0 0 2 268435456 0 0
6 0 0 3 268435456 0 0
7 0 0 0 268435456 0 0
7 0 0 1 268435456 0 0
7 0 0 2 268435456 0 0
7 0 0 3 268435456 0 0
8 0 0 0 268435456 0 0
8 0 0 1 268435456 0 0
8 0 0 2 268435456 0 0
8 0 0 3 268435456 0 0
shell>
```

The following table includes options that are specific to ndbinfo_select_all. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndbinfo_select_all), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

**Table 18.225 Command-line options for the ndbinfo_select_all program**

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--delay=#</td>
<td>Set the delay in seconds between loops. Default is 5</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--loops=#,</td>
<td>Set the number of times to perform the select. Default is 1</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-l</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--database=db_name,</td>
<td>Name of the database where the table located</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--parallelism=#,</td>
<td>Set the degree of parallelism</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-p</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **--delay=seconds**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--delay=#</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>5</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>MAX_INT</td>
</tr>
</tbody>
</table>

This option sets the number of seconds to wait between executing loops. Has no effect if **--loops** is set to 0 or 1.

- **--loops=number, -l number**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--loops=#</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>MAX_INT</td>
</tr>
</tbody>
</table>

This option sets the number of times to execute the select. Use **--delay** to set the time between loops.

### 18.4.3 ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)

ndbmtd is a multithreaded version of ndbd, the process that is used to handle all the data in tables using the NDBCLUSTER storage engine. ndbmtd is intended for use on host computers having multiple CPU cores. Except where otherwise noted, ndbmtd functions in the same way as ndbd; therefore, in this section, we concentrate on the ways in which ndbmtd differs from ndbd, and you should consult Section 18.4.1, "ndbd — The NDB Cluster Data Node Daemon", for additional information about running NDB Cluster data nodes that apply to both the single-threaded and multithreaded versions of the data node process.

Command-line options and configuration parameters used with ndbd also apply to ndbmtd. For more information about these options and parameters, see Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”, and Section 18.3.3.6, "Defining NDB Cluster Data Nodes", respectively.

ndbmtd is also file system-compatible with ndbd. In other words, a data node running ndbd can be stopped, the binary replaced with ndbmtd, and then restarted without any loss of data. (However, when doing this, you must make sure that MaxNoOfExecutionThreads is set to an appropriate value.
before restarting the node if you wish for \texttt{ndbtd} to run in multithreaded fashion.) Similarly, an \texttt{ndbtd} binary can be replaced with \texttt{ndbd} simply by stopping the node and then starting \texttt{ndbd} in place of the multithreaded binary. It is not necessary when switching between the two to start the data node binary using \texttt{--initial}.

Using \texttt{ndbtd} differs from using \texttt{ndbd} in two key respects:

1. Because \texttt{ndbtd} runs by default in single-threaded mode (that is, it behaves like \texttt{ndbd}), you must configure it to use multiple threads. This can be done by setting an appropriate value in the \texttt{config.ini} file for the \texttt{MaxNoOfExecutionThreads} configuration parameter or (in NDB 7.2.3 and later) the \texttt{ThreadConfig} configuration parameter. Using \texttt{MaxNoOfExecutionThreads} is simpler, but \texttt{ThreadConfig} offers more flexibility. For more information about these configuration parameters and their use, see Multi-Threading Configuration Parameters (\texttt{ndbtd}).

2. Trace files are generated by critical errors in \texttt{ndbtd} processes in a somewhat different fashion from how these are generated by \texttt{ndbd} failures. These differences are discussed in more detail in the next few paragraphs.

Like \texttt{ndbd}, \texttt{ndbtd} generates a set of log files which are placed in the directory specified by \texttt{DataDir} in the \texttt{config.ini} configuration file. Except for trace files, these are generated in the same way and have the same names as those generated by \texttt{ndbd}.

In the event of a critical error, \texttt{ndbtd} generates trace files describing what happened just prior to the error occurrence. These files, which can be found in the data node's \texttt{DataDir}, are useful for analysis of problems by the NDB Cluster Development and Support teams. One trace file is generated for each \texttt{ndbtd} thread. The names of these files have the following pattern:

\texttt{ndb\_node\_id\_trace.log.trace\_id\_t\_thread\_id}

In this pattern, \texttt{node\_id} stands for the data node's unique node ID in the cluster, \texttt{trace\_id} is a trace sequence number, and \texttt{thread\_id} is the thread ID. For example, in the event of the failure of an \texttt{ndbtd} process running as an NDB Cluster data node having the node ID 3 and with \texttt{MaxNoOfExecutionThreads} equal to 4, four trace files are generated in the data node's data directory. If the is the first time this node has failed, then these files are named \texttt{ndb\_3\_trace.log.1\_t1}, \texttt{ndb\_3\_trace.log.1\_t2}, \texttt{ndb\_3\_trace.log.1\_t3}, and \texttt{ndb\_3\_trace.log.1\_t4}. Internally, these trace files follow the same format as \texttt{ndbd} trace files.

The \texttt{ndbd} exit codes and messages that are generated when a data node process shuts down prematurely are also used by \texttt{ndbtd}. See Data Node Error Messages, for a listing of these.

\section*{18.4.4 \texttt{ndb\_mgmd} — The NDB Cluster Management Server Daemon}

The management server is the process that reads the cluster configuration file and distributes this information to all nodes in the cluster that request it. It also maintains a log of cluster activities. Management clients can connect to the management server and check the cluster's status.

The following table includes options that are specific to the NDB Cluster management server program \texttt{ndb\_mgmd}. Additional descriptions follow the table. For options common to most NDB Cluster programs (including \texttt{ndb\_mgmd}), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

\begin{itemize}
\item [\textbullet] \texttt{ndb\_mgmd} — The NDB Cluster Management Server Daemon
\end{itemize}
Table 18.226 Command-line options for the ndb_mgmd program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--bind-address=host</code></td>
<td>Local bind address</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>`--config-cache=[TRUE</td>
<td>FALSE]`</td>
<td>Enable the management server configuration cache; TRUE by default</td>
</tr>
<tr>
<td><code>--config-file=file, -f</code></td>
<td>Specify the cluster configuration file; in NDB-6.4.0 and later, needs --reload or --initial to override configuration cache if present</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--configdir=directory, --config-dir=directory</code></td>
<td>Specify the cluster management server's configuration cache directory</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--daemon, -d</code></td>
<td>Run ndb_mgmd in daemon mode (default)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--initial</code></td>
<td>Causes the management server reload its configuration data from the configuration file, bypassing the configuration cache</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--install=[name]</code></td>
<td>Used to install the management server process as a Windows service. Does not apply on non-Windows platforms</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--interactive</code></td>
<td>Run ndb_mgmd in interactive mode (not officially supported in production; for testing purposes only)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--log-name=name</code></td>
<td>A name to use when writing messages applying to this node in the cluster log</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--mycnf</code></td>
<td>Read cluster configuration data from the my.cnf file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--no-nodeid-checks</code></td>
<td>Do not provide any node id checks</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nodaemon</code></td>
<td>Do not run ndb_mgmd as a daemon</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nowait-nodes=list</code></td>
<td>Do not wait for these management nodes when starting this management server. Also requires --ndb-nodeid to be used</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--print-full-config, -P</code></td>
<td>Print full configuration and exit</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
**ndb_mgmd** — The NDB Cluster Management Server Daemon

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--reload</td>
<td>Causes the management server to compare the configuration file with its configuration cache</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--remove[=name]</td>
<td>Used to remove a management server process that was previously installed as a Windows service, optionally specifying the name of the service to be removed. Does not apply on non-Windows platforms</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--verbose, -v</td>
<td>Write additional information to the log</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

- **--bind-address=host**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--bind-address=host</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

Causes the management server to bind to a specific network interface (host name or IP address). This option has no default value.

- **--daemon, -d**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--daemon</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

Instructs `ndb_mgmd` to start as a daemon process. This is the default behavior.

This option has no effect when running `ndb_mgmd` on Windows platforms.

- **--config-cache**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--config-cache[=TRUE</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

This option, whose default value is 1 (or TRUE, or ON), can be used to disable the management server's configuration cache, so that it reads its configuration from `config.ini` every time it starts (see Section 18.3.3, "NDB Cluster Configuration Files"). You can do this by starting the `ndb_mgmd` process with any one of the following options:

- **--config-cache=0**
• --config-cache=FALSE
• --config-cache=OFF
• --skip-config-cache

Using one of the options just listed is effective only if the management server has no stored configuration at the time it is started. If the management server finds any configuration cache files, then the --config-cache option or the --skip-config-cache option is ignored. Therefore, to disable configuration caching, the option should be used the first time that the management server is started. Otherwise—that is, if you wish to disable configuration caching for a management server that has already created a configuration cache—you must stop the management server, delete any existing configuration cache files manually, then restart the management server with --skip-config-cache (or with --config-cache set equal to 0, OFF, or FALSE).

Configuration cache files are normally created in a directory named mysql-cluster under the installation directory (unless this location has been overridden using the --configdir option). Each time the management server updates its configuration data, it writes a new cache file. The files are named sequentially in order of creation using the following format:

```
ndb_node-id_config.bin.seq-number
```

`node-id` is the management server’s node ID; `seq-number` is a sequence number, beginning with 1. For example, if the management server’s node ID is 5, then the first three configuration cache files would, when they are created, be named ndb_5_config.bin.1, ndb_5_config.bin.2, and ndb_5_config.bin.3.

If your intent is to purge or reload the configuration cache without actually disabling caching, you should start ndb_mgmd with one of the options --reload or --initial instead of --skip-config-cache.

To re-enable the configuration cache, simply restart the management server, but without the --config-cache or --skip-config-cache option that was used previously to disable the configuration cache.

Beginning with NDB 7.2.5, ndb_mgmd no longer checks for the configuration directory (--configdir) or attempts to create one when --skip-config-cache is used. (Bug #13428853)

• --config-file=filename, -f filename

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--config-file=file</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

Instructs the management server as to which file it should use for its configuration file. By default, the management server looks for a file named config.ini in the same directory as the ndb_mgmd executable; otherwise the file name and location must be specified explicitly.

This option has no default value, and is ignored unless the management server is forced to read the configuration file, either because ndb_mgmd was started with the --reload or --initial option, or because the management server could not find any configuration cache. This option is also read if
ndb_mgmd — The NDB Cluster Management Server Daemon

ndb_mgmd was started with --config-cache=OFF. See Section 18.3.3, "NDB Cluster Configuration Files", for more information.

Formerly, using this option together with --initial caused removal of the configuration cache even if the file was not found. This issue was resolved in NDB 7.2.13. (Bug #1299289)

- --configdir=dir_name

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--configdir=directory</td>
</tr>
<tr>
<td></td>
<td>--config-dir=directory</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td>$INSTALLDIR/mysql-cluster</td>
</tr>
</tbody>
</table>

 Specifies the cluster management server's configuration cache directory. --config-dir is an alias for this option.

- --initial

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--initial</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

 Configuration data is cached internally, rather than being read from the cluster global configuration file each time the management server is started (see Section 18.3.3, "NDB Cluster Configuration Files"). Using the --initial option overrides this behavior, by forcing the management server to delete any existing cache files, and then to re-read the configuration data from the cluster configuration file and to build a new cache.

This differs in two ways from the --reload option. First, --reload forces the server to check the configuration file against the cache and reload its data only if the contents of the file are different from the cache. Second, --reload does not delete any existing cache files.

If ndb_mgmd is invoked with --initial but cannot find a global configuration file, the management server cannot start.

When a management server starts, it checks for another management server in the same NDB Cluster and tries to use the other management server's configuration data. This behavior has implications when performing a rolling restart of an NDB Cluster with multiple management nodes. See Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster", for more information.

Formerly, using this option together with the --config-file option caused removal of the configuration cache even if the file was not found. Starting with NDB 7.2.13, the cache is cleared in such cases only if the configuration file is actually found. (Bug #1299289)

- --install[=name]

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--install[=name]</td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
</tbody>
</table>
- **--install**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>String</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>ndb_mgmd</td>
</tr>
</tbody>
</table>

Causes `ndb_mgmd` to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to `ndb_mgmd`. Although it is preferable to specify other `ndb_mgmd` program options in a `my.ini` or `my.cnf` configuration file, it is possible to use them together with `--install`. However, in such cases, the `--install` option must be specified first, before any other options are given, for the Windows service installation to succeed.

It is generally not advisable to use this option together with the `--initial` option, since this causes the configuration cache to be wiped and rebuilt every time the service is stopped and started. Care should also be taken if you intend to use any other `ndb_mgmd` options that affect the starting of the management server, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

The `--install` option has no effect on non-Windows platforms.

- **--interactive**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--interactive</code></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Boolean</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Starts `ndb_mgmd` in interactive mode; that is, an `ndb_mgm` client session is started as soon as the management server is running. This option does not start any other NDB Cluster nodes.

- **--log-name=name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--log-name=name</code></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>String</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>MgmtSrvr</td>
</tr>
</tbody>
</table>

Provides a name to be used for this node in the cluster log.

- **--mycnf**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--mycnf</code></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Boolean</td>
</tr>
<tr>
<td><strong>Default Value</strong></td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Read configuration data from the `my.cnf` file.

- **--no-nodeid-checks**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command-Line Format</strong></td>
<td><code>--no-nodeid-checks</code></td>
</tr>
</tbody>
</table>
**ndb_mgmd** — The NDB Cluster Management Server Daemon

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Do not perform any checks of node IDs.

- **--nodaemon**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--nodaemon</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Instructs **ndb_mgmd** not to start as a daemon process.

The default behavior for **ndb_mgmd** on Windows is to run in the foreground, making this option unnecessary on Windows platforms.

- **--nowait-nodes**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--nowait-nodes=list</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>255</td>
</tr>
</tbody>
</table>

When starting an NDB Cluster is configured with two management nodes, each management server normally checks to see whether the other **ndb_mgmd** is also operational and whether the other management server’s configuration is identical to its own. However, it is sometimes desirable to start the cluster with only one management node (and perhaps to allow the other **ndb_mgmd** to be started later). This option causes the management node to bypass any checks for any other management nodes whose node IDs are passed to this option, permitting the cluster to start as though configured to use only the management node that was started.

For purposes of illustration, consider the following portion of a `config.ini` file (where we have omitted most of the configuration parameters that are not relevant to this example):

```plaintext
[ndbd]
NodeId = 1
HostName = 198.51.100.101

[ndbd]
NodeId = 2
HostName = 198.51.100.102

[ndbd]
NodeId = 3
HostName = 198.51.100.103

[ndbd]
NodeId = 4
HostName = 198.51.100.104
```

2365
Assume that you wish to start this cluster using only the management server having node ID 10 and running on the host having the IP address 198.51.100.150. (Suppose, for example, that the host computer on which you intend to the other management server is temporarily unavailable due to a hardware failure, and you are waiting for it to be repaired.) To start the cluster in this way, use a command line on the machine at 198.51.100.150 to enter the following command:

```
shell> ndb_mgmd --ndb-nodeid=10 --nowait-nodes=11
```

As shown in the preceding example, when using `--nowait-nodes`, you must also use the `--ndb-nodeid` option to specify the node ID of this `ndb_mgmd` process.

You can then start each of the cluster's data nodes in the usual way. If you wish to start and use the second management server in addition to the first management server at a later time without restarting the data nodes, you must start each data node with a connection string that references both management servers, like this:

```
shell> ndbd -c 198.51.100.150,198.51.100.151
```

The same is true with regard to the connection string used with any `mysqld` processes that you wish to start as NDB Cluster SQL nodes connected to this cluster. See Section 18.3.3.3, “NDB Cluster Connection Strings”, for more information.

When used with `ndb_mgmd`, this option affects the behavior of the management node with regard to other management nodes only. Do not confuse it with the `--nowait-nodes` option used with `ndbd` or `ndbmtmd` to permit a cluster to start with fewer than its full complement of data nodes; when used with data nodes, this option affects their behavior only with regard to other data nodes.

Multiple management node IDs may be passed to this option as a comma-separated list. Each node ID must be no less than 1 and no greater than 255. In practice, it is quite rare to use more than two management servers for the same NDB Cluster (or to have any need for doing so); in most cases you need to pass to this option only the single node ID for the one management server that you do not wish to use when starting the cluster.

---

**Note**

When you later start the “missing” management server, its configuration must match that of the management server that is already in use by the cluster. Otherwise, it fails the configuration check performed by the existing management server, and does not start.
• `--print-full-config`, `-P`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--print-full-config</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Shows extended information regarding the configuration of the cluster. With this option on the command line the `ndb_mgmd` process prints information about the cluster setup including an extensive list of the cluster configuration sections as well as parameters and their values. Normally used together with the `--config-file (-f)` option.

• `--reload`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--reload</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

NDB Cluster configuration data is stored internally rather than being read from the cluster global configuration file each time the management server is started (see Section 18.3.3, “NDB Cluster Configuration Files”). Using this option forces the management server to check its internal data store against the cluster configuration file and to reload the configuration if it finds that the configuration file does not match the cache. Existing configuration cache files are preserved, but not used.

This differs in two ways from the `--initial` option. First, `--initial` causes all cache files to be deleted. Second, `--initial` forces the management server to re-read the global configuration file and construct a new cache.

If the management server cannot find a global configuration file, then the `--reload` option is ignored.

When `--reload` is used, the management server must be able to communicate with data nodes and any other management servers in the cluster before it attempts to read the global configuration file; otherwise, the management server fails to start. This can happen due to changes in the networking environment, such as new IP addresses for nodes or an altered firewall configuration. In such cases, you must use `--initial` instead to force the existing cached configuration to be discarded and reloaded from the file. See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”, for additional information.

• `--remove{=name]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--remove{=name]</code></td>
</tr>
<tr>
<td>Platform Specific</td>
<td>Windows</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>ndb_mgmd</code></td>
</tr>
</tbody>
</table>

Remove a management server process that has been installed as a Windows service, optionally specifying the name of the service to be removed. Applies only to Windows platforms.
Remove a management server process that has been installed as a Windows service, optionally specifying the name of the service to be removed. Applies only to Windows platforms.

It is not strictly necessary to specify a connection string when starting the management server. However, if you are using more than one management server, a connection string should be provided and each node in the cluster should specify its node ID explicitly.

See Section 18.3.3.3, “NDB Cluster Connection Strings”, for information about using connection strings. Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”, describes other options for ndb_mgmd.

The following files are created or used by ndb_mgmd in its starting directory, and are placed in the DataDir as specified in the config.ini configuration file. In the list that follows, node_id is the unique node identifier.

- config.ini is the configuration file for the cluster as a whole. This file is created by the user and read by the management server. Section 18.3, “Configuration of NDB Cluster”, discusses how to set up this file.

- ndb_node_id_cluster.log is the cluster events log file. Examples of such events include checkpoint startup and completion, node startup events, node failures, and levels of memory usage. A complete listing of cluster events with descriptions may be found in Section 18.5, “Management of NDB Cluster”.

By default, when the size of the cluster log reaches one million bytes, the file is renamed to ndb_node_id_cluster.log.seq_id, where seq_id is the sequence number of the cluster log file. (For example: If files with the sequence numbers 1, 2, and 3 already exist, the next log file is named using the number 4.) You can change the size and number of files, and other characteristics of the cluster log, using the LogDestination configuration parameter.

- ndb_node_id_out.log is the file used for stdout and stderr when running the management server as a daemon.

- ndb_node_id.pid is the process ID file used when running the management server as a daemon.

18.4.5 ndb_mgm — The NDB Cluster Management Client

The ndb_mgm management client process is actually not needed to run the cluster. Its value lies in providing a set of commands for checking the cluster's status, starting backups, and performing other administrative functions. The management client accesses the management server using a C API. Advanced users can also employ this API for programming dedicated management processes to perform tasks similar to those performed by ndb_mgm.

To start the management client, it is necessary to supply the host name and port number of the management server:

```
shell> ndb_mgm [host_name [port_num]]
```

For example:
The default host name and port number are `localhost` and 1186, respectively.

The following table includes options that are specific to the NDB Cluster management client program `ndb_mgm`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_mgm`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

### Table 18.227 Command-line options for the `ndb_mgm` program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--try-reconnect=#</code>, -t</td>
<td>Set the number of times to retry a connection before giving up; synonym for <code>--connect-retries</code></td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--execute=name</code>, -e</td>
<td>Execute command and exit</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

- **`--execute=command`, `-e` command**

This option can be used to send a command to the NDB Cluster management client from the system shell. For example, either of the following is equivalent to executing `SHOW` in the management client:

```
shell> ndb_mgm -e "SHOW"
shell> ndb_mgm --execute="SHOW"
```

This is analogous to how the `--execute` or `-e` option works with the `mysql` command-line client. See Section 4.2.2.1, “Using Options on the Command Line”.

**Note**

If the management client command to be passed using this option contains any space characters, then the command *must* be enclosed in quotation marks. Either single or double quotation marks may be used. If the management client command contains no space characters, the quotation marks are optional.

- **`--try-reconnect=number`**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--try-reconnect=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>3</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>4294967295</td>
</tr>
</tbody>
</table>

If the connection to the management server is broken, the node tries to reconnect to it every 5 seconds until it succeeds. By using this option, it is possible to limit the number of attempts to `number` before giving up and reporting an error instead.
ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables

Additional information about using ndb_mgm can be found in Section 18.5.2, “Commands in the NDB Cluster Management Client”.

18.4.6 ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables

This tool can be used to check for and remove orphaned BLOB column parts from NDB tables, as well as to generate a file listing any orphaned parts. It is sometimes useful in diagnosing and repairing corrupted or damaged NDB tables containing BLOB or TEXT columns.

The basic syntax for ndb_blob_tool is shown here:

```bash
ndb_blob_tool [options] table [column, ...]
```

Unless you use the `--help` option, you must specify an action to be performed by including one or more of the options `--check-orphans`, `--delete-orphans`, or `--dump-file`. These options cause ndb_blob_tool to check for orphaned BLOB parts, remove any orphaned BLOB parts, and generate a dump file listing orphaned BLOB parts, respectively, and are described in more detail later in this section.

You must also specify the name of a table when invoking ndb_blob_tool. In addition, you can optionally follow the table name with the (comma-separated) names of one or more BLOB or TEXT columns from that table. If no columns are listed, the tool works on all of the table’s BLOB and TEXT columns. If you need to specify a database, use the `--database (-d)` option.

The `--verbose` option provides additional information in the output about the tool's progress.

The following table includes options that are specific to ndb_blob_tool. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_blob_tool), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.228 Command-line options for the ndb_blob_tool program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--check-orphans</code></td>
<td>Check for blob parts having no corresponding inline parts</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--database=db_name, -d</code></td>
<td>Database to find the table in</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--delete-orphans</code></td>
<td>Delete blob parts having no corresponding inline parts</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--dump-file=file</code></td>
<td>Write orphan keys to specified file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--verbose, -v</code></td>
<td>Verbose output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

- `--check-orphans`
### ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Check for orphaned BLOB parts in NDB Cluster tables.

- `--database=db_name, -d`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--database=db_name</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

Specify the database to find the table in.

- `--delete-orphans`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--delete-orphans</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Remove orphaned BLOB parts from NDB Cluster tables.

- `--dump-file=file`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--dump-file=file</code></td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

Writes a list of orphaned BLOB column parts to `file`. The information written to the file includes the table key and BLOB part number for each orphaned BLOB part.

- `--verbose`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--verbose</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Provide extra information in the tool's output regarding its progress.

### Example

First we create an NDB table in the `test` database, using the `CREATE TABLE` statement shown here:

```sql
USE test;
CREATE TABLE btest (
```
Then we insert a few rows into this table, using a series of statements similar to this one:

```
INSERT INTO btest VALUES (NULL, 'x', REPEAT('x', 1000));
```

When run with `--check-orphans` against this table, `ndb_blob_tool` generates the following output:

```
shell> ndb_blob_tool --check-orphans --verbose -d test btest
connected
processing 2 blobs
processing blob #0 c1 NDB$BLOB_19_1
NDB$BLOB_19_1: nextResult: res=1
  total parts: 0
  orphan parts: 0
processing blob #1 c2 NDB$BLOB_19_2
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=1
  total parts: 10
  orphan parts: 0
disconnected
NDBT_ProgramExit: 0 - OK
```

The tool reports that there are no `NDB BLOB` column parts associated with column `c1`, even though `c1` is a `TEXT` column. This is due to the fact that, in an `NDB` table, only the first 256 bytes of a `BLOB` or `TEXT` column value are stored inline, and only the excess, if any, is stored separately; thus, if there are no values using more than 256 bytes in a given column of one of these types, no `BLOB` column parts are created by `NDB` for this column. See Section 11.6, “Data Type Storage Requirements”, for more information.

### 18.4.7 ndb_config — Extract NDB Cluster Configuration Information

This tool extracts current configuration information for data nodes, SQL nodes, and API nodes from one of a number of sources: an NDB Cluster management node, or its `config.ini` or `my.cnf` file. By default, the management node is the source for the configuration data; to override the default, execute `ndb_config` with the `--config-file` or `--mycnf` option. It is also possible to use a data node as the source by specifying its node ID with `--config_from_node=node_id`.

`ndb_config` can also provide an offline dump of all configuration parameters which can be used, along with their default, maximum, and minimum values and other information. The dump can be produced in either text or XML format; for more information, see the discussion of the `--configinfo` and `--xml` options later in this section).

You can filter the results by section (`DB`, `SYSTEM`, or `CONNECTIONS`) using one of the options `--nodes`, `--system`, or `--connections`.

The following table includes options that are specific to `ndb_config`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_config`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.
### Table 18.229 Command-line options for the ndb_config program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--config-file=file_name</td>
<td>Set the path to config.ini file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--config-from-node=#</td>
<td>Obtain configuration data from the node having this ID (must be a data node)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--configinfo</td>
<td>Dumps information about all NDB configuration parameters in text format with default, maximum, and minimum values. Use with --xml to obtain XML output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--connections</td>
<td>Print connections information ([tcp], [tcp default], [sci], [sci default], [shm], or [shm default] sections of cluster configuration file) only. Cannot be used with --system or --nodes</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--fields=string, -f</td>
<td>Field separator</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--host=name</td>
<td>Specify host</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--mycnf</td>
<td>Read configuration data from my.cnf file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--nodeid, --id (&lt;=7.5.0)</td>
<td>Get configuration of node with this ID</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--nodes</td>
<td>Print node information ([ndbd] or [ndbd default] section of cluster configuration file) only. Cannot be used with --system or --connections</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-c</td>
<td>Short form for --ndb-connectstring</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--query=string, -q</td>
<td>One or more query options (attributes)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--query-all, -a</td>
<td>Dumps all parameters and values to a single comma-delimited string</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--rows=string, -r</td>
<td>Row separator</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--system</td>
<td>Print SYSTEM section information only (see ndb_config --configinfo output). Cannot be used with --nodes or --connections</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
ndb_config — Extract NDB Cluster Configuration Information

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--type=name</td>
<td>Specify node type</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--configinfo --xml</td>
<td>Use --xml with --configinfo to obtain a dump of all NDB configuration parameters in XML format with default, maximum, and minimum values</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

• **--configinfo**

The **--configinfo** option causes `ndb_config` to dump a list of each NDB Cluster configuration parameter supported by the NDB Cluster distribution of which `ndb_config` is a part, including the following information:

• A brief description of each parameter's purpose, effects, and usage
• The section of the `config.ini` file where the parameter may be used
• The parameter's data type or unit of measurement
• Where applicable, the parameter's default, minimum, and maximum values
• NDB Cluster release version and build information

By default, this output is in text format. Part of this output is shown here:

```
shell> ndb_config --configinfo

***** SYSTEM *****
Name (String)
Name of system (NDB Cluster)  MANDATORY
PrimaryMGMNode (Non-negative Integer)
Node id of Primary ndb_mgmd(MGM) node
Default: 0 (Min: 0, Max: 4294967039)
ConfigGenerationNumber (Non-negative Integer)
Configuration generation number
Default: 0 (Min: 0, Max: 4294967039)

***** DB *****
MaxNoOfSubscriptions (Non-negative Integer)
Max no of subscriptions (default 0 == MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)
MaxNoOfSubscribers (Non-negative Integer)
Max no of subscribers (default 0 == 2 * MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)
```

Use this option together with the **--xml** option to obtain output in XML format.
• **--config-file=path-to-file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--config-file=file_name</td>
</tr>
<tr>
<td>Type</td>
<td>File name</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Gives the path to the management server's configuration file (*config.ini*). This may be a relative or absolute path. If the management node resides on a different host from the one on which *ndb_config* is invoked, then an absolute path must be used.

• **--config-from-node=#**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--config-from-node=#</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>none</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>48</td>
</tr>
</tbody>
</table>

Obtain the cluster's configuration data from the data node that has this ID.

If the node having this ID is not a data node, *ndb_config* fails with an error. (To obtain configuration data from the management node instead, simply omit this option.)

• **--connections**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--connections</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Tells *ndb_config* to print CONNECTIONS information only—that is, information about parameters found in the [tcp], [tcp default], [sci], [sci default], [shm], or [shm default] sections of the cluster configuration file (see Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”, and Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”, for more information).

This option is mutually exclusive with --nodes and --system; only one of these 3 options can be used.

• **--fields=delimiter, -f delimiter**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--fields=string</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
**ndb_config** — Extract NDB Cluster Configuration Information

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Specifies a *delimiter* string used to separate the fields in the result. The default is `,` (the comma character).

**Note**

If the *delimiter* contains spaces or escapes (such as `\n` for the linefeed character), then it must be quoted.

• **--host=hostname**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--host=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Specifies the host name of the node for which configuration information is to be obtained.

**Note**

While the hostname `localhost` usually resolves to the IP address `127.0.0.1`, this may not necessarily be true for all operating platforms and configurations. This means that it is possible, when `localhost` is used in `config.ini`, for `ndb_config --host=localhost` to fail if `ndb_config` is run on a different host where `localhost` resolves to a different address (for example, on some versions of SUSE Linux, this is `127.0.0.2`). In general, for best results, you should use numeric IP addresses for all NDB Cluster configuration values relating to hosts, or verify that all NDB Cluster hosts handle `localhost` in the same fashion.

• **--ndb-connectstring=connection_string, -c connection_string**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--ndb-connectstring=connectionstring</td>
</tr>
<tr>
<td></td>
<td>--connect-string=connectionstring</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>localhost:1186</td>
</tr>
</tbody>
</table>

Specifies the connection string to use in connecting to the management server. The format for the connection string is the same as described in Section 18.3.3.3, “NDB Cluster Connection Strings”, and defaults to `localhost:1186`.

• **--mycnf**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--mycnf</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
**ndb_config** — Extract NDB Cluster Configuration Information

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Read configuration data from the `my.cnf` file.

- `--nodeid=node_id, --id=node_id`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-nodeid=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

Specify the node ID of the node for which configuration information is to be obtained. `--nodeid` is the preferred form; `--id` is deprecated and subject to removal in a later version of NDB Cluster.

- `--nodes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--nodes</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Tells `ndb_config` to print information relating only to parameters defined in a `[ndbd]` or `[ndbd default]` section of the cluster configuration file (see Section 18.3.6, “Defining NDB Cluster Data Nodes”).

This option is mutually exclusive with `--connections` and `--system`; only one of these 3 options can be used.

- `--rows=separator, -r separator`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--rows=string</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Specifies a `separator` string used to separate the rows in the result. The default is a space character.

**Note**

If the `separator` contains spaces or escapes (such as \n for the linefeed character), then it must be quoted.

- `--query=query-options, -q query-options`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--query=string</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>
### ndb_config — Extract NDB Cluster Configuration Information

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

This is a comma-delimited list of _query options_—that is, a list of one or more node attributes to be returned. These include `nodeid` (node ID), type (node type—that is, `ndbd`, `mysqld`, or `ndb_mgmd`), and any configuration parameters whose values are to be obtained.

For example, _--query=nodeid,type,indexmemory,datamemory_ returns the node ID, node type, `IndexMemory`, and `DataMemory` for each node.

`id` is accepted as a synonym for `nodeid`, but is deprecated and subject to removal in a later version of NDB Cluster.

**Note**
If a given parameter is not applicable to a certain type of node, than an empty string is returned for the corresponding value. See the examples later in this section for more information.

#### --system

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><em>--system</em></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td><em>FALSE</em></td>
</tr>
</tbody>
</table>

Tells _ndb_config_ to print _SYSTEM_ information only. This consists of system variables that cannot be changed at run time; thus, there is no corresponding section of the cluster configuration file for them. They can be seen (prefixed with `****** SYSTEM *****`) in the output of _ndb_config --configinfo_.

This option is mutually exclusive with _--nodes_ and _--connections_; only one of these 3 options can be used.

#### --type=node_type

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><em>--type=name</em></td>
</tr>
<tr>
<td>Type</td>
<td>Enumeration</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
<tr>
<td>Valid Values</td>
<td>ndbd</td>
</tr>
<tr>
<td></td>
<td>mysqlfd</td>
</tr>
<tr>
<td></td>
<td>ndb_mgmd</td>
</tr>
</tbody>
</table>

Filters results so that only configuration values applying to nodes of the specified `node_type` (`ndbd`, `mysqld`, or `ndb_mgmd`) are returned.
ndb_config — Extract NDB Cluster Configuration Information

- **--usage, --help, or --?**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--help, --usage</td>
</tr>
</tbody>
</table>

Causes ndb_config to print a list of available options, and then exit.

- **--version, -V**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--version</td>
</tr>
</tbody>
</table>

Causes ndb_config to print a version information string, and then exit.

- **--configinfo --xml**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--configinfo --xml</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>false</td>
</tr>
</tbody>
</table>

Causes ndb_config --configinfo to provide output as XML by adding this option. A portion of such output is shown in this example:

```
shell> ndb_config --configinfo --xml

<configvariables protocolversion="1" ndbversionstring="5.5.65-ndb-7.2.39" ndbversion="458758" ndbversionmajor="7" ndbversionminor="0" ndbversionbuild="6">
  <section name="SYSTEM">
    <param name="Name" comment="Name of system (NDB Cluster)" type="string" mandatory="true"/>
    <param name="PrimaryMGMNode" comment="Node id of Primary ndb_mgmd(MGM) node" type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="ConfigGenerationNumber" comment="Configuration generation number" type="unsigned" default="0" min="0" max="4294967039"/>
  </section>
  <section name="NDBD">
    <param name="MaxNoOfSubscriptions" comment="Max no of subscriptions (default 0 == MaxNoOfTables)" type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="MaxNoOfSubscribers" comment="Max no of subscribers (default 0 == 2 * MaxNoOfTables)" type="unsigned" default="0" min="0" max="4294967039"/>
  </section>
  ...
</configvariables>
```
Note

Normally, the XML output produced by `ndb_config --configinfo --xml` is formatted using one line per element; we have added extra whitespace in the previous example, as well as the next one, for reasons of legibility. This should not make any difference to applications using this output, since most XML processors either ignore nonessential whitespace as a matter of course, or can be instructed to do so.

The XML output also indicates when changing a given parameter requires that data nodes be restarted using the `--initial` option. This is shown by the presence of an `initial="true"` attribute in the corresponding `<param>` element. In addition, the restart type (system or node) is also shown; if a given parameter requires a system restart, this is indicated by the presence of a `restart="system"` attribute in the corresponding `<param>` element. For example, changing the value set for the Diskless parameter requires a system initial restart, as shown here (with the `restart` and `initial` attributes highlighted for visibility):

```xml
<param name="Diskless" comment="Run wo/ disk" type="bool" default="false" restart="system" initial="true"/>
```

Currently, no `initial` attribute is included in the XML output for `<param>` elements corresponding to parameters which do not require initial restarts; in other words, `initial="false"` is the default, and the value `false` should be assumed if the attribute is not present. Similarly, the default restart type is `node` (that is, an online or “rolling” restart of the cluster), but the `restart` attribute is included only if the restart type is `system` (meaning that all cluster nodes must be shut down at the same time, then restarted).

Important

The `--xml` option can be used only with the `--configinfo` option. Using `--xml` without `--configinfo` fails with an error.

Unlike the options used with this program to obtain current configuration data, `--configinfo` and `--xml` use information obtained from the NDB Cluster sources when `ndb_config` was compiled. For this reason, no connection to a running NDB Cluster or access to a `config.ini` or `my.cnf` file is required for these two options.

Combining other `ndb_config` options (such as `--query` or `--type`) with `--configinfo` (with or without the `--xml` option) is not supported. Currently, if you attempt to do so, the usual result is that all other options besides `--configinfo` or `--xml` are simply ignored. However, this behavior is not guaranteed and is subject to change at any time. In addition, since `ndb_config`, when used with the `--configinfo` option, does not access the NDB Cluster or read any files, trying to specify additional options such as `--ndb-connectstring` or `--config-file` with `--configinfo` serves no purpose.

Examples

1. To obtain the node ID and type of each node in the cluster:

```
shell> ./ndb_config --query=id,type --fields=':' --rows='
'
1:ndbd
2:ndbd
3:ndbd
4:ndbd
5:ndb_mgmd
6:mysqld
7:mysqld
```
In this example, we used the `--fields` options to separate the ID and type of each node with a colon character (`:`), and the `--rows` options to place the values for each node on a new line in the output.

2. To produce a connection string that can be used by data, SQL, and API nodes to connect to the management server:

```shell
dbshell> ./ndb_config --config-file=usr/local/mysql/cluster-data/config.ini \
   --query=hostname,portnumber --fields=: --rows=, --type=ndb_mgmd
198.51.100.179:1186
```

3. This invocation of `ndb_config` checks only data nodes (using the `--type` option), and shows the values for each node's ID and host name, as well as the values set for its DataMemory, IndexMemory, and DataDir parameters:

```shell
dbshell> ./ndb_config --type=ndbd -q id,host,datamemory,indexmemory,datadir -f : -r '
' 1: 198.51.100.193 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
2: 198.51.100.112 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
4: 198.51.100.119 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
```

In this example, we used the short options `-f` and `-r` for setting the field delimiter and row separator, respectively, as well as the short option `-q` to pass a list of parameters to be obtained.

4. To exclude results from any host except one in particular, use the `--host` option:

```shell
dbshell> ./ndb_config --host=198.51.100.176 -f : -r '
' -q id,type
3:ndbd
5:ndb_mgmd
```

In this example, we also used the short form `-q` to determine the attributes to be queried.

Similarly, you can limit results to a node with a specific ID using the `--nodeid` option.

### 18.4.8 ndb_cpcd — Automate Testing for NDB Development

A utility having this name was formerly part of an internal automated test framework used in testing and debugging NDB Cluster. It was deprecated in NDB Cluster 7.0, and removed from NDB Cluster distributions provided by Oracle beginning with NDB 7.2.1.

### 18.4.9 ndb_delete_all — Delete All Rows from an NDB Table

`ndb_delete_all` deletes all rows from the given NDB table. In some cases, this can be much faster than `DELETE` or even `TRUNCATE TABLE`.

Usage

```
ndb_delete_all -c connection_string tbl_name -d db_name
```

This deletes all rows from the table named `tbl_name` in the database named `db_name`. It is exactly equivalent to executing `TRUNCATE db_name.tbl_name` in MySQL.

The following table includes options that are specific to `ndb_delete_all`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_delete_all`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.
ndb_desc — Describe NDB Tables

### Table 18.230 Command-line options for the ndb_delete_all program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--database=dbname, -d</td>
<td>Name of the database in which the table is found</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--transactional, -t</td>
<td>Perform the delete in a single transaction (may run out of operations)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--tupscan</td>
<td>Run tup scan</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--diskscan</td>
<td>Run disk scan</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

- **--transactional, -t**

Use of this option causes the delete operation to be performed as a single transaction.

**Warning**

With very large tables, using this option may cause the number of operations available to the cluster to be exceeded.

18.4.10 ndb_desc — Describe NDB Tables

ndb_desc provides a detailed description of one or more NDB tables.

#### Usage

```
ndb_desc -c connection_string tbl_name -d db_name [options]
```

(NDB 7.2.9 and later:)

```
ndb_desc -c connection_string index_name -d db_name -t tbl_name
```

Additional options that can be used with ndb_desc are listed later in this section.

#### Sample Output

MySQL table creation and population statements:

```
USE test;

CREATE TABLE fish (  
    id INT(11) NOT NULL AUTO_INCREMENT,  
    name VARCHAR(20) NOT NULL,  
    length_mm INT(11) NOT NULL,  
    weight_gm INT(11) NOT NULL,  
    PRIMARY KEY pk (id),  
    UNIQUE KEY uk (name)  
) ENGINE=NDB;

INSERT INTO fish VALUES  
    ("",'guppy', 35, 2), ("",'tuna', 2500, 150000),  
    ("",'shark', 3000, 110000), ("",'manta ray', 1500, 50000),
```

2382
Output from `ndb_desc`:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 2
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 311
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=MEMORY
weight_gm Int NOT NULL AT=FIXED ST=MEMORY
-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex
-- Per partition info --
Partition  Row count  Commit count  Frag fixed memory ...
0          2          2             32768             ...
1          4          4             32768             ...
... Frag varsized memory  Extent_space  Free extent_space
... 32768             0             0
... 32768             0             0
NDBT_ProgramExit: 0 - OK
```

Information about multiple tables can be obtained in a single invocation of `ndb_desc` by using their names, separated by spaces. All of the tables must be in the same database.

Beginning with NDB 7.2.9, it is possible to obtain additional information about a specific index using the `--table` (short form: `-t`) option introduced in this version and supplying the name of the index as the first argument to `ndb_desc`, as shown here:

```
shell> ./ndb_desc uk -d test -t fish
-- uk --
Version: 3
Base table: fish
Number of attributes: 1
Logging: 0
Index type: OrderedIndex
Index status: Retrieved
-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
-- IndexTable 10/uk --
Version: 3
Fragment type: FragUndefined
K Value: 6
Min load factor: 78
```
Max load factor: 80
Temporary table: yes
Number of attributes: 2
Number of primary keys: 1
Length of frm data: 0
Row Checksum: 1
Row GCI: 1
SingleUserMode: 2
ForceVarPart: 0
FragmentCount: 4
ExtraRowGciBits: 0
ExtraRowAuthorBits: 0
TableStatus: Retrieved

-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
NDB$TNODE Unsigned [64] PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(NDB$TNODE) - UniqueHashIndex

NDBT_ProgramExit: 0 - OK

When an index is specified in this way, the --extra-partition-info and --extra-node-info options have no effect.

The Version column in the output contains the table’s schema object version. For information about interpreting this value, see NDB Schema Object Versions.

The Extent_space and Free extent_space columns are applicable only to NDB tables having columns on disk; for tables having only in-memory columns, these columns always contain the value 0.

To illustrate their use, we modify the previous example. First, we must create the necessary Disk Data objects, as shown here:

```sql
CREATE LOGFILE GROUP lg_1
  ADD UNDOFILE 'undo_1.log'
  INITIAL_SIZE 16M
  UNDO_BUFFER_SIZE 2M
  ENGINE NDB;

ALTER LOGFILE GROUP lg_1
  ADD UNDOFILE 'undo_2.log'
  INITIAL_SIZE 12M
  ENGINE NDB;

CREATE TABLESPACE ts_1
  ADD DATAFILE 'data_1.dat'
  USE LOGFILE GROUP lg_1
  INITIAL_SIZE 32M
  ENGINE NDB;

ALTER TABLESPACE ts_1
  ADD DATAFILE 'data_2.dat'
  INITIAL_SIZE 48M
  ENGINE NDB;
```

(For more information on the statements just shown and the objects created by them, see Section 18.5.12.1, “NDB Cluster Disk Data Objects”, as well as Section 13.1.14, “CREATE LOGFILE GROUP Statement”, and Section 13.1.18, “CREATE TABLESPACE Statement”.)

Now we can create and populate a version of the fish table that stores 2 of its columns on disk (deleting the previous version of the table first, if it already exists):

```sql
CREATE TABLE fish (
    id INT(11) NOT NULL AUTO_INCREMENT,
```
When run against this version of the table, \texttt{ndb_desc} displays the following output:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 3
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 321
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=DISK
weight_gm Int NOT NULL AT=FIXED ST=DISK
-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex
-- Per partition info --
Partition  Row count  Commit count  Frag fixed memory ...
0          2          2             32768             ...
1          4          4             32768             ...
... Frag varsized memory  Extent_space  Free extent_space
... 32768  0             0
... 32768  0             0
NDBT_ProgramExit: 0 - OK
```

This means that 1048576 bytes are allocated from the tablespace for this table on each partition, of which 1044440 bytes remain free for additional storage. In other words, 1048576 - 1044440 = 4136 bytes per partition is currently being used to store the data from this table's disk-based columns. The number of bytes shown as \texttt{Free extent\_space} is available for storing on-disk column data from the \textit{fish} table only; for this reason, it is not visible when selecting from the \texttt{INFORMATION_SCHEMA.FILES} table.

The following table includes options that are specific to \texttt{ndb_desc}. Additional descriptions follow the table. For options common to most NDB Cluster programs (including \texttt{ndb_desc}), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

<table>
<thead>
<tr>
<th>Option Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{-f} \textit{host}</td>
</tr>
<tr>
<td>\texttt{-d} \textit{database}</td>
</tr>
<tr>
<td>\texttt{-p} \textit{password}</td>
</tr>
<tr>
<td>\texttt{-h} \textit{port}</td>
</tr>
<tr>
<td>\texttt{-v}</td>
</tr>
</tbody>
</table>

\texttt{ndb_desc} displays information about the \textit{fish} table, including its attributes and indexes, as well as per-partition information. This information is useful for understanding how data is distributed across the partitions and how much storage is available for additional data.

The tablespace for the \textit{fish} table is allocated with 1048576 bytes per partition, of which 1044440 bytes remain free. This means that 4136 bytes are currently being used to store the data from the table's disk-based columns. The \texttt{Free extent\_space} shown in the output indicates the remaining space available for on-disk column data, which is not visible when selecting from the \texttt{INFORMATION_SCHEMA.FILES} table.

For a more detailed understanding of the output, refer to the documentation for \texttt{ndb_desc}, which includes options specific to this program. Additionally, Section 18.4.27 provides common options for NDB Cluster programs, including \texttt{ndb_desc}.
### Table 18.231 Command-line options for the ndb_desc program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--blob-info, -b</td>
<td>Include partition information for BLOB tables in output. Requires that the -p option also be used</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--database=dbname, -d</td>
<td>Name of database containing table</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--extra-node-info, -n</td>
<td>Include partition-to-data-node mappings in output. Requires that the -p option also be used</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--extra-partition-info, -p</td>
<td>Display information about partitions</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--retries=#, -r</td>
<td>Number of times to retry the connection (once per second)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--table=tbl_name, -t</td>
<td>Specify the table in which to find an index. When this option is used, -p and -n have no effect and are ignored</td>
<td>ADDED: NDB 7.2.9</td>
</tr>
<tr>
<td>--unqualified, -u</td>
<td>Use unqualified table names</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

- **--blob-info, -b**
  
  Include information about subordinate BLOB and TEXT columns.
  
  Use of this option also requires the use of the **--extra-partition-info (-p)** option.

- **--database=db_name, -d**
  
  Specify the database in which the table should be found.

- **--extra-node-info, -n**
  
  Include information about the mappings between table partitions and the data nodes upon which they reside. This information can be useful for verifying distribution awareness mechanisms and supporting more efficient application access to the data stored in NDB Cluster.
  
  Use of this option also requires the use of the **--extra-partition-info (-p)** option.

- **--extra-partition-info, -p**
  
  Print additional information about the table's partitions.

- **--retries=#, -r**
  
  Try to connect this many times before giving up. One connect attempt is made per second.

- **--table=tbl_name, -t**
Specify the table in which to look for an index.

This option was added in NDB 7.2.9.

- \(-u\)

Use unqualified table names.

**18.4.11 ndb_drop_index — Drop Index from an NDB Table**

`ndb_drop_index` drops the specified index from an NDB table. *It is recommended that you use this utility only as an example for writing NDB API applications—see the Warning later in this section for details.*

**Usage**

```
ndb_drop_index -c connection_string table_name index -d db_name
```

The statement shown above drops the index named `index` from the `table` in the `database`.

The following table includes options that are specific to `ndb_drop_index`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_drop_index`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(--database=dbname), -d</td>
<td>Name of the database in which the table is found</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

**Warning**

Operations performed on Cluster table indexes using the NDB API are not visible to MySQL and make the table unusable by a MySQL server. If you use this program to drop an index, then try to access the table from an SQL node, an error results, as shown here:

```
shell> ./ndb_drop_index -c localhost dogs ix -d ctest1
Dropping index dogs/idx...OK
NDBT_ProgramExit: 0 - OK

shell> ./mysql -u jon -p ctest1
Enter password: *******
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 7 to server version: 5.5.65-ndb-7.2.39
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.
mysql> SHOW TABLES;
+------------------+
| Tables_in_ctest1 |
+------------------+
    a              |
    bt1            |
    bt2            |
```
ndb_drop_table — Drop an NDB Table

In such a case, your only option for making the table available to MySQL again is to drop the table and re-create it. You can use either the SQL statement `DROP TABLE` or the `ndb_drop_table` utility (see Section 18.4.12, "ndb_drop_table — Drop an NDB Table") to drop the table.

18.4.12 ndb_drop_table — Drop an NDB Table

`ndb_drop_table` drops the specified NDB table. (If you try to use this on a table created with a storage engine other than NDB, the attempt fails with the error `723: No such table exists`.) This operation is extremely fast; in some cases, it can be an order of magnitude faster than using a MySQL `DROP TABLE` statement on an NDB table.

Usage

```
ndb_drop_table -c connection_string tbl_name -d db_name
```

The following table includes options that are specific to `ndb_drop_table`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_drop_table`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.233 Command-line options for the ndb_drop_table program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--database=dbname, -d</code></td>
<td>Name of the database in which the</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td></td>
<td>table is found</td>
<td>based releases)</td>
</tr>
</tbody>
</table>

18.4.13 ndb_error_reporter — NDB Error-Reporting Utility

`ndb_error_reporter` creates an archive from data node and management node log files that can be used to help diagnose bugs or other problems with a cluster. It is highly recommended that you make use of this utility when filing reports of bugs in NDB Cluster.

The following table includes command options specific to the NDB Cluster program `ndb_error_reporter`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_error_reporter`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

`ndb_error_reporter` did not support the `--help` option prior to NDB 7.2.14 (Bug #11756666, Bug #48606). The `--connection-timeout` and `--dry-scp` options were also added in this release (Bug #16602002).

Table 18.234 Command-line options for the ndb_error_reporter program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--connection-timeout=timeout</code></td>
<td>Number of seconds to wait when</td>
<td>ADDED: NDB 7.2.14</td>
</tr>
<tr>
<td></td>
<td>connecting to nodes before timing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>out</td>
<td></td>
</tr>
</tbody>
</table>
### ndb_error_reporter — NDB Error-Reporting Utility

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--dry-scp</code></td>
<td>Disable scp with remote hosts; used only for testing</td>
<td>ADDED: NDB 7.2.14</td>
</tr>
<tr>
<td><code>--fs</code></td>
<td>Include file system data in error report; can use a large amount of disk space</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--skip-nodegroup=nodegroup_id</code></td>
<td>Skip all nodes in the node group having this ID</td>
<td>ADDED: NDB 7.2.14</td>
</tr>
</tbody>
</table>

## Usage

```
ndb_error_reporter path/to/config-file [username] [options]
```

This utility is intended for use on a management node host, and requires the path to the management host configuration file (usually named `config.ini`). Optionally, you can supply the name of a user that is able to access the cluster's data nodes using SSH, to copy the data node log files. `ndb_error_reporter` then includes all of these files in archive that is created in the same directory in which it is run. The archive is named `ndb_error_reporter_YYYYMMDDhhmmss.tar.bz2`, where `YYYYMMDDhhmmss` is a datetime string.

`ndb_error_reporter` also accepts the options listed here:

- `--connection-timeout=timeout`

  **Property** | **Value**
  --- | ---
  Command-Line Format | `--connection-timeout=timeout`
  Introduced | 5.5.34-ndb-7.2.14
  Type | Integer
  Default Value | 0

  Wait this many seconds when trying to connect to nodes before timing out.

- `--dry-scp`

  **Property** | **Value**
  --- | ---
  Command-Line Format | `--dry-scp`
  Introduced | 5.5.34-ndb-7.2.14
  Type | Boolean
  Default Value | TRUE

  Run `ndb_error_reporter` without using scp from remote hosts. Used for testing only.

- `--fs`

  **Property** | **Value**
  --- | ---
  Command-Line Format | `--fs`
  Type | Boolean
  Default Value | FALSE
Copy the data node file systems to the management host and include them in the archive. Because data node file systems can be extremely large, even after being compressed, we ask that you please do not send archives created using this option to Oracle unless you are specifically requested to do so.

• `--skip-nodegroup=nodegroup_id`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--connection-timeout=timeout</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.34-ndb-7.2.14</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
</tbody>
</table>

Skip all nodes belong to the node group having the supplied node group ID.

18.4.14 ndb_index_stat — NDB Index Statistics Utility

`ndb_index_stat` provides per-fragment statistical information about indexes on NDB tables. This includes cache version and age, number of index entries per partition, and memory consumption by indexes.

Usage

To obtain basic index statistics about a given NDB table, invoke `ndb_index_stat` as shown here, with the name of the table as the first argument and the name of the database containing this table specified immediately following it, using the `--database` option:

```
ndb_index_stat table -d database
```

In this example, we use `ndb_index_stat` to obtain such information about an NDB table named `mytable` in the `test` database:

```
shell> ndb_index_stat -d test mytable
table:City index:PRIMARY fragCount:2
query cache: valid:1 sampleCount:1994 totalBytes:27916
times in ms: save: 7.133 sort: 1.974 sort per sample: 0.000
NDBT_ProgramExit: 0 - OK
```

`sampleVersion` is the version number of the cache from which the statistics data is taken. Running `ndb_index_stat` with the `--update` option causes sampleVersion to be incremented.

`loadTime` shows when the cache was last updated. This is expressed as seconds since the Unix Epoch.

`sampleCount` shows the number of index entries found per partition. You can estimate the total number of entries by multiplying this by the number of fragments (shown as `fragCount`).

`sampleCount` can be compared with the cardinality of `SHOW INDEX` or `INFORMATION_SCHEMA.STATISTICS`, although the latter two provide a view of the table as a whole, while `ndb_index_stat` provides a per-fragment average.

`keyBytes` is the number of bytes used by the index. In this example, the primary key is an integer, which requires four bytes for each index, so `keyBytes` can be calculated in this case as shown here:
keyBytes = sampleCount * (4 bytes per index) = 1994 * 4 = 7976

This information can also be obtained using the corresponding column definitions from INFORMATION_SCHEMA.COLUMNS (this requires a MySQL Server and a MySQL client application).

totalBytes is the total memory consumed by all indexes on the table, in bytes.

Timings shown in the preceding examples are specific to each invocation of ndb_index_stat.

The --verbose option provides some additional output, as shown here:

```
shell> ndb_index_stat -d test mytable --verbose
connected
loop 1 of 1
table:mytable index:PRIMARY fragCount:4
sampleVersion:2 loadTime:1336751773 sampleCount:0 keyBytes:0
read stats
query cache created
query cache: valid:1 sampleCount:0 totalBytes:0
times in ms: save: 20.766 sort: 0.001
disconnected
NDBT_ProgramExit: 0 - OK
shell>
```

If the only output from the program is NDBT_ProgramExit: 0 - OK, this may indicate that no statistics yet exist. To force them to be created (or updated if they already exist), invoke ndb_index_stat with the --update option, or execute ANALYZE TABLE on the table in the mysql client.

Options

The following table includes options that are specific to the NDB Cluster ndb_index_stat utility. Additional descriptions are listed following the table. For options common to most NDB Cluster programs (including ndb_index_stat), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--database=name, -d</td>
<td>Name of the database containing the table</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--delete</td>
<td>Delete index statistics for the given table, stopping any auto-update previously configured</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--update</td>
<td>Update index statistics for the given table, restarting any auto-update previously configured</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--dump</td>
<td>Print the query cache</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--query=#</td>
<td>Perform a number of random range queries on first key attr (must be int unsigned)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
### ndb_index_stat — NDB Index Statistics Utility

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--sys-drop</td>
<td>Drop any statistics tables and events in NDB kernel (all statistics are lost)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-create</td>
<td>Create all statistics tables and events in NDB kernel, if none of them already exist</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-create-if-not-exist</td>
<td>Create any statistics tables and events in NDB kernel that do not already exist</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-create-if-not-valid</td>
<td>Create any statistics tables or events that do not already exist in the NDB kernel. after dropping any that are invalid</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-check</td>
<td>Verify that NDB system index statistics and event tables exist</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-skip-tables</td>
<td>Do not apply sys-* options to tables</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--sys-skip-events</td>
<td>Do not apply sys-* options to events</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--verbose, -v</td>
<td>Turn on verbose output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--loops=#</td>
<td>Set the number of times to perform a given command. Default is 0</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

**ndb_index_stat statistics options.** The following options are used to generate index statistics. They work with a given table and database. They cannot be mixed with system options (see ndb_index_stat system options).

- **--database=name, -d name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--database=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

The name of the database that contains the table being queried.

- **--delete**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--delete</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>false</td>
</tr>
</tbody>
</table>

2392
Delete the index statistics for the given table, stopping any auto-update that was previously configured.

- **--update**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--update</strong></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td><strong>false</strong></td>
</tr>
<tr>
<td>Minimum Value</td>
<td></td>
</tr>
<tr>
<td>Maximum Value</td>
<td></td>
</tr>
</tbody>
</table>

Update the index statistics for the given table, and restart any auto-update that was previously configured.

- **--dump**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--dump</strong></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td><strong>false</strong></td>
</tr>
<tr>
<td>Minimum Value</td>
<td></td>
</tr>
<tr>
<td>Maximum Value</td>
<td></td>
</tr>
</tbody>
</table>

Dump the contents of the query cache.

- **--query=#**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--query=#</strong></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td><strong>MAX_INT</strong></td>
</tr>
</tbody>
</table>

Perform random range queries on first key attribute (must be int unsigned).

**ndb_index_stat system options.** The following options are used to generate and update the statistics tables in the NDB kernel. None of these options can be mixed with statistics options (see **ndb_index_stat statistics options**).

- **--sys-drop**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><strong>--sys-drop</strong></td>
</tr>
</tbody>
</table>
Drop all statistics tables and events in the NDB kernel. *This causes all statistics to be lost.*

- **--sys-create**

Create all statistics tables and events in the NDB kernel. This works only if none of them exist previously.

- **sys-create-if-not-exist**

Create any NDB system statistics tables or events (or both) that do not already exist when the program is invoked.

- **--sys-create-if-not-valid**

Create any NDB system statistics tables or events that do not already exist, after dropping any that are invalid.

- **--sys-check**
Verify that all required system statistics tables and events exist in the NDB kernel.

- **--sys-skip-tables**

Do not apply any --sys-* options to any statistics tables.

- **--sys-skip-events**

Do not apply any --sys-* options to any events.

- **--verbose**

Turn on verbose output.

- **--loops=#**
Repeats commands this number of times (for use in testing).

### 18.4.15 ndb_move_data — NDB Data Copy Utility

*ndb_move_data* copies data from one NDB table to another.

#### Usage

The program is invoked with the names of the source and target tables; either or both of these may be qualified optionally with the database name. Both tables must use the NDB storage engine.

```
ndb_move_data options source target
```

The following table includes options that are specific to *ndb_move_data*. Additional descriptions follow the table. For options common to most NDB Cluster programs (including *ndb_move_data*), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

**Table 18.236 Command-line options for the ndb_move_data program**

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--abort-on-error</td>
<td>Dump core on permanent error (debug option)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--character-sets-dir=name</td>
<td>Directory where character sets are</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--database=dbname, -d</td>
<td>Name of the database in which the table is found</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--drop-source</td>
<td>Drop source table after all rows have been moved</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--error-insert</td>
<td>Insert random temporary errors (testing option)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--exclude-missing-columns</td>
<td>Ignore extra columns in source or target table</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--lossy-conversions, -l</td>
<td>Allow attribute data to be truncated when converted to a smaller type</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--promote-attributes, -A</td>
<td>Allow attribute data to be converted to a larger type</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--staging-tries=x[,y[,z]]</td>
<td>Specify tries on temporary errors. Format is x[,y[,z]] where x=max tries (0=no limit), y=min delay (ms), z=max delay (ms)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--verbose</td>
<td>Enable verbose messages</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
### ndb_move_data — NDB Data Copy Utility

#### --abort-on-error

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--abort-on-error</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Dump core on permanent error (debug option).

#### --character-sets-dir=name

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--character-sets-dir=name</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>[none]</td>
</tr>
</tbody>
</table>

Directory where character sets are.

#### --database=dbname, -d

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--database=dbname</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>TEST_DB</td>
</tr>
</tbody>
</table>

Name of the database in which the table is found.

#### --drop-source

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--drop-source</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Drop source table after all rows have been moved.

#### --error-insert

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--error-insert</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Insert random temporary errors (testing option).

#### --exclude-missing-columns

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--exclude-missing-columns</td>
</tr>
</tbody>
</table>

2397
ndb_print_backup_file — Print NDB Backup File Contents

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Ignore extra columns in source or target table.

- **--lossy-conversions, -l**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--lossy-conversions</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Allow attribute data to be truncated when converted to a smaller type.

- **--promote-attributes, -A**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--promote-attributes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Allow attribute data to be converted to a larger type.

- **--staging-tries=x[,y[,z]]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--staging-tries=x[,y[,z]]</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>0,1000,60000</td>
</tr>
</tbody>
</table>

Specify tries on temporary errors. Format is x,y,z where x=max tries (0=no limit), y=min delay (ms), z=max delay (ms).

- **--verbose**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--verbose</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Enable verbose messages.

18.4.16 ndb_print_backup_file — Print NDB Backup File Contents

ndb_print_backup_file obtains diagnostic information from a cluster backup file.

**Usage**

```
ndb_print_backup_file file_name
```
**ndb_print_file** — Print NDB Disk Data File Contents

$file_name$ is the name of a cluster backup file. This can be any of the files (.Data, .ctl, or .log file) found in a cluster backup directory. These files are found in the data node's backup directory under the subdirectory BACKUP-#, where # is the sequence number for the backup. For more information about cluster backup files and their contents, see Section 18.5.3.1, “NDB Cluster Backup Concepts”.

Like **ndb_print_schema_file** and **ndb_print_sys_file** (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) **ndb_print_backup_file** must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

**Additional Options**

None.

### 18.4.17 ndb_print_file — Print NDB Disk Data File Contents

**ndb_print_file** obtains information from an NDB Cluster Disk Data file.

**Usage**

```
ndb_print_file [-v] [-q] $file_name$
```

$file_name$ is the name of an NDB Cluster Disk Data file. Multiple filenames are accepted, separated by spaces.

Like **ndb_print_schema_file** and **ndb_print_sys_file** (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) **ndb_print_file** must be run on an NDB Cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

**Additional Options**

**ndb_print_file** supports the following options:

- `-v`: Make output verbose.
- `-q`: Suppress output (quiet mode).
- `--help`, `-h`, `-?`: Print help message.

This option did not work correctly prior to NDB 7.2.18. (Bug #17069285)

For more information, see Section 18.5.12, “NDB Cluster Disk Data Tables”.

### 18.4.18 ndb_print_schema_file — Print NDB Schema File Contents

**ndb_print_schema_file** obtains diagnostic information from a cluster schema file.

**Usage**

```
ndb_print_schema_file $file_name$
```

$file_name$ is the name of a cluster schema file. For more information about cluster schema files, see **NDB Cluster Data Node File System Directory Files**.
**ndb_print_sys_file** — Print NDB System File Contents

Like *ndb_print_backup_file* and *ndb_print_sys_file* (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) *ndb_print_schema_file* must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

**Additional Options**

None.

### 18.4.19 *ndb_print_sys_file* — Print NDB System File Contents

*ndb_print_sys_file* obtains diagnostic information from an NDB Cluster system file.

**Usage**

`ndb_print_sys_file  file_name`

*file_name* is the name of a cluster system file (sysfile). Cluster system files are located in a data node's data directory (`DataDir`); the path under this directory to system files matches the pattern `ndb_#_fs/D/#/DBDIH/P/#.sysfile`. In each case, the # represents a number (not necessarily the same number). For more information, see NDB Cluster Data Node File System Directory Files.

Like *ndb_print_backup_file* and *ndb_print_schema_file* (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) *ndb_print_backup_file* must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

**Additional Options**

None.

### 18.4.20 *ndb_redo_log_reader* — Check and Print Content of Cluster Redo Log

Reads a redo log file, checking it for errors, printing its contents in a human-readable format, or both. *ndb_redo_log_reader* is intended for use primarily by NDB Cluster developers and Support personnel in debugging and diagnosing problems.

This utility remains under development, and its syntax and behavior are subject to change in future NDB Cluster releases.

**Note**

Prior to NDB 7.2, this utility was named *ndbd_redo_log_reader*.

The C++ source files for *ndb_redo_log_reader* can be found in the directory `/storage/ndb/src/kernel/blocks/dblqh/redoLogReader`.

The following table includes options that are specific to the NDB Cluster program *ndb_redo_log_reader*. Additional descriptions follow the table. For options common to most NDB Cluster programs (including *ndb_redo_log_reader*), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

---

2400
### Table 18.237 Command-line options for the ndb_redo_log_reader program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-dump</td>
<td>Print dump info</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-filedescriptors</td>
<td>Print file descriptors only</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--help</td>
<td>Print usage information</td>
<td>ADDED: NDB 7.2.15</td>
</tr>
<tr>
<td>-lap</td>
<td>Provide lap info, with max GCI started and completed</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-mbyte #</td>
<td>Starting megabyte</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-mbyteheaders</td>
<td>Show only the first page header of every megabyte in the file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-nocheck</td>
<td>Do not check records for errors</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-noprint</td>
<td>Do not print records</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-page #</td>
<td>Start with this page</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-pageheaders</td>
<td>Show page headers only</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-pageindex #</td>
<td>Start with this page index</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-twiddle</td>
<td>Bit-shifted dump</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

### Usage

```
ndb_redo_log_reader file_name [options]
```

**file_name** is the name of a cluster redo log file. redo log files are located in the numbered directories under the data node’s data directory (DataDir); the path under this directory to the redo log files matches the pattern `ndb_nodeid_fs/D#/DBLQH/S#.FragLog.nodeid` is the data node’s node ID. The two instances of # each represent a number (not necessarily the same number); the number following D is in the range 8-39 inclusive; the range of the number following S varies according to the value of the **NoOfFragmentLogFiles** configuration parameter, whose default value is 16; thus, the default range of the number in the file name is 0-15 inclusive. For more information, see NDB Cluster Data Node File System Directory Files.

The name of the file to be read may be followed by one or more of the options listed here:

- **-dump**
**ndb_redo_log_reader** — Check and Print Content of Cluster Redo Log

Print dump info.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>-filedescriptors</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

- **-filedescriptors**: Print file descriptors only.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--help</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.35-ndb-7.2.15</td>
</tr>
</tbody>
</table>

--**help**: Print usage information.

Added in NDB 7.2.15. (Bug #11749591, Bug #36805)

- **-lap**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>-lap</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Provide lap info, with max GCI started and completed.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>-mbyte #</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>15</td>
</tr>
</tbody>
</table>

- **-mbyte #**: Starting megabyte.

# is an integer in the range 0 to 15, inclusive.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>-mbyteheaders</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

- **-mbyteheaders**: Show only the first page header of every megabyte in the file.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>-noprint</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
**ndb_redo_log_reader** — Check and Print Content of Cluster Redo Log

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

- **-noprint**: Do not print the contents of the log file.

- **Property** | **Value** |
  | Command-Line Format | -nocheck    |
  | Type              | Boolean     |
  | Default Value     | FALSE       |

- **-nocheck**: Do not check the log file for errors.

- **Property** | **Value** |
  | Command-Line Format | -page #    |
  | Type              | Integer    |
  | Default Value     | 0          |
  | Minimum Value     | 0          |
  | Maximum Value     | 31         |

- **-page #**: Start at this page.

  # is an integer in the range 0 to 31, inclusive.

- **Property** | **Value** |
  | Command-Line Format | -pageheaders |
  | Type              | Boolean     |
  | Default Value     | FALSE       |

- **-pageheaders**: Show page headers only.

- **Property** | **Value** |
  | Command-Line Format | -pageindex # |
  | Type              | Integer     |
  | Default Value     | 12          |
  | Minimum Value     | 12          |
  | Maximum Value     | 8191        |

- **-pageindex #**: Start at this page index.

  # is an integer between 12 and 8191, inclusive.

- **-twiddle**

- **Property** | **Value** |
  | Command-Line Format | -twiddle    |
  | Type              | Boolean    |
  | Default Value     | FALSE      |
Bit-shifted dump.

Like `ndb_print_backup_file` and `ndb_print_schema_file` (and unlike most of the NDB utilities that are intended to be run on a management server host or to connect to a management server), `ndb_redo_log_reader` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

**18.4.21 ndb_restore — Restore an NDB Cluster Backup**

The NDB Cluster restoration program is implemented as a separate command-line utility `ndb_restore`, which can normally be found in the MySQL `bin` directory. This program reads the files created as a result of the backup and inserts the stored information into the database.

```
Note
Beginning with NDB 7.2.38, this program no longer prints
`NDBT_ProgramExit: ...` when it finishes its run. Applications depending on
this behavior should be modified accordingly when upgrading from NDB 7.2.37 or
earlier to a later NDB 7.2 release.

Note
Before using `ndb_restore`, it is recommended that the cluster be running in
single user mode, unless you are restoring multiple data nodes in parallel. See
Section 18.5.8, “NDB Cluster Single User Mode”, for more information.
```

The following table includes options that are specific to the NDB Cluster native backup restoration program `ndb_restore`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_restore`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

**Table 18.238 Command-line options for the ndb_restore program**

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--append</td>
<td>Append data to a tab-delimited file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--backup-path=dir_name</td>
<td>Path to backup files directory</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--backupid=#, -b</td>
<td>Restore from the backup with the given ID</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--connect, -c</td>
<td>Alias for --connectstring</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--disable-indexes</td>
<td>Causes indexes from a backup to be ignored; may decrease time needed to restore data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--dont-ignore-systab-0, -f</code></td>
<td>Do not ignore system table during restore. Experimental only; not for production use</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--exclude-databases=db-list</code></td>
<td>List of one or more databases to exclude (includes those not named)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>`--exclude-intermediate-sql-tables[=TRUE</td>
<td>FALSE]`</td>
<td>If TRUE (the default), do not restore any intermediate tables (having names prefixed with ‘#sql-’) that were left over from copying ALTER TABLE operations</td>
</tr>
<tr>
<td><code>--exclude-missing-columns</code></td>
<td>Causes columns from the backup version of a table that are missing from the version of the table in the database to be ignored</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--exclude-missing-tables</code></td>
<td>Causes tables from the backup that are missing from the database to be ignored</td>
<td>ADDED: NDB 7.2.18</td>
</tr>
<tr>
<td><code>--exclude-tables=table-list</code></td>
<td>List of one or more tables to exclude (includes those in the same database that are not named); each table reference must include the database name</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--fields-enclosed-by=char</code></td>
<td>Fields are enclosed with the indicated character</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--fields-optionally-enclosed-by</code></td>
<td>Fields are optionally enclosed with the indicated character</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--fields-terminated-by=char</code></td>
<td>Fields are terminated by the indicated character</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--hex</code></td>
<td>Print binary types in hexadecimal format</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--include-databases=db-list</code></td>
<td>List of one or more databases to restore (excludes those not named)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--include-tables=table-list</code></td>
<td>List of one or more tables to restore (excludes those in same database that are not named); each table reference must include the database name</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--lines-terminated-by=char</code></td>
<td>Lines are terminated by the indicated character</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--lossy-conversions, -L</code></td>
<td>Allow lossy conversions of column values (type demotions or changes in sign) when restoring data from backup</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
### ndb_restore — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--no-binlog</td>
<td>If a mysqld is connected and using binary logging, do not log the restored data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--no-restore-disk-objects,</td>
<td>Do not restore objects relating to Disk Data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-d</td>
<td>Do not upgrade array type for varsize attributes which do not already resize VAR data, and do not change column attributes</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--ndb-nodegroup-map=map,</td>
<td>Nodegroup map for NDBCLUSTER storage engine. Syntax: list of (source_nodegroup, destination_nodegroup)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-z</td>
<td>ID of node where backup was taken</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--nodeid=#,</td>
<td>Number of parallel transactions to use while restoring data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-n</td>
<td>Allow preservation of trailing spaces (including padding) when promoting fixed-width string types to variable-width types</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--print</td>
<td>Print metadata, data and log to stdout (equivalent to --print-meta --print-data --print-log)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--print-data</td>
<td>Print data to stdout</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--print-log</td>
<td>Print to stdout</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--print-meta</td>
<td>Print metadata to stdout</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--progress-frequency=#</td>
<td>Print status of restoration each given number of seconds</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--promote-attributes,</td>
<td>Allow attributes to be promoted when restoring data from backup</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>-A</td>
<td>Causes multithreaded rebuilding of ordered indexes found in the backup. Number of threads used is determined by setting BuildIndexThreads parameter</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--restore-data,</td>
<td>Restore table data and logs into NDB Cluster using the NDB API</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--restore-epoch, -e</td>
<td>Restore epoch info into the status table. Convenient on a MySQL Cluster replication slave for starting replication. The row in mysql.ndb_apply_status with id 0 will be updated/inserted</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--restore-meta, -m</td>
<td>Restore metadata to NDB Cluster using the NDB API</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--restore-privilege-tables</td>
<td>Restore MySQL privilege tables that were previously moved to NDB</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--rewrite-database=olddb,newdb</td>
<td>Restores to a database with a different name than the original</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--skip-broken-objects</td>
<td>Causes missing blob tables in the backup file to be ignored</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--skip-table-check, -s</td>
<td>Skip table structure check during restoring of data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--skip-unknown-objects</td>
<td>Causes schema objects not recognized by ndb_restore to be ignored when restoring a backup made from a newer MySQL Cluster version to an older version</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--tab=dir_name, -T dir_name</td>
<td>Creates a tab-separated .txt file for each table in the given path</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--verbose=#</td>
<td>Level of verbosity in output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

Typical options for this utility are shown here:

```sh
ndb_restore [-c connection_string] -n node_id -b backup_id \ [-m] -r --backup-path=/path/to/backup/files
```

Normally, when restoring from an NDB Cluster backup, `ndb_restore` requires at a minimum the `--nodeid` (short form: `-n`), `--backupid` (short form: `-b`), and `--backup-path` options. In addition, when `ndb_restore` is used to restore any tables containing unique indexes, you must include `--disable-indexes` or `--rebuild-indexes`. (Bug #57782, Bug #11764893)

The `-c` option is used to specify a connection string which tells `ndb_restore` where to locate the cluster management server (see Section 18.3.3.3, “NDB Cluster Connection Strings”). If this option is not used, then `ndb_restore` attempts to connect to a management server on `localhost:1186`. This utility acts as a cluster API node, and so requires a free connection "slot" to connect to the cluster management server. This means that there must be at least one `[api]` or `[mysqld]` section that can be used by it in the cluster `config.ini` file. It is a good idea to keep at least one empty `[api]` or `[mysqld]` section in `config.ini` that is not being used for a MySQL server or other application for this reason (see Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”).

2407
You can verify that `ndb_restore` is connected to the cluster by using the `SHOW` command in the `ndb_mgm` management client. You can also accomplish this from a system shell, as shown here:

```
shell> ndb_mgm -e "SHOW"
```

More detailed information about all options used by `ndb_restore` can be found in the following list:

### --append

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--append</code></td>
</tr>
</tbody>
</table>

When used with the `--tab` and `--print-data` options, this causes the data to be appended to any existing files having the same names.

### --backup-path=dir_name

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--backup-path=dir_name</code></td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
<tr>
<td>Default Value</td>
<td>./</td>
</tr>
</tbody>
</table>

The path to the backup directory is required; this is supplied to `ndb_restore` using the `--backup-path` option, and must include the subdirectory corresponding to the ID backup of the backup to be restored. For example, if the data node's `DataDir` is `/var/lib/mysql-cluster`, then the backup directory is `/var/lib/mysql-cluster/BACKUP`, and the backup files for the backup with the ID 3 can be found in `/var/lib/mysql-cluster/BACKUP/BACKUP-3`. The path may be absolute or relative to the directory in which the `ndb_restore` executable is located, and may be optionally prefixed with `backup-path=.`.

It is possible to restore a backup to a database with a different configuration than it was created from. For example, suppose that a backup with backup ID 12, created in a cluster with two storage nodes having the node IDs 2 and 3, is to be restored to a cluster with four nodes. Then `ndb_restore` must be run twice—one for each storage node in the cluster where the backup was taken. However, `ndb_restore` cannot always restore backups made from a cluster running one version of MySQL to a cluster running a different MySQL version. See Section 18.2.7, “Upgrading and Downgrading NDB Cluster”, for more information.

### Important

It is not possible to restore a backup made from a newer version of NDB Cluster using an older version of `ndb_restore`. You can restore a backup made from a newer version of MySQL to an older cluster, but you must use a copy of `ndb_restore` from the newer NDB Cluster version to do so.

For example, to restore a cluster backup taken from a cluster running NDB 7.2.5 to a cluster running NDB 7.1.21, you must use the `ndb_restore` that comes with the NDB 7.2.5 distribution.

For more rapid restoration, the data may be restored in parallel, provided that there is a sufficient number of cluster connections available. That is, when restoring to multiple nodes in parallel, you must have an `[api]` or `[mysqld]` section in the cluster `config.ini` file available for each concurrent `ndb_restore` process. However, the data files must always be applied before the logs.

### --backupid=#, -b
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--backupid=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>none</td>
</tr>
</tbody>
</table>

This option is used to specify the ID or sequence number of the backup, and is the same number shown by the management client in the `Backup backup_id completed` message displayed upon completion of a backup. (See Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”.)

---

**Important**

When restoring cluster backups, you must be sure to restore all data nodes from backups having the same backup ID. Using files from different backups will at best result in restoring the cluster to an inconsistent state, and may fail altogether.

- **--connect**, `-c`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--connect</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>localhost:1186</code></td>
</tr>
</tbody>
</table>

Alias for `--ndb-connectstring`.

- **--disable-indexes**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--disable-indexes</code></td>
</tr>
</tbody>
</table>

Disable restoration of indexes during restoration of the data from a native NDB backup. Afterwards, you can restore indexes for all tables at once with multithreaded building of indexes using `--rebuild-indexes`, which should be faster than rebuilding indexes concurrently for very large tables.

- **--dont-ignore-systab-0**, `-f`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--dont-ignore-systab-0</code></td>
</tr>
</tbody>
</table>

 Normally, when restoring table data and metadata, ndb_restore ignores the copy of the NDB system table that is present in the backup. `--dont-ignore-systab-0` causes the system table to be restored. *This option is intended for experimental and development use only, and is not recommended in a production environment.*

- **--exclude-databases=db-list**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--exclude-databases=db-list</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Comma-delimited list of one or more databases which should not be restored.

This option is often used in combination with `--exclude-tables`; see that option's description for further information and examples.

- `--exclude-intermediate-sql-tables[=TRUE|FALSE]`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--exclude-intermediate-sql-tables[=TRUE</td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.37-ndb-7.2.17</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

When performing copying `ALTER TABLE` operations, `mysqld` creates intermediate tables (whose names are prefixed with `#sql-`). When `TRUE`, the `--exclude-intermediate-sql-tables` option keeps `ndb_restore` from restoring such tables that may have been left over from these operations. This option is `TRUE` by default.

This option was introduced in NDB 7.2.17. (Bug #17882305)

- `--exclude-missing-columns`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--exclude-missing-columns</code></td>
</tr>
</tbody>
</table>

It is possible to restore only selected table columns using this option, which causes `ndb_restore` to ignore any columns missing from tables being restored as compared to the versions of those tables found in the backup. This option applies to all tables being restored. If you wish to apply this option only to selected tables or databases, you can use it in combination with one or more of the `--include-` or `--exclude-` options described elsewhere in this section to do so, then restore data to the remaining tables using a complementary set of these options.

- `--exclude-missing-tables`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--exclude-missing-tables</code></td>
</tr>
<tr>
<td>Introduced</td>
<td>5.5.40-ndb-7.2.18</td>
</tr>
</tbody>
</table>

It is possible to restore only selected tables using this option, which causes `ndb_restore` to ignore any tables from the backup that are not found in the target database.

This option was introduced in NDB 7.2.18.

- `--exclude-tables=table-list`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--exclude-tables=table-list</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
</tbody>
</table>
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

List of one or more tables to exclude; each table reference must include the database name. Often used together with `--exclude-databases`.

When `--exclude-databases` or `--exclude-tables` is used, only those databases or tables named by the option are excluded; all other databases and tables are restored by ndb_restore.

This table shows several invocations of ndb_restore using `--exclude-*` options (other options possibly required have been omitted for clarity), and the effects these options have on restoring from an NDB Cluster backup:

**Table 18.239 Several invocations of ndb_restore using --exclude-* options, and the effects these options have on restoring from an NDB Cluster backup.**

<table>
<thead>
<tr>
<th>Option</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--exclude-databases=db1</code></td>
<td>All tables in all databases except <code>db1</code> are restored; no tables in <code>db1</code> are restored</td>
</tr>
<tr>
<td><code>--exclude-databases=db1,db2</code> (or <code>--exclude-databases=db1 --exclude-databases=db2</code>)</td>
<td>All tables in all databases except <code>db1</code> and <code>db2</code> are restored; no tables in <code>db1</code> or <code>db2</code> are restored</td>
</tr>
<tr>
<td><code>--exclude-tables=db1.t1</code></td>
<td>All tables except <code>t1</code> in database <code>db1</code> are restored; all other tables in <code>db1</code> are restored; all tables in all other databases are restored</td>
</tr>
<tr>
<td><code>--exclude-tables=db1.t2,db2.t1</code> (or <code>--exclude-tables=db1.t2 --exclude-tables=db2.t1</code>)</td>
<td>All tables in database <code>db1</code> except for <code>t2</code> and all tables in database <code>db2</code> except for table <code>t1</code> are restored; no other tables in <code>db1</code> or <code>db2</code> are restored; all tables in all other databases are restored</td>
</tr>
</tbody>
</table>

You can use these two options together. For example, the following causes all tables in all databases except for databases `db1` and `db2`, and tables `t1` and `t2` in database `db3`, to be restored:

```
shell> ndb_restore [...] --exclude-databases=db1,db2 --exclude-tables=db3.t1,db3.t2
```

(Again, we have omitted other possibly necessary options in the interest of clarity and brevity from the example just shown.)

You can use `--include-*` and `--exclude-*` options together, subject to the following rules:

- The actions of all `--include-*` and `--exclude-*` options are cumulative.

- All `--include-*` and `--exclude-*` options are evaluated in the order passed to ndb_restore, from right to left.

- In the event of conflicting options, the first (rightmost) option takes precedence. In other words, the first option (going from right to left) that matches against a given database or table “wins”.

For example, the following set of options causes ndb_restore to restore all tables from database `db1` except `db1.t1`, while restoring no other tables from any other databases:
ndb_restore — Restore an NDB Cluster Backup

```
--include-databases=db1 --exclude-tables=db1.t1
```

However, reversing the order of the options just given simply causes all tables from database db1 to be restored (including db1.t1, but no tables from any other database), because the `--include-databases` option, being farthest to the right, is the first match against database db1 and thus takes precedence over any other option that matches db1 or any tables in db1:

```
--exclude-tables=db1.t1 --include-databases=db1
```

- `--fields-enclosed-by=char`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--fields-enclosed-by=char</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

Each column value is enclosed by the string passed to this option (regardless of data type; see the description of `--fields-optionally-enclosed-by`).

- `--fields-optionally-enclosed-by`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--fields-optionally-enclosed-by</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td></td>
</tr>
</tbody>
</table>

The string passed to this option is used to enclose column values containing character data (such as `CHAR`, `VARCHAR`, `BINARY`, `TEXT`, or `ENUM`).

- `--fields-terminated-by=char`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--fields-terminated-by=char</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>\t (tab)</td>
</tr>
</tbody>
</table>

The string passed to this option is used to separate column values. The default value is a tab character (\t).

- `--hex`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--hex</code></td>
</tr>
</tbody>
</table>

If this option is used, all binary values are output in hexadecimal format.

- `--include-databases=db-list`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--include-databases=db-list</code></td>
</tr>
</tbody>
</table>
ndb_restore — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>Comma-delimited list of one or more databases to restore. Often used together with (--include-tables); see the description of that option for further information and examples.</td>
</tr>
</tbody>
</table>

- \(--include-tables=table-list\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--include-tables=table-list</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td>Comma-delimited list of tables to restore; each table reference must include the database name.</td>
</tr>
</tbody>
</table>

When \(--include-databases\) or \(--include-tables\) is used, only those databases or tables named by the option are restored; all other databases and tables are excluded by ndb_restore, and are not restored.

The following table shows several invocations of ndb_restore using \(--include-*\) options (other options possibly required have been omitted for clarity), and the effects these have on restoring from an NDB Cluster backup:

**Table 18.240 Several invocations of ndb_restore using \(--include-*\) options, and their effects on restoring from an NDB Cluster backup.**

<table>
<thead>
<tr>
<th>Option</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>(--include-databases=db1)</td>
<td>Only tables in database \textit{db1} are restored; all tables in all other databases are ignored</td>
</tr>
<tr>
<td>(--include-databases=db1,db2) (or (--include-databases=db1 --include-databases=db2))</td>
<td>Only tables in databases \textit{db1} and \textit{db2} are restored; all tables in all other databases are ignored</td>
</tr>
<tr>
<td>(--include-tables=db1.t1)</td>
<td>Only table \textit{t1} in database \textit{db1} is restored; no other tables in \textit{db1} or in any other database are restored</td>
</tr>
</tbody>
</table>
### ndb_restore — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Option</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--include-tables=db1.t2,db2.t1</code> (or <code>--include-tables=db1.t2 --include-tables=db2.t1</code>)</td>
<td>Only the table <code>t2</code> in database <code>db1</code> and the table <code>t1</code> in database <code>db2</code> are restored; no other tables in <code>db1</code>, <code>db2</code>, or any other database are restored.</td>
</tr>
</tbody>
</table>

You can also use these two options together. For example, the following causes all tables in databases `db1` and `db2`, together with the tables `t1` and `t2` in database `db3`, to be restored (and no other databases or tables):

```
shell> ndb_restore [...] --include-databases=db1,db2 --include-tables=db3.t1,db3.t2
```

(Again we have omitted other, possibly required, options in the example just shown.)

It is also possible to restore only selected databases, or selected tables from a single database, without any `--include-*` (or `--exclude-*`) options, using the syntax shown here:

```
ndb_restore other_options db_name,[db_name][,...] | tbl_name[,tbl_name][,...]
```

In other words, you can specify either of the following to be restored:

- All tables from one or more databases
- One or more tables from a single database

#### Command-Line Format

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lines-terminated-by=char</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>\n</code> (linebreak)</td>
</tr>
</tbody>
</table>

Specifies the string used to end each line of output. The default is a linefeed character (`\n`).

- `--lossy-conversions, -L`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--lossy-conversions</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>FALSE</code> (If option is not used)</td>
</tr>
</tbody>
</table>

This option is intended to complement the `--promote-attributes` option. Using `--lossy-conversions` allows lossy conversions of column values (type demotions or changes in sign) when restoring data from backup. With some exceptions, the rules governing demotion are the same as for MySQL replication; see Replication of Columns Having Different Data Types, for information about specific type conversions currently supported by attribute demotion.

`ndb_restore` reports any truncation of data that it performs during lossy conversions once per attribute and column.

- `--no-binlog`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--no-binlog</code></td>
</tr>
</tbody>
</table>
This option prevents any connected SQL nodes from writing data restored by `ndb_restore` to their binary logs.

- **--no-restore-disk-objects, -d**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--no-restore-disk-objects</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

This option stops `ndb_restore` from restoring any NDB Cluster Disk Data objects, such as tablespaces and log file groups; see Section 18.5.12, "NDB Cluster Disk Data Tables", for more information about these.

- **--no-upgrade, -u**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--no-upgrade</code></td>
</tr>
</tbody>
</table>

When using `ndb_restore` to restore a backup, VARCHAR columns created using the old fixed format are resized and recreated using the variable-width format now employed. This behavior can be overridden by specifying `--no-upgrade`.

- **--ndb-nodegroup-map=map, -z**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-nodegroup-map=map</code></td>
</tr>
</tbody>
</table>

This option can be used to restore a backup taken from one node group to a different node group. Its argument is a list of the form `source_node_group, target_node_group`.

- **--nodeid=#, -n**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--nodeid=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>none</td>
</tr>
</tbody>
</table>

Specify the node ID of the data node on which the backup was taken.

When restoring to a cluster with different number of data nodes from that where the backup was taken, this information helps identify the correct set or sets of files to be restored to a given node. (In such cases, multiple files usually need to be restored to a single data node.) See Section 18.4.21.1, "Restoring to a different number of data nodes", for additional information and examples.

- **--parallelism=#, -p**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--parallelism=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>2415</td>
</tr>
</tbody>
</table>
**ndb_restore** — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>128</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>1024</td>
</tr>
</tbody>
</table>

The work of performing the inserts is parallelized across the threads in the data nodes involved. This mechanism is employed for restoring bulk data from the `.Data` file—that is, the fuzzy snapshot of the data; it is not used for building or rebuilding indexes. The change log is applied serially; index drops and builds are DDL operations and handled separately. There is no thread-level parallelism on the client side of the restore.

- **--preserve-trailing-spaces**, `-P`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--preserve-trailing-spaces</code></td>
</tr>
</tbody>
</table>

Cause trailing spaces to be preserved when promoting a fixed-width character data type to its variable-width equivalent—that is, when promoting a `CHAR` column value to `VARCHAR`, or a `BINARY` column value to `VARBINARY`. Otherwise, any trailing spaces are dropped from such column values when they are inserted into the new columns.

**Note**

Although you can promote `CHAR` columns to `VARCHAR` and `BINARY` columns to `VARBINARY`, you cannot promote `VARCHAR` columns to `CHAR` or `VARBINARY` columns to `BINARY`.

- **--print**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--print</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Causes **ndb_restore** to print all data, metadata, and logs to `stdout`. Equivalent to using the **--print-data**, **--print-meta**, and **--print-log** options together.

**Note**

Use of **--print** or any of the **--print_*** options is in effect performing a dry run. Including one or more of these options causes any output to be redirected to `stdout`; in such cases, **ndb_restore** makes no attempt to restore data or metadata to an NDB Cluster.

- **--print-data**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--print-data</code></td>
</tr>
</tbody>
</table>
ndb_restore — Restore an NDB Cluster Backup

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Cause `ndb_restore` to direct its output to `stdout`. Often used together with one or more of `--tab`, `--fields-enclosed-by`, `--fields-optionally-enclosed-by`, `--fields-terminated-by`, `--hex`, and `--append`.

`TEXT` and `BLOB` column values are always truncated. In NDB 7.2.18 and earlier, such values are truncated to the first 240 bytes in the output; in NDB 7.2.19 and later, they are truncated to 256 bytes. (Bug #14571512, Bug #65467) This cannot currently be overridden when using `--print-data`.

•  `--print-log`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--print-log</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Cause `ndb_restore` to output its log to `stdout`.

•  `--print-meta`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--print-meta</code></td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Print all metadata to `stdout`.

•  `--progress-frequency=N`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--progress-frequency=#</code></td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>65535</td>
</tr>
</tbody>
</table>

Print a status report each $N$ seconds while the restore is in progress. 0 (the default) causes no status reports to be printed. The maximum is 65535.

•  `--promote-attributes, -A`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--promote-attributes</code></td>
</tr>
</tbody>
</table>

`ndb_restore` supports limited `attribute promotion` in much the same way that it is supported by `MySQL` replication; that is, data backed up from a column of a given type can generally be restored to a column
using a “larger, similar” type. For example, data from a \texttt{CHAR(20)} column can be restored to a column declared as \texttt{VARCHAR(20)}, \texttt{VARCHAR(30)}, or \texttt{CHAR(30)}; data from a \texttt{MEDIUMINT} column can be restored to a column of type \texttt{INT} or \texttt{BIGINT}. See \url{Replication of Columns Having Different Data Types}, for a table of type conversions currently supported by attribute promotion.

Attribute promotion by \texttt{ndb_restore} must be enabled explicitly, as follows:

1. Prepare the table to which the backup is to be restored. \texttt{ndb_restore} cannot be used to re-create the table with a different definition from the original; this means that you must either create the table manually, or alter the columns which you wish to promote using \texttt{ALTER TABLE} after restoring the table metadata but before restoring the data.

2. Invoke \texttt{ndb_restore} with the \texttt{--promote-attributes} option (short form \texttt{-A}) when restoring the table data. Attribute promotion does not occur if this option is not used; instead, the restore operation fails with an error.

Prior to NDB 7.2.14, conversions between character data types and \texttt{TEXT} or \texttt{BLOB} were not handled correctly.

Prior to NDB 7.2.18, demotion of \texttt{TEXT} to \texttt{TINYTEXT} was not handled correctly (Bug \#18875137).

When converting between character data types and \texttt{TEXT} or \texttt{BLOB}, only conversions between character types (\texttt{CHAR} and \texttt{VARCHAR}) and binary types (\texttt{BINARY} and \texttt{VARBINARY}) can be performed at the same time. For example, you cannot promote an \texttt{INT} column to \texttt{BIGINT} while promoting a \texttt{VARCHAR} column to \texttt{TEXT} in the same invocation of \texttt{ndb_restore}.

Converting between \texttt{TEXT} columns using different character sets is not supported. Beginning with NDB 7.2.18, it is expressly disallowed (Bug \#18875137).

When performing conversions of character or binary types to \texttt{TEXT} or \texttt{BLOB} with \texttt{ndb_restore}, you may notice that it creates and uses one or more staging tables named \texttt{table_name}\$\text{STnode_id}. These tables are not needed afterwards, and are normally deleted by \texttt{ndb_restore} following a successful restoration.

- \texttt{--rebuild-indexes}

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>\texttt{--rebuild-indexes}</td>
</tr>
</tbody>
</table>

Enable multithreaded rebuilding of the ordered indexes while restoring a native NDB backup. The number of threads used for building ordered indexes by \texttt{ndb_restore} with this option is controlled by the \texttt{BuildIndexThreads} data node configuration parameter and the number of LDMs.

It is necessary to use this option only for the first run of \texttt{ndb_restore}; this causes all ordered indexes to be rebuilt without using \texttt{--rebuild-indexes} again when restoring subsequent nodes. You should use this option prior to inserting new rows into the database; otherwise, it is possible for a row to be inserted that later causes a unique constraint violation when trying to rebuild the indexes.

Building of ordered indices is parallelized with the number of LDMs by default. Offline index builds performed during node and system restarts can be made faster using the \texttt{BuildIndexThreads} data node configuration parameter; this parameter has no effect on dropping and rebuilding of indexes by \texttt{ndb_restore}, which is performed online.

Rebuilding of unique indexes uses disk write bandwidth for redo logging and local checkpointing. An insufficient amount of this bandwidth can lead to redo buffer overload or log overload errors. In such
cases you can run `ndb_restore --rebuild-indexes` again; the process resumes at the point where the error occurred. You can also do this when you have encountered temporary errors. You can repeat execution of `ndb_restore --rebuild-indexes` indefinitely; you may be able to stop such errors by reducing the value of `--parallelism`. If the problem is insufficient space, you can increase the size of the redo log (`FragmentLogFileSize` node configuration parameter), or you can increase the speed at which LCPs are performed (`MaxDiskWriteSpeed` and related parameters), in order to free space more quickly.

- `--restore-data, -r`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--restore-data</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Output NDB table data and logs.

- `--restore-epoch, -e`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--restore-epoch</td>
</tr>
</tbody>
</table>

Add (or restore) epoch information to the cluster replication status table. This is useful for starting replication on an NDB Cluster replication slave. When this option is used, the row in the `mysql.ndb_apply_status` having 0 in the `id` column is updated if it already exists; such a row is inserted if it does not already exist. (See Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”.)

- `--restore-meta, -m`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--restore-meta</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

This option causes `ndb_restore` to print NDB table metadata.

The first time you run the `ndb_restore` restoration program, you also need to restore the metadata. In other words, you must re-create the database tables—this can be done by running it with the `--restore-meta (-m)` option. Restoring the metadata need be done only on a single data node; this is sufficient to restore it to the entire cluster.

Note

The cluster should have an empty database when starting to restore a backup. (In other words, you should start the data nodes with `--initial` prior to performing the restore.)

- `--restore-privilege-tables`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--restore-privilege-tables</td>
</tr>
</tbody>
</table>
**ndb_restore** does not by default restore distributed MySQL privilege tables. This option causes **ndb_restore** to restore the privilege tables.

This works only if the privilege tables were converted to NDB before the backup was taken. For more information, see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”.

This option was added in NDB 7.2.0.

- **--rewrite-database=olddb,newdb**

This option makes it possible to restore to a database having a different name from that used in the backup. For example, if a backup is made of a database named `products`, you can restore the data it contains to a database named `inventory`, use this option as shown here (omitting any other options that might be required):

```bash
shell> ndb_restore --rewrite-database=product,inventory
```

The option can be employed multiple times in a single invocation of **ndb_restore**. Thus it is possible to restore simultaneously from a database named `db1` to a database named `db2` and from a database named `db3` to one named `db4` using `--rewrite-database=db1,db2 --rewrite-database=db3,db4`. Other **ndb_restore** options may be used between multiple occurrences of `--rewrite-database`.

In the event of conflicts between multiple `--rewrite-database` options, the last `--rewrite-database` option used, reading from left to right, is the one that takes effect. For example, if `--rewrite-database=db1,db2 --rewrite-database=db1,db3` is used, only `--rewrite-database=db1,db3` is honored, and `--rewrite-database=db1,db2` is ignored. It is also possible to restore from multiple databases to a single database, so that `--rewrite-database=db1,db3 --rewrite-database=db2,db3` restores all tables and data from databases `db1` and `db2` into database `db3`.

**Important**

When restoring from multiple backup databases into a single target database using `--rewrite-database`, no check is made for collisions between table or other object names, and the order in which rows are restored is not guaranteed. This means that it is possible in such cases for rows to be overwritten and updates to be lost.
• **--skip-broken-objects**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-broken-objects</td>
</tr>
</tbody>
</table>

This option causes `ndb_restore` to ignore corrupt tables while reading a native NDB backup, and to continue restoring any remaining tables (that are not also corrupted). Currently, the `--skip-broken-objects` option works only in the case of missing blob parts tables.

• **--skip-table-check, -s**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-table-check</td>
</tr>
</tbody>
</table>

It is possible to restore data without restoring table metadata. By default when doing this, `ndb_restore` fails with an error if a mismatch is found between the table data and the table schema; this option overrides that behavior.

Some of the restrictions on mismatches in column definitions when restoring data using `ndb_restore` are relaxed; when one of these types of mismatches is encountered, `ndb_restore` does not stop with an error as it did previously, but rather accepts the data and inserts it into the target table while issuing a warning to the user that this is being done. This behavior occurs whether or not either of the options `--skip-table-check` or `--promote-attributes` is in use. These differences in column definitions are of the following types:

• Different `COLUMN_FORMAT` settings (`FIXED, DYNAMIC, DEFAULT`)
• Different `STORAGE` settings (`MEMORY, DISK`)
• Different default values
• Different distribution key settings
• **--skip-unknown-objects**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--skip-unknown-objects</td>
</tr>
</tbody>
</table>

This option causes `ndb_restore` to ignore any schema objects it does not recognize while reading a native NDB backup. This can be used for restoring a backup made from a cluster running NDB 7.5 to a cluster running NDB Cluster 7.4.

• **--tab=dir_name, -T dir_name**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--tab=dir_name</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Directory name</th>
</tr>
</thead>
</table>

Causes `--print-data` to create dump files, one per table, each named `tbl_name.txt`. It requires as its argument the path to the directory where the files should be saved; use `.` for the current directory.
**ndb_restore** — Restore an NDB Cluster Backup

- **--verbose=**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--verbose=</td>
</tr>
<tr>
<td>Type</td>
<td>Numeric</td>
</tr>
<tr>
<td>Default Value</td>
<td>1</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>255</td>
</tr>
</tbody>
</table>

Sets the level for the verbosity of the output. The minimum is 0; the maximum is 255. The default value is 1.

**Error reporting.**

*ndb_restore* reports both temporary and permanent errors. In the case of temporary errors, it may able to recover from them, and reports *Restore successful, but encountered temporary error, please look at configuration* in such cases.

---

**Important**

After using *ndb_restore* to initialize an NDB Cluster for use in circular replication, binary logs on the SQL node acting as the replication slave are not automatically created, and you must cause them to be created manually. To cause the binary logs to be created, issue a *SHOW TABLES* statement on that SQL node before running *START SLAVE*. This is a known issue in NDB Cluster.

### 18.4.21.1 Restoring to a different number of data nodes

It is possible to restore from an NDB backup to a cluster having a different number of data nodes than the original from which the backup was taken. The following two sections discuss, respectively, the cases where the target cluster has a lesser or greater number of data nodes than the source of the backup.

**Restoring to Fewer Nodes Than the Original**

You can restore to a cluster having fewer data nodes than the original provided that the larger number of nodes is an even multiple of the smaller number. In the following example, we use a backup taken on a cluster having four data nodes to a cluster having two data nodes.

1. The management server for the original cluster is on host **host10**. The original cluster has four data nodes, with the node IDs and host names shown in the following extract from the management server's *config.ini* file:

```
[nbd]
NodeId=2
HostName=host2

[nbd]
NodeId=4
HostName=host4

[nbd]
NodeId=6
HostName=host6

[nbd]
NodeId=8
HostName=host8
```
We assume that each data node was originally started with `ndbmtd --ndb-connectstring=host10` or the equivalent.

2. Perform a backup in the normal manner. See Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”, for information about how to do this.

3. The files created by the backup on each data node are listed here, where $N$ is the node ID and $B$ is the backup ID.

   - `BACKUP-B-0.N.Data`
   - `BACKUP-B.N.ctl`
   - `BACKUP-B.N.log`

   These files are found under `BackupDataDir/BACKUP/BACKUP-B`, on each data node. For the rest of this example, we assume that the backup ID is 1.

   Have all of these files available for later copying to the new data nodes (where they can be accessed on the data node’s local file system by `ndb_restore`). It is simplest to copy them all to a single location; we assume that this is what you have done.

4. The management server for the target cluster is on host `host20`, and the target has two data nodes, with the node IDs and host names shown, from the management server `config.ini` file on `host20`:

   ```ini
   [ndbd]
   NodeId=3
   hostname=host3
   
   [ndbd]
   NodeId=5
   hostname=host5
   ```

   Each of the data node processes on `host3` and `host5` should be started with `ndbmtd -c host20 --initial` or the equivalent, so that the new (target) cluster starts with clean data node file systems.
5. Copy two different sets of two backup files to each of the target data nodes. For this example, copy the backup files from nodes 2 and 4 from the original cluster to node 3 in the target cluster. These files are listed here:

- BACKUP-1-0.2.Data
- BACKUP-1.2.ctl
- BACKUP-1.2.log
- BACKUP-1-0.6.Data
- BACKUP-1.6.ctl
- BACKUP-1.6.log

Then copy the backup files from nodes 6 and 8 to node 5; these files are shown in the following list:

- BACKUP-1-0.4.Data
- BACKUP-1.4.ctl
- BACKUP-1.4.log
- BACKUP-1-0.8.Data
- BACKUP-1.8.ctl
- BACKUP-1.8.log

For the remainder of this example, we assume that the respective backup files have been saved to the directory /BACKUP-1 on each of nodes 3 and 5.

6. On each of the two target data nodes, you must restore from both sets of backups. First, restore the backups from nodes 2 and 4 to node 3 by invoking `ndb_restore` on `host3` as shown here:

```shell
ndb_restore -c host20 --nodeid=2 --backupid=1 --restore-data --backup-path=/BACKUP-1
ndb_restore -c host20 --nodeid=4 --backupid=1 --restore-data --backup-path=/BACKUP-1
```

Then restore the backups from nodes 6 and 8 to node 5 by invoking `ndb_restore` on `host5`, like this:

```shell
ndb_restore -c host20 --nodeid=6 --backupid=1 --restore-data --backup-path=/BACKUP-1
ndb_restore -c host20 --nodeid=8 --backupid=1 --restore-data --backup-path=/BACKUP-1
```

**Restoring to More Nodes Than the Original**

The node ID specified for a given `ndb_restore` command is that of the node in the original backup and not that of the data node to restore it to. When performing a backup using the method described in this section, `ndb_restore` connects to the management server and obtains a list of data nodes in the cluster the backup is being restored to. The restored data is distributed accordingly, so that the number of nodes in the target cluster does not need to be known or calculated when performing the backup.

**Note**

When changing the total number of LCP threads or LQH threads per node group, you should recreate the schema from backup created using `mysqldump`. 
1. **Create the backup of the data.** You can do this by invoking the `ndb_mgm` client `START_BACKUP` command from the system shell, like this:

```shell
shell> ndb_mgm -e "START_BACKUP 1"
```

This assumes that the desired backup ID is 1.

2. **Create a backup of the schema (see also below):**

```shell
shell> mysqldump --no-data --routines --events --triggers --databases > myschema.sql
```

**Important**

You must not make any schema changes between the first and second steps.

3. Copy the backup directories from above to the new cluster. For example if the backup you want to restore is has ID 1 and `BackupDataDir = /backups/node_nodeid`, then the path to the backup on this node is `/backups/node_1/BACKUP/BACKUP-1`. Inside this directory there are three files, listed here:

- **BACKUP-1-0.1.Data**
- **BACKUP-1.1.ctl**
- **BACKUP-1.1.log**

You should copy the entire directory to the new node.

There is no requirement for the backup to be restored from a specific node or nodes.

To restore from the backup just created, perform the following steps:

1. **Restore the schema.** Import the schema file using the `mysql` client, as shown here:

```shell
shell> mysql < myschema.sql
```

2. **Restore the data.** The following commands can be run in parallel:

   ```shell
   ndb_restore --nodeid=1 --backupid=1 --restore-data --backup-path=/backups/node_1/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=2 --backupid=1 --restore-data --backup-path=/backups/node_2/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=3 --backupid=1 --restore-data --backup-path=/backups/node_3/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=4 --backupid=1 --restore-data --backup-path=/backups/node_4/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=5 --backupid=1 --restore-data --backup-path=/backups/node_5/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=6 --backupid=1 --restore-data --backup-path=/backups/node_6/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=7 --backupid=1 --restore-data --backup-path=/backups/node_7/BACKUP/BACKUP-1 --disable-indexes
   ndb_restore --nodeid=8 --backupid=1 --restore-data --backup-path=/backups/node_8/BACKUP/BACKUP-1 --disable-indexes
   ```

Add the `--ndb-connectstring` option as needed.

If you in 3. for example copied the backups from the “old” nodes having node IDs 1 and 2 to a “new” node whose node ID is 1, you should perform the two invocations of `ndb_restore` with `--nodeid=1` and `--nodeid=2` on the new node that has 1 as its node ID.

3. **Rebuild the indexes.** These were disabled by the `--disable-indexes` option used in the commands just shown. Recreating the indexes avoids errors due to the restore not being consistent at all points. Rebuilding the indexes can also improve performance in some cases. To rebuild the indexes, execute the following command once, on a single node:

```shell
shell> ndb_restore --nodeid=1 --backupid=1 --backup-path=/backups/node_1/BACKUP/BACKUP-1 --rebuild-indexes
```
Important

You should be aware that the supported number of partitions in each table depends on the number of data nodes, node groups, and LDM threads in the cluster. Other conditions (such as the values of MaxNoOfExecutionThreads, ThreadConfig, NoOfReplicas, and so on) being the same, a cluster with (for example) two data nodes supports fewer partitions than a cluster with eight data nodes supports. This means that using ndb_restore --restore-meta to restore the schema does not always work since this restores a given table with the same number of partitions as in the original; it is safer to restore the schema from a backup written by mysqldump—as in the example shown previously—when restoring to a cluster having fewer data nodes, LDM threads, or both, than were used in the original cluster.

The support for fewer partitions when restoring to a smaller cluster also means the maximum number of rows per table is lower. However, with the larger hash maps available in MySQL Cluster 7.2.9 and later (used by default for new tables), this is not likely to be an issue.

18.4.22 ndb_select_all — Print Rows from an NDB Table

ndb_select_all prints all rows from an NDB table to stdout.

Usage

ndb_select_all -c connection_string tbl_name -d db_name [> file_name]

The following table includes options that are specific to the NDB Cluster native backup restoration program ndb_select_all. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_select_all), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.241 Command-line options for the ndb_select_all program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--database=dbname,</td>
<td>Name of the database in which the</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td>-d</td>
<td>table is found</td>
<td>based releases)</td>
</tr>
<tr>
<td>--parallelism=#,</td>
<td>Degree of parallelism</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td>-p</td>
<td></td>
<td>based releases)</td>
</tr>
<tr>
<td>--lock=#,</td>
<td>Lock type</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td>-l</td>
<td></td>
<td>based releases)</td>
</tr>
<tr>
<td>--order=index,</td>
<td>Sort resultset according to index</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td>-o</td>
<td>whose name is supplied</td>
<td>based releases)</td>
</tr>
<tr>
<td>--descending,</td>
<td>Sort resultset in descending order</td>
<td>(Supported in all MySQL 5.5</td>
</tr>
<tr>
<td>-z</td>
<td>(requires order flag)</td>
<td>based releases)</td>
</tr>
<tr>
<td>--header,</td>
<td>Print header (set to 0</td>
<td>FALSE to disable headers in</td>
</tr>
<tr>
<td>-h</td>
<td>output)</td>
<td>based releases)</td>
</tr>
</tbody>
</table>
**ndb_select_all** — Print Rows from an NDB Table

### Format

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--useHexFormat</code>, <code>--delimiter=char, D</code></td>
<td>Output numbers in hexadecimal format or Set a column delimiter</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--disk</code></td>
<td>Print disk references (useful only for Disk Data tables having nonindexed columns)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--rowid</code></td>
<td>Print rowid</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--gci</code></td>
<td>Include GCI in output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--gci64</code></td>
<td>Include GCI and row epoch in output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--tupscan</code>, <code>-t</code></td>
<td>Scan in tup order</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--nodata</code></td>
<td>Do not print table column data</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

### Options

- **`--database=dbname, -d dbname`**
  
  Name of the database in which the table is found. The default value is **TEST_DB**.

- **parallelism=#, -p #**
  
  Specifies the degree of parallelism.

- **`--lock=lock_type, -l lock_type`**
  
  Employs a lock when reading the table. Possible values for **lock_type** are:
  
  - **0**: Read lock
  - **1**: Read lock with hold
  - **2**: Exclusive read lock
  
  There is no default value for this option.

- **`--order=index_name, -o index_name`**
  
  Orders the output according to the index named **index_name**. Note that this is the name of an index, not of a column, and that the index must have been explicitly named when created.

- **`--descending, -z`**
  
  Sorts the output in descending order. This option can be used only in conjunction with the `-o (--order)` option.

- **`--header=FALSE`**
Excludes column headers from the output.

- `--useHexFormat -x`
  Causes all numeric values to be displayed in hexadecimal format. This does not affect the output of numerals contained in strings or datetime values.

- `--delimiter=character, -D character`
  Causes the `character` to be used as a column delimiter. Only table data columns are separated by this delimiter.
  The default delimiter is the tab character.

- `--disk`
  Adds a disk reference column to the output. The column is nonempty only for Disk Data tables having nonindexed columns.

- `--rowid`
  Adds a `ROWID` column providing information about the fragments in which rows are stored.

- `--gci`
  Adds a `GCI` column to the output showing the global checkpoint at which each row was last updated. See Section 18.1, “NDB Cluster Overview”, and Section 18.5.6.2, “NDB Cluster Log Events”, for more information about checkpoints.

- `--gci64`
  Adds a `ROW$GCI64` column to the output showing the global checkpoint at which each row was last updated, as well as the number of the epoch in which this update occurred.

- `--tupscan, -t`
  Scan the table in the order of the tuples.

- `--nodata`
  Causes any table data to be omitted.

**Sample Output**

Output from a MySQL `SELECT` statement:

```
mysql> SELECT * FROM ctest1.fish;
+----+-----------+
| id | name      |
+----+-----------+
|  3 | shark     |
|  6 | puffer    |
|  2 | tuna      |
|  4 | manta ray |
|  5 | grouper   |
|  1 | guppy     |
+----+-----------+
6 rows in set (0.04 sec)
```

Output from the equivalent invocation of `ndb_select_all`:

```
2428
```
ndb_select_all — Print Row Counts for NDB Tables

shell> ./ndb_select_all -c localhost fish -d ctest1

```
id      name
3       [shark]
6       [puffer]
2       [tuna]
4       [manta ray]
5       [grouper]
1       [guppy]
6 rows returned
```  

NDBT_ProgramExit: 0 - OK

All string values are enclosed by square brackets ([]) in the output of `ndb_select_all`. Now consider the table created and populated as shown here:

```
CREATE TABLE dogs (  
id INT(11) NOT NULL AUTO_INCREMENT,  
name VARCHAR(25) NOT NULL,  
breed VARCHAR(50) NOT NULL,  
PRIMARY KEY pk (id),  
KEY ix (name)  
)  
TABLESPACE ts STORAGE DISK  
ENGINE=NDBCluster;
```

```
INSERT INTO dogs VALUES  
('', 'Lassie', 'collie'),  
('', 'Scooby-Doo', 'Great Dane'),  
('', 'Rin-Tin-Tin', 'Alsatian'),  
('', 'Rosscoe', 'Mutt');
```

This demonstrates the use of several additional `ndb_select_all` options:

```
shell> ./ndb_select_all -d ctest1 dogs -o ix -z --gci --disk
```

```
GCI   id   name          breed        DISK_REF
834461 2  [Scooby-Doo]  [Great Dane] [ m_file_no: 0 m_page: 98 m_page_idx: 0 ]
834878 4  [Rosscoe]     [Mutt]       [ m_file_no: 0 m_page: 98 m_page_idx: 16 ]
834463 3  [Rin-Tin-Tin] [Alsatian]   [ m_file_no: 0 m_page: 34 m_page_idx: 0 ]
835657 1  [Lassie]      [Collie]     [ m_file_no: 0 m_page: 66 m_page_idx: 0 ]
4 rows returned
```  

NDBT_ProgramExit: 0 - OK

18.4.23 ndb_select_count — Print Row Counts for NDB Tables

`ndb_select_count` prints the number of rows in one or more NDB tables. With a single table, the result is equivalent to that obtained by using the MySQL statement

```
SELECT COUNT(*) FROM tbl_name.
```

Usage

```
ndb_select_count [-c connection_string] -d db_name tbl_name[, tbl_name2[, ...]]
```

The following table includes options that are specific to the NDB Cluster native backup restoration program `ndb_select_count`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_select_count`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

<table>
<thead>
<tr>
<th>Table 18.242 Command-line options for the ndb_select_count program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Format</strong></td>
</tr>
<tr>
<td><code>--database=dbname</code>,</td>
</tr>
</tbody>
</table>
ndb_show_tables — Display List of NDB Tables

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-d</td>
<td>Degree of parallelism</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--parallelism=#,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-p</td>
<td>Lock type</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--lock=#,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-l</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

You can obtain row counts from multiple tables in the same database by listing the table names separated by spaces when invoking this command, as shown under Sample Output.

### Sample Output

```
shell> ./ndb_select_count --c localhost -d ctest1 fish dogs
6 records in table fish
4 records in table dogs
```

2430

18.4.24 ndb_show_tables — Display List of NDB Tables

ndb_show_tables displays a list of all NDB database objects in the cluster. By default, this includes not only both user-created tables and NDB system tables, but NDB-specific indexes, internal triggers, and NDB Cluster Disk Data objects as well.

The following table includes options that are specific to the NDB Cluster native backup restoration program ndb_show_tables. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_show_tables), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.243 Command-line options for the ndb_show_tables program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--database=string, -d</td>
<td>Specifies the database in which the table is found</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--loops=#, -l</td>
<td>Number of times to repeat output</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--parsable, -p</td>
<td>Return output suitable for MySQL LOAD DATA statement</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--show-temp-status</td>
<td>Show table temporary flag</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--type=#, -t</td>
<td>Limit output to objects of this type</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--unqualified, -u</td>
<td>Do not qualify table names</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>
Usage

```
ndb_show_tables [-c connection_string]
```

- **--database, -d**
  Specifies the name of the database in which the tables are found.

- **--loops, -l**
  Specifies the number of times the utility should execute. This is 1 when this option is not specified, but if you do use the option, you must supply an integer argument for it.

- **--parsable, -p**
  Using this option causes the output to be in a format suitable for use with `LOAD DATA`.

- **--show-temp-status**
  If specified, this causes temporary tables to be displayed.

- **--type, -t**
  Can be used to restrict the output to one type of object, specified by an integer type code as shown here:
  - **1**: System table
  - **2**: User-created table
  - **3**: Unique hash index
  Any other value causes all NDB database objects to be listed (the default).

- **--unqualified, -u**
  If specified, this causes unqualified object names to be displayed.

**Note**

Only user-created NDB Cluster tables may be accessed from MySQL; system tables such as `SYSTAB_0` are not visible to `mysqld`. However, you can examine the contents of system tables using NDB API applications such as `ndb_select_all` (see Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table").

18.4.25 ndb_size.pl — NDBCLUSTER Size Requirement Estimator

This is a Perl script that can be used to estimate the amount of space that would be required by a MySQL database if it were converted to use the NDBCLUSTER storage engine. Unlike the other utilities discussed in this section, it does not require access to an NDB Cluster (in fact, there is no reason for it to do so). However, it does need to access the MySQL server on which the database to be tested resides.

**Requirements**

- A running MySQL server. The server instance does not have to provide support for NDB Cluster.
- A working installation of Perl.
• The **DBI** module, which can be obtained from CPAN if it is not already part of your Perl installation. (Many Linux and other operating system distributions provide their own packages for this library.)

• A MySQL user account having the necessary privileges. If you do not wish to use an existing account, then creating one using `GRANT USAGE ON db_name.*`—where *db_name* is the name of the database to be examined—is sufficient for this purpose.

**ndb_size.pl** can also be found in the MySQL sources in *storage/ndb/tools*.

The following table includes options that are specific to the NDB Cluster program **ndb_size.pl**. Additional descriptions follow the table. For options common to most NDB Cluster programs (including **ndb_size.pl**), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

### Table 18.244 Command-line options for the **ndb_size.pl** program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--database=dbname</code></td>
<td>The database or databases to examine; accepts a comma-delimited list; the default is ALL (use all databases found on the server)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--hostname[:port]</code></td>
<td>Specify host and optional port as host[:port]</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--socket=file_name</code></td>
<td>Specify a socket to connect to</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--user=string</code></td>
<td>Specify a MySQL user name</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--password=string</code></td>
<td>Specify a MySQL user password</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--format=string</code></td>
<td>Set output format (text or HTML)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--excludetables=tbl_list</code></td>
<td>Skip any tables in a comma-separated list of tables</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--excludedbs=db_list</code></td>
<td>Skip any databases in a comma-separated list of databases</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--savequeries=file</code></td>
<td>Saves all queries to the database into the file specified</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--loadqueries=file</code></td>
<td>Loads all queries from the file specified</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td><code>--real_table_name=table</code></td>
<td>Designates a table to handle unique index size calculations</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

### Usage

```bash
perl ndb_size.pl [--database={db_name|ALL}] [--hostname=host[:port]] [--socket=socket] \
   [--user=user] [--password=password] \
   [--help|-h] [--format={html|text}] \
   [--loadqueries=file_name] [--savequeries=file_name]
```
By default, this utility attempts to analyze all databases on the server. You can specify a single database using the `--database` option; the default behavior can be made explicit by using `ALL` for the name of the database. You can also exclude one or more databases by using the `--excludedbs` option with a comma-separated list of the names of the databases to be skipped. Similarly, you can cause specific tables to be skipped by listing their names, separated by commas, following the optional `--excludetables` option. A host name can be specified using `--hostname`; the default is `localhost`. In NDB 7.2.6 and later, you can specify a port in addition to the host using `host:port` format for the value of `--hostname`. The default port number is 3306. If necessary, you can also specify a socket; the default is `/var/lib/mysql.sock`. A MySQL user name and password can be specified the corresponding options shown. It also possible to control the format of the output using the `--format` option; this can take either of the values `html` or `text`, with `text` being the default. An example of the text output is shown here:

```shell
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock
ndb_size.pl report for database: 'test' (1 tables)
--------------------------------------------------
Connected to: DBI:mysql:host=localhost;mysql_socket=/tmp/mysql.sock
Including information for versions: 4.1, 5.0, 5.1

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Varsized</th>
<th>Key</th>
<th>4.1</th>
<th>5.0</th>
<th>5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIDDEN_NDB_PKEY</td>
<td>bigint</td>
<td></td>
<td>PRI</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>c2</td>
<td>varchar(50)</td>
<td>Y</td>
<td>52</td>
<td>52</td>
<td>4*</td>
<td></td>
</tr>
<tr>
<td>c1</td>
<td>int(11)</td>
<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Fixed Size Columns DM/Row: 64
Varsize Columns DM/Row: 0

DataMemory for Indexes:

<table>
<thead>
<tr>
<th>Index Name</th>
<th>Type</th>
<th>4.1</th>
<th>5.0</th>
<th>5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY</td>
<td>BTREE</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

Total Index DM/Row: 16

IndexMemory for Indexes:

<table>
<thead>
<tr>
<th>Index Name</th>
<th>4.1</th>
<th>5.0</th>
<th>5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY</td>
<td>33</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

Indexes IM/Row: 33

Summary (for THIS table):

<table>
<thead>
<tr>
<th>4.1</th>
<th>5.0</th>
<th>5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Overhead DM/Row: 12</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>NULL Bytes/Row: 4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>DataMemory/Row: 96</td>
<td>96</td>
<td>48</td>
</tr>
</tbody>
</table>

(Includes overhead, bitmap and indexes)
For debugging purposes, the Perl arrays containing the queries run by this script can be read from the file specified using the `--savequeries` option; a file containing such arrays can be read during script execution can be specified using `--loadqueries`. Neither of these options has a default value.

To produce output in HTML format, use the `--format` option and redirect the output to a file, as shown here:

```
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock --format=html > ndb_size.html
```

(Without the redirection, the output is sent to `stdout`.)

The output from this script includes the following information:

- Minimum values for the `DataMemory`, `IndexMemory`, `MaxNoOfTables`, `MaxNoOfAttributes`, `MaxNoOfOrderedIndexes`, `MaxNoOfUniqueHashIndexes`, and `MaxNoOfTriggers` configuration parameters required to accommodate the tables analyzed.
- Memory requirements for all of the tables, attributes, ordered indexes, and unique hash indexes defined in the database.
- The `IndexMemory` and `DataMemory` required per table and table row.

### 18.4.26 ndb_waiter — Wait for NDB Cluster to Reach a Given Status

`ndb_waiter` repeatedly (each 100 milliseconds) prints out the status of all cluster data nodes until either the cluster reaches a given status or the `--timeout` limit is exceeded, then exits. By default, it waits for the cluster to achieve `STARTED` status, in which all nodes have started and connected to the cluster. This can be overridden using the `--no-contact` and `--not-started` options.

The node states reported by this utility are as follows:

- **NO_CONTACT**: The node cannot be contacted.
- **UNKNOWN**: The node can be contacted, but its status is not yet known. Usually, this means that the node has received a `START` or `RESTART` command from the management server, but has not yet acted on it.
- **NOT_STARTED**: The node has stopped, but remains in contact with the cluster. This is seen when restarting the node using the management client's `RESTART` command.
- **STARTING**: The node's `ndbd` process has started, but the node has not yet joined the cluster.
- **STARTED**: The node is operational, and has joined the cluster.
- **SHUTTING_DOWN**: The node is shutting down.
- **SINGLE_USER_MODE**: This is shown for all cluster data nodes when the cluster is in single user mode.
The following table includes options that are specific to the NDB Cluster native backup restoration program \texttt{ndb\_waiter}. Additional descriptions follow the table. For options common to most NDB Cluster programs (including \texttt{ndb\_waiter}), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.245 Command-line options for the \texttt{ndb\_waiter} program

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{--no-contact, -n}</td>
<td>Wait for cluster to reach NO CONTACT state</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>\texttt{--not-started}</td>
<td>Wait for cluster to reach NOT STARTED state</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>\texttt{--single-user}</td>
<td>Wait for cluster to enter single user mode</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>\texttt{--timeout=#, -t}</td>
<td>Wait this many seconds, then exit whether or not cluster has reached desired state; default is 2 minutes (120 seconds)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>\texttt{--nowait-nodes=list}</td>
<td>List of nodes not to be waited for</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>\texttt{--wait-nodes=list, -w}</td>
<td>List of nodes to be waited for</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

Usage

\texttt{ndb\_waiter [-c connection\_string]}

Additional Options

- \texttt{--no-contact, -n}

Instead of waiting for the \texttt{STARTED} state, \texttt{ndb\_waiter} continues running until the cluster reaches \texttt{NO\_CONTACT} status before exiting.

- \texttt{--not-started}

Instead of waiting for the \texttt{STARTED} state, \texttt{ndb\_waiter} continues running until the cluster reaches \texttt{NOT\_STARTED} status before exiting.

- \texttt{--timeout=seconds, -t seconds}

Time to wait. The program exits if the desired state is not achieved within this number of seconds. The default is 120 seconds (1200 reporting cycles).

- \texttt{--single-user}

The program waits for the cluster to enter single user mode.

- \texttt{--nowait-nodes=list}

When this option is used, \texttt{ndb\_waiter} does not wait for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:
ndb_waiter — Wait for NDB Cluster to Reach a Given Status

<table>
<thead>
<tr>
<th>Important</th>
</tr>
</thead>
</table>

Do not use this option together with the `--wait-nodes` option.

- `--wait-nodes=list, -w list`

When this option is used, `ndb_waiter` waits only for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:

```
shell> ndb_waiter --wait-nodes=2,4-6,10
```

<table>
<thead>
<tr>
<th>Important</th>
</tr>
</thead>
</table>

Do not use this option together with the `--nowait-nodes` option.

**Sample Output.** Shown here is the output from `ndb_waiter` when run against a 4-node cluster in which two nodes have been shut down and then started again manually. Duplicate reports (indicated by ...) are omitted.

```
shell> ./ndb_waiter -c localhost

Connecting to mgmsrv at (localhost)
State node 1 STARTED
State node 2 NO_CONTACT
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED
...
State node 1 STARTED
State node 2 UNKNOWN
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED
...
State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED
...
State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 UNKNOWN
Waiting for cluster enter state STARTED
...
State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED
...
```

2436
... State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED
...
State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTED
Waiting for cluster enter state STARTED
NDBT_ProgramExit: 0 - OK

Note
If no connection string is specified, then ndb_waiter tries to connect to a management on localhost, and reports Connecting to mgmsrv at (null).

18.4.27 Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs

All NDB Cluster programs accept the options described in this section, with the following exceptions:

- **mysqld**
- **ndb_print_backup_file**
- **ndb_print_schema_file**
- **ndb_print_sys_file**

Users of earlier NDB Cluster versions should note that some of these options have been changed to make them consistent with one another as well as with mysqld. You can use the `--help` option with any NDB Cluster program—with the exception of ndb_print_backup_file, ndb_print_schema_file, and ndb_print_sys_file—to view a list of the options which the program supports.

The options in the following table are common to all NDB Cluster executables (except those noted previously in this section).

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Added, Deprecated, or Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>--character-sets-dir=dir_name</td>
<td>Directory where character sets are installed</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--core-file</td>
<td>Write core on errors (defaults to TRUE in debug builds)</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--debug=options</td>
<td>Enable output from debug calls. Can be used only for versions compiled with debugging enabled</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--defaults-extra-file=filename</td>
<td>Read this file after global option files are read</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>Format</td>
<td>Description</td>
<td>Added, Deprecated, or Removed</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>--defaults-file=filename</td>
<td>Read default options from this file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--help, --usage, -?</td>
<td>Display help message and exit</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--ndb-connectstring=connectstring</td>
<td>Set connection string for connecting to ndb_mgmd. Syntax: [nodeid=&lt;id&gt;]; [host=&lt;hostname&gt;[:&lt;port&gt;]. Overrides entries specified in NDB_CONNECTSTRING or my.cnf</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--connect-string=connectstring, -c</td>
<td>Set connection string for connecting to ndb_mgmd. Syntax: [nodeid=&lt;id&gt;]; [host=&lt;hostname&gt;[:&lt;port&gt;]. Overrides entries specified in NDB_CONNECTSTRING or my.cnf</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--ndb-mgmd-host=host[:port]</td>
<td>Set the host (and port, if desired) for connecting to management server</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--ndb-nodeid=#</td>
<td>Set node id for this node</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--ndb-optimized-node-selection</td>
<td>Select nodes for transactions in a more optimal way</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--no-defaults</td>
<td>Do not read default options from any option file other than login file</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--print-defaults</td>
<td>Print the program argument list and exit</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
<tr>
<td>--version, -V</td>
<td>Output version information and exit</td>
<td>(Supported in all MySQL 5.5 based releases)</td>
</tr>
</tbody>
</table>

For options specific to individual NDB Cluster programs, see Section 18.4, “NDB Cluster Programs”. See MySQL Server Options for NDB Cluster, for mysql options relating to NDB Cluster.

- **--character-sets-dir=**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--character-sets-dir=dir_name</td>
</tr>
<tr>
<td>Type</td>
<td>Directory name</td>
</tr>
</tbody>
</table>

Tells the program where to find character set information.

- **--core-file**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--core-file</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
</tbody>
</table>
Write a core file if the program dies. The name and location of the core file are system-dependent. (For NDB Cluster programs nodes running on Linux, the default location is the program's working directory— for a data node, this is the node's `DataDir`.) For some systems, there may be restrictions or limitations. For example, it might be necessary to execute `ulimit -c unlimited` before starting the server. Consult your system documentation for detailed information.

If NDB Cluster was built using the `--debug` option for `configure`, then `--core-file` is enabled by default. For regular builds, `--core-file` is disabled by default.

- `--debug[=options]`

This option can be used only for versions compiled with debugging enabled. It is used to enable output from debug calls in the same manner as for the `mysqld` process.

- `--defaults-extra-file=filename`

Read this file after global option files are read.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- `--defaults-file=filename`

Read default options from this file.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- `--help, --usage, -?`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--help</code></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--help</code></td>
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</tbody>
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Prints a short list with descriptions of the available command options.

- `--usage`

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<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--ndb-connectstring=connection_string</code></td>
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<tr>
<td></td>
<td><code>--connect-string=connection_string</code></td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>localhost:1186</code></td>
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</tbody>
</table>

This option takes an NDB Cluster connection string that specifies the management server for the application to connect to, as shown here:

```shell
ndbd --ndb-connectstring="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

For more information, see Section 18.3.3.3, “NDB Cluster Connection Strings”.

- `--ndb-mgmd-host=host[:port]`

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<tr>
<td>Command-Line Format</td>
<td><code>--ndb-mgmd-host=host[:port]</code></td>
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<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>Default Value</td>
<td><code>localhost:1186</code></td>
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</table>

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

- `--ndb-nodeid=#`

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<tr>
<td>Command-Line Format</td>
<td><code>--ndb-nodeid=#</code></td>
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<tr>
<td>Type</td>
<td>Numeric</td>
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<tr>
<td>Default Value</td>
<td>0</td>
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Sets this node's NDB Cluster node ID. The range of permitted values depends on the node's type (data, management, or API) and the NDB Cluster software version. See Section 18.1.7.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”, for more information.

- `--no-defaults`

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<tr>
<td>Type</td>
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**18.5 Management of NDB Cluster**

Managing an NDB Cluster involves a number of tasks, the first of which is to configure and start NDB Cluster. This is covered in Section 18.3, “Configuration of NDB Cluster”, and Section 18.4, “NDB Cluster Programs”.

The next few sections cover the management of a running NDB Cluster.

For information about security issues relating to management and deployment of an NDB Cluster, see Section 18.5.11, “NDB Cluster Security Issues”.

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### Management of NDB Cluster

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<td>Default Value</td>
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Do not read default options from any option file other than login file.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--ndb-optimized-node-selection**

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Optimize selection of nodes for transactions. Enabled by default.

- **--print-defaults**

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<td>Default Value</td>
<td>TRUE</td>
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Print the program argument list and exit.

For additional information about this and other option-file options, see Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”.

- **--version, -V**

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Prints the NDB Cluster version number of the executable. The version number is relevant because not all versions can be used together, and the NDB Cluster startup process verifies that the versions of the binaries being used can co-exist in the same cluster. This is also important when performing an online (rolling) software upgrade or downgrade of NDB Cluster.

See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”), for more information.
There are essentially two methods of actively managing a running NDB Cluster. The first of these is through the use of commands entered into the management client whereby cluster status can be checked, log levels changed, backups started and stopped, and nodes stopped and started. The second method involves studying the contents of the cluster log

```
ndb_node_id_cluster.log
```

This is usually found in the management server's `DataDir` directory, but this location can be overridden using the `LogDestination` option. (Recall that `node_id` represents the unique identifier of the node whose activity is being logged.) The cluster log contains event reports generated by `ndbd`. It is also possible to send cluster log entries to a Unix system log.

Some aspects of the cluster's operation can be also be monitored from an SQL node using the `SHOW ENGINE NDB STATUS` statement.

More detailed information about NDB Cluster operations is available in real time through an SQL interface using the `ndbinfo` database. For more information, see Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

NDB statistics counters provide improved monitoring using the `mysql` client. These counters, implemented in the NDB kernel, relate to operations performed by or affecting `Ndb` objects, such as starting, closing, and aborting transactions; primary key and unique key operations; table, range, and pruned scans; blocked threads waiting for various operations to complete; and data and events sent and received by NDB Cluster. The counters are incremented by the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes.

`mysql` exposes the NDB API statistics counters as system status variables, which can be identified from the prefix common to all of their names (`Ndb_api_`). The values of these variables can be read in the `mysql` client from the output of a `SHOW STATUS` statement, or by querying either the `SESSION_STATUS` table or the `GLOBAL_STATUS` table (in the `INFORMATION_SCHEMA` database). By comparing the values of the status variables before and after the execution of an SQL statement that acts on `NDB` tables, you can observe the actions taken on the NDB API level that correspond to this statement, which can be beneficial for monitoring and performance tuning of NDB Cluster.

MySQL Cluster Manager provides an advanced command-line interface that simplifies many otherwise complex NDB Cluster management tasks, such as starting, stopping, or restarting an NDB Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as `mysqld` server options and variables relating to NDB Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

### 18.5.1 Summary of NDB Cluster Start Phases

This section provides a simplified outline of the steps involved when NDB Cluster data nodes are started. More complete information can be found in NDB Cluster Start Phases, in the NDB Internals Guide.

These phases are the same as those reported in the output from the `node_id STATUS` command in the management client (see Section 18.5.2, “Commands in the NDB Cluster Management Client”). These start phases are also reported in the `start_phase` column of the `ndbinfo.nodes` table.

**Start types.** There are several different startup types and modes, as shown in the following list:

- **Initial start.** The cluster starts with a clean file system on all data nodes. This occurs either when the cluster started for the very first time, or when all data nodes are restarted using the `--initial` option.

  **Note**
  
  Disk Data files are not removed when restarting a node using `--initial`.
Summary of NDB Cluster Start Phases

• **System restart.**  The cluster starts and reads data stored in the data nodes. This occurs when the cluster has been shut down after having been in use, when it is desired for the cluster to resume operations from the point where it left off.

• **Node restart.**  This is the online restart of a cluster node while the cluster itself is running.

• **Initial node restart.**  This is the same as a node restart, except that the node is reinitialized and started with a clean file system.

**Setup and initialization (phase -1).**  Prior to startup, each data node (ndbd process) must be initialized. Initialization consists of the following steps:

1. Obtain a node ID
2. Fetch configuration data
3. Allocate ports to be used for inter-node communications
4. Allocate memory according to settings obtained from the configuration file

When a data node or SQL node first connects to the management node, it reserves a cluster node ID. To make sure that no other node allocates the same node ID, this ID is retained until the node has managed to connect to the cluster and at least one ndbd reports that this node is connected. This retention of the node ID is guarded by the connection between the node in question and ndb_mgmd.

After each data node has been initialized, the cluster startup process can proceed. The stages which the cluster goes through during this process are listed here:

• **Phase 0.**  The NDBFS and NDBCNTR blocks start (see NDB Kernel Blocks). Data node file systems are cleared on those data nodes that were started with **--initial** option.

• **Phase 1.**  In this stage, all remaining NDB kernel blocks are started. NDB Cluster connections are set up, inter-block communications are established, and heartbeats are started. In the case of a node restart, API node connections are also checked.

  **Note**  
  When one or more nodes hang in Phase 1 while the remaining node or nodes hang in Phase 2, this often indicates network problems. One possible cause of such issues is one or more cluster hosts having multiple network interfaces. Another common source of problems causing this condition is the blocking of TCP/IP ports needed for communications between cluster nodes. In the latter case, this is often due to a misconfigured firewall.

• **Phase 2.**  The NDBCNTR kernel block checks the states of all existing nodes. The master node is chosen, and the cluster schema file is initialized.

• **Phase 3.**  The DBLQH and DBTC kernel blocks set up communications between them. The startup type is determined; if this is a restart, the DBDIH block obtains permission to perform the restart.

• **Phase 4.**  For an initial start or initial node restart, the redo log files are created. The number of these files is equal to NoOfFragmentLogFiles.

For a system restart:

• Read schema or schemas.

• Read data from the local checkpoint.
• Apply all redo information until the latest restorable global checkpoint has been reached.

For a node restart, find the tail of the redo log.

• **Phase 5.** Most of the database-related portion of a data node start is performed during this phase. For an initial start or system restart, a local checkpoint is executed, followed by a global checkpoint. Periodic checks of memory usage begin during this phase, and any required node takeovers are performed.

• **Phase 6.** In this phase, node groups are defined and set up.

• **Phase 7.** The arbitrator node is selected and begins to function. The next backup ID is set, as is the backup disk write speed. Nodes reaching this start phase are marked as *Started*. It is now possible for API nodes (including SQL nodes) to connect to the cluster.

• **Phase 8.** If this is a system restart, all indexes are rebuilt (by **DBDIH**).

• **Phase 9.** The node internal startup variables are reset.

• **Phase 100 (OBSOLETE).** Formerly, it was at this point during a node restart or initial node restart that API nodes could connect to the node and begin to receive events. Currently, this phase is empty.

• **Phase 101.** At this point in a node restart or initial node restart, event delivery is handed over to the node joining the cluster. The newly-joined node takes over responsibility for delivering its primary data to subscribers. This phase is also referred to as **SUMA handover phase**.

After this process is completed for an initial start or system restart, transaction handling is enabled. For a node restart or initial node restart, completion of the startup process means that the node may now act as a transaction coordinator.

### 18.5.2 Commands in the NDB Cluster Management Client

In addition to the central configuration file, a cluster may also be controlled through a command-line interface available through the management client **ndb_mgm**. This is the primary administrative interface to a running cluster.

Commands for the event logs are given in [Section 18.5.6, “Event Reports Generated in NDB Cluster”](#); commands for creating backups and restoring from them are provided in [Section 18.5.3, “Online Backup of NDB Cluster”](#).

**Using ndb_mgm with MySQL Cluster Manager.** MySQL Cluster Manager handles starting and stopping processes and tracks their states internally, so it is not necessary to use **ndb_mgm** for these tasks for an NDB Cluster that is under MySQL Cluster Manager control. It is recommended not to use the **ndb_mgm** command-line client that comes with the NDB Cluster distribution to perform operations that involve starting or stopping nodes. These include but are not limited to the **START**, **STOP**, **RESTART**, and **SHUTDOWN** commands. For more information, see [MySQL Cluster Manager Process Commands](#).

The management client has the following basic commands. In the listing that follows, **node_id** denotes either a storage node ID or the keyword **ALL**, which indicates that the command should be applied to all of the cluster’s data nodes.

• **HELP**

  Displays information on all available commands.

• **CONNECT connection-string**

  Connects to the management server indicated by the connection string. If the client is already connected to this server, the client reconnects.
• **SHOW**

Displays information on the cluster's status. Possible node status values include **UNKNOWN**, **NO_CONTACT**, **NOT_STARTED**, **STARTING**, **STARTED**, **SHUTTING_DOWN**, and **RESTARTING**. The output from this command also indicates when the cluster is in single user mode (status **SINGLE USER MODE**).

• **node_id START**

Brings online the data node identified by `node_id` (or all data nodes).

**ALL START** works on all data nodes only, and does not affect management nodes.

**Important**

To use this command to bring a data node online, the data node must have been started using **--nostart** or **-n**.

• **node_id STOP [-a] [-f]**

Stop the data or management node identified by `node_id`.

**Note**

**ALL STOP** works to stop all data nodes only, and does not affect management nodes.

A node affected by this command disconnects from the cluster, and its associated `ndbd` or `ndb_mgmd` process terminates.

The **-a** option causes the node to be stopped immediately, without waiting for the completion of any pending transactions.

Normally, **STOP** fails if the result would cause an incomplete cluster. The **-f** option forces the node to shut down without checking for this. If this option is used and the result is an incomplete cluster, the cluster immediately shuts down.

**Warning**

Use of the **-a** option also disables the safety check otherwise performed when **STOP** is invoked to insure that stopping the node does not cause an incomplete cluster. In other words, you should exercise extreme care when using the **-a** option with the **STOP** command, due to the fact that this option makes it possible for the cluster to undergo a forced shutdown because it no longer has a complete copy of all data stored in **NDB**.
Commands in the NDB Cluster Management Client

- **node_id** RESTART [-n] [-i] [-a] [-f]

  Restarts the data node identified by **node_id** (or all data nodes).

  Using the `-i` option with **RESTART** causes the data node to perform an initial restart; that is, the node's file system is deleted and recreated. The effect is the same as that obtained from stopping the data node process and then starting it again using `ndbd --initial` from the system shell.

  **Note**
  Backup files and Disk Data files are not removed when this option is used.

  Using the `-n` option causes the data node process to be restarted, but the data node is not actually brought online until the appropriate **START** command is issued. The effect of this option is the same as that obtained from stopping the data node and then starting it again using `ndbd --nostart` or `ndbd -n` from the system shell.

  Using the `-a` causes all current transactions relying on this node to be aborted. No GCP check is done when the node rejoins the cluster.

  Normally, **RESTART** fails if taking the node offline would result in an incomplete cluster. The `-f` option forces the node to restart without checking for this. If this option is used and the result is an incomplete cluster, the entire cluster is restarted.

- **node_id** STATUS

  Displays status information for the data node identified by **node_id** (or for all data nodes).

  The output from this command also indicates when the cluster is in single user mode.

- **node_id** REPORT report-type

  Displays a report of type **report-type** for the data node identified by **node_id**, or for all data nodes using **ALL**.

  Currently, there are three accepted values for **report-type**:

  - **BackupStatus** provides a status report on a cluster backup in progress
  - **MemoryUsage** displays how much data memory and index memory is being used by each data node as shown in this example:

    ```
    ndb_mgm> ALL REPORT MEMORY
    Node 1: Data usage is 5%(177 32K pages of total 3200)
    Node 1: Index usage is 0%(108 8K pages of total 12832)
    Node 2: Data usage is 5%(177 32K pages of total 3200)
    ```
Node 2: Index usage is 0% (108 8K pages of total 12832)

This information is also available from the `ndbinfo.memoryusage` table.

- **EventLog** reports events from the event log buffers of one or more data nodes.

`report-type` is case-insensitive and “fuzzy”; for `MemoryUsage`, you can use `MEMORY` (as shown in the prior example), `memory`, or even simply `MEM` (or `mem`). You can abbreviate `BackupStatus` in a similar fashion.

Prior to NDB 7.2.10, `ALL REPORT BackupStatus` did not work correctly with multithreaded data nodes. (Bug #15908907)

- **ENTER SINGLE USER MODE node_id**

Enters single user mode, whereby only the MySQL server identified by the node ID `node_id` is permitted to access the database.

- **EXIT SINGLE USER MODE**

Exits single user mode, enabling all SQL nodes (that is, all running `mysqld` processes) to access the database.

**Note**

It is possible to use `EXIT SINGLE USER MODE` even when not in single user mode, although the command has no effect in this case.

- **QUIT, EXIT**

Terminates the management client.

This command does not affect any nodes connected to the cluster.

- **SHUTDOWN**

Shuts down all cluster data nodes and management nodes. To exit the management client after this has been done, use `EXIT` or `QUIT`.

This command does not shut down any SQL nodes or API nodes that are connected to the cluster.

- **CREATE NODEGROUP nodeid[, nodeid, ...]**

Creates a new NDB Cluster node group and causes data nodes to join it.

This command is used after adding new data nodes online to an NDB Cluster, and causes them to join a new node group and thus to begin participating fully in the cluster. The command takes as its sole parameter a comma-separated list of node IDs—these are the IDs of the nodes just added and started that are to join the new node group. The number of nodes must be the same as the number of nodes in each node group that is already part of the cluster (each NDB Cluster node group must have the same number of nodes). In other words, if the NDB Cluster has 2 node groups of 2 data nodes each, then the new node group must also have 2 data nodes.

The node group ID of the new node group created by this command is determined automatically, and always the next highest unused node group ID in the cluster; it is not possible to set it manually.

For more information, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.
Online Backup of NDB Cluster

- **DROP NODEGROUP nodegroup_id**

Drops the NDB Cluster node group with the given `nodegroup_id`.

This command can be used to drop a node group from an NDB Cluster. **DROP NODEGROUP** takes as its sole argument the node group ID of the node group to be dropped.

**DROP NODEGROUP** acts only to remove the data nodes in the effected node group from that node group. It does not stop data nodes, assign them to a different node group, or remove them from the cluster's configuration. A data node that does not belong to a node group is indicated in the output of the management client **SHOW** command with `no nodegroup` in place of the node group ID, like this (indicated using bold text):

```
id=3 010.100.2.67 (5.5.65-ndb-7.2.39, no nodegroup)
```

Prior to NDB 7.0.4, the **SHOW** output was not updated correctly following **DROP NODEGROUP**. (Bug #43413)

**DROP NODEGROUP** works only when all data nodes in the node group to be dropped are completely empty of any table data and table definitions. Since there is currently no way using **ndb_mgm** or the **mysql** client to remove all data from a specific data node or node group, this means that the command succeeds only in the two following cases:

1. After issuing **CREATE NODEGROUP** in the **ndb_mgm** client, but before issuing any **ALTER ONLINE TABLE ... REORGANIZE PARTITION** statements in the **mysql** client.
2. After dropping all **NDBCLUSTER** tables using **DROP TABLE**.

**TRUNCATE TABLE** does not work for this purpose because this removes only the table data; the data nodes continue to store an **NDBCLUSTER** table's definition until a **DROP TABLE** statement is issued that causes the table metadata to be dropped.

For more information about **DROP NODEGROUP**, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

**Additional commands.** A number of other commands available in the **ndb_mgm** client are described elsewhere, as shown in the following list:

- **START BACKUP** is used to perform an online backup in the **ndb_mgm** client; the **ABORT BACKUP** command is used to cancel a backup already in progress. For more information, see Section 18.5.3, “Online Backup of NDB Cluster”.

- The **CLUSTERLOG** command is used to perform various logging functions. See Section 18.5.6, “Event Reports Generated in NDB Cluster”, for more information and examples.

- For testing and diagnostics work, the client also supports a **DUMP** command which can be used to execute internal commands on the cluster. It should never be used in a production setting unless directed to do so by MySQL Support. For more information, see MySQL NDB Cluster Internals Manual.

### 18.5.3 Online Backup of NDB Cluster

The next few sections describe how to prepare for and then to create an NDB Cluster backup using the functionality for this purpose found in the **ndb_mgm** management client. To distinguish this type of backup from a backup made using **mysqldump**, we sometimes refer to it as a “native” NDB Cluster backup. (For information about the creation of backups with **mysqldump**, see Section 4.5.4, “mysqldump — A Database Backup Program”). Restoration of NDB Cluster backups is done using the **ndb_restore** utility
Online Backup of NDB Cluster

provided with the NDB Cluster distribution; for information about ndb_restore and its use in restoring NDB Cluster backups, see Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”.

18.5.3.1 NDB Cluster Backup Concepts

A backup is a snapshot of the database at a given time. The backup consists of three main parts:

- **Metadata.** The names and definitions of all database tables
- **Table records.** The data actually stored in the database tables at the time that the backup was made
- **Transaction log.** A sequential record telling how and when data was stored in the database

Each of these parts is saved on all nodes participating in the backup. During backup, each node saves these three parts into three files on disk:

- **BACKUP-backup_id.node_id.ctl**
  A control file containing control information and metadata. Each node saves the same table definitions (for all tables in the cluster) to its own version of this file.

- **BACKUP-backup_id-0.node_id.data**
  A data file containing the table records, which are saved on a per-fragment basis. That is, different nodes save different fragments during the backup. The file saved by each node starts with a header that states the tables to which the records belong. Following the list of records there is a footer containing a checksum for all records.

- **BACKUP-backup_id.node_id.log**
  A log file containing records of committed transactions. Only transactions on tables stored in the backup are stored in the log. Nodes involved in the backup save different records because different nodes host different database fragments.

In the listing just shown, `backup_id` stands for the backup identifier and `node_id` is the unique identifier for the node creating the file.

The location of the backup files is determined by the `BackupDataDir` parameter.

18.5.3.2 Using The NDB Cluster Management Client to Create a Backup

Before starting a backup, make sure that the cluster is properly configured for performing one. (See Section 18.5.3.3, “Configuration for NDB Cluster Backups”.)

The `START BACKUP` command is used to create a backup:

```
START BACKUP [backup_id] [wait_option] [snapshot_option]
```

**wait_option:**

WAIT (STARTED | COMPLETED) | NOWAIT

**snapshot_option:**

SNAPSHOTSTART | SNAPSHOTEND

Successive backups are automatically identified sequentially, so the `backup_id`, an integer greater than or equal to 1, is optional; if it is omitted, the next available value is used. If an existing `backup_id` value is used, the backup fails with the error `Backup failed: file already exists`. If used, the `backup_id` must follow `START BACKUP` immediately, before any other options are used.
Online Backup of NDB Cluster

The `wait_option` can be used to determine when control is returned to the management client after a `START BACKUP` command is issued, as shown in the following list:

- If `NOWAIT` is specified, the management client displays a prompt immediately, as seen here:

  ```
  ndb_mgm> START BACKUP NOWAIT
  ndb_mgm>
  ```

  In this case, the management client can be used even while it prints progress information from the backup process.

- With `WAIT STARTED` the management client waits until the backup has started before returning control to the user, as shown here:

  ```
  ndb_mgm> START BACKUP WAIT STARTED
  Waiting for started, this may take several minutes
  Node 2: Backup 3 started from node 1
  ndb_mgm>
  ```

- `WAIT COMPLETED` causes the management client to wait until the backup process is complete before returning control to the user.

  `WAIT COMPLETED` is the default.

A `snapshot_option` can be used to determine whether the backup matches the state of the cluster when `START BACKUP` was issued, or when it was completed. `SNAPSHOTSTART` causes the backup to match the state of the cluster when the backup began; `SNAPSHOTEND` causes the backup to reflect the state of the cluster when the backup was finished. `SNAPSHOTEND` is the default, and matches the behavior found in previous NDB Cluster releases.

**Note**

If you use the `SNAPSHOTSTART` option with `START BACKUP`, and the `CompressedBackup` parameter is enabled, only the data and control files are compressed—the log file is not compressed.

If both a `wait_option` and a `snapshot_option` are used, they may be specified in either order. For example, all of the following commands are valid, assuming that there is no existing backup having 4 as its ID:

```
START BACKUP WAIT STARTED SNAPSHOTSTART
START BACKUP SNAPSHOTSTART WAIT STARTED
START BACKUP 4 WAIT COMPLETED SNAPSHOTSTART
START BACKUP SNAPSHOTEND WAIT COMPLETED
START BACKUP 4 NOWAIT SNAPSHOTSTART
```

The procedure for creating a backup consists of the following steps:

1. Start the management client (`ndb_mgm`), if it not running already.

2. Execute the `START BACKUP` command. This produces several lines of output indicating the progress of the backup, as shown here:

  ```
  ndb_mgm> START BACKUP
  Waiting for completed, this may take several minutes
  Node 2: Backup 1 started from node 1
  Node 2: Backup 1 started from node 1 completed
  StartGCP: 177 StopGCP: 180
  #Records: 7362 #LogRecords: 0
  Data: 453648 bytes Log: 0 bytes
  ndb_mgm>
  ```
3. When the backup has started the management client displays this message:

```
Backup backup_id started from node node_id
```

`backup_id` is the unique identifier for this particular backup. This identifier is saved in the cluster log, if it has not been configured otherwise. `node_id` is the identifier of the management server that is coordinating the backup with the data nodes. At this point in the backup process the cluster has received and processed the backup request. It does not mean that the backup has finished. An example of this statement is shown here:

```
Node 2: Backup 1 started from node 1
```

4. The management client indicates with a message like this one that the backup has started:

```
Backup backup_id started from node node_id completed
```

As is the case for the notification that the backup has started, `backup_id` is the unique identifier for this particular backup, and `node_id` is the node ID of the management server that is coordinating the backup with the data nodes. This output is accompanied by additional information including relevant global checkpoints, the number of records backed up, and the size of the data, as shown here:

```
Node 2: Backup 1 started from node 1 completed
StartGCP: 177 StopGCP: 180
#Records: 7362 #LogRecords: 0
Data: 453648 bytes Log: 0 bytes
```

It is also possible to perform a backup from the system shell by invoking `ndb_mgm` with the `-e` or `--execute` option, as shown in this example:

```
shell> ndb_mgm -e "START BACKUP 6 WAIT COMPLETED SNAPSHOTSTART"
```

When using `START BACKUP` in this way, you must specify the backup ID.

Cluster backups are created by default in the `BACKUP` subdirectory of the `DataDir` on each data node. This can be overridden for one or more data nodes individually, or for all cluster data nodes in the `config.ini` file using the `BackupDataDir` configuration parameter. The backup files created for a backup with a given `backup_id` are stored in a subdirectory named `BACKUP-backup_id` in the backup directory.

**Cancelling backups.** To cancel or abort a backup that is already in progress, perform the following steps:

1. Start the management client.
2. Execute this command:

```
ndb_mgm> ABORT BACKUP backup_id
```

The number `backup_id` is the identifier of the backup that was included in the response of the management client when the backup was started (in the message `Backup backup_id started from node management_node_id`).

3. The management client will acknowledge the abort request with `Abort of backup backup_id ordered`.

**Note**

At this point, the management client has not yet received a response from the cluster data nodes to this request, and the backup has not yet actually been aborted.
Online Backup of NDB Cluster

4. After the backup has been aborted, the management client will report this fact in a manner similar to what is shown here:

<table>
<thead>
<tr>
<th>Node 1: Backup 3 started from 5 has been aborted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error: 1321 - Backup aborted by user request: Permanent error: User defined error</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Node 3: Backup 3 started from 5 has been aborted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error: 1323 - 1323: Permanent error: Internal error</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Node 2: Backup 3 started from 5 has been aborted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error: 1323 - 1323: Permanent error: Internal error</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Node 4: Backup 3 started from 5 has been aborted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error: 1323 - 1323: Permanent error: Internal error</td>
</tr>
</tbody>
</table>

In this example, we have shown sample output for a cluster with 4 data nodes, where the sequence number of the backup to be aborted is 3, and the management node to which the cluster management client is connected has the node ID 5. The first node to complete its part in aborting the backup reports that the reason for the abort was due to a request by the user. (The remaining nodes report that the backup was aborted due to an unspecified internal error.)

Note

There is no guarantee that the cluster nodes respond to an ABORT BACKUP command in any particular order.

The Backup backup_id started from node management_node_id has been aborted messages mean that the backup has been terminated and that all files relating to this backup have been removed from the cluster file system.

It is also possible to abort a backup in progress from a system shell using this command:

```
shell> ndb_mgm -e "ABORT BACKUP backup_id"
```

Note

If there is no backup having the ID backup_id running when an ABORT BACKUP is issued, the management client makes no response, nor is it indicated in the cluster log that an invalid abort command was sent.

18.5.3.3 Configuration for NDB Cluster Backups

Five configuration parameters are essential for backup:

- **BackupDataBufferSize**
  The amount of memory used to buffer data before it is written to disk.

- **BackupLogBufferSize**
  The amount of memory used to buffer log records before these are written to disk.

- **BackupMemory**
  The total memory allocated in a data node for backups. This should be the sum of the memory allocated for the backup data buffer and the backup log buffer.

- **BackupWriteSize**
  The default size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

- **BackupMaxWriteSize**
The maximum size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

More detailed information about these parameters can be found in Backup Parameters.

You can also set a location for the backup files using the BackupDataDir configuration parameter. The default is FileSystemPath /BACKUP/BACKUP-backup_id.

18.5.3.4 NDB Cluster Backup Troubleshooting

If an error code is returned when issuing a backup request, the most likely cause is insufficient memory or disk space. You should check that there is enough memory allocated for the backup.

Important

If you have set BackupDataBufferSize and BackupLogBufferSize and their sum is greater than 4MB, then you must also set BackupMemory as well.

You should also make sure that there is sufficient space on the hard drive partition of the backup target.

NDB does not support repeatable reads, which can cause problems with the restoration process. Although the backup process is “hot”, restoring an NDB Cluster from backup is not a 100% “hot” process. This is due to the fact that, for the duration of the restore process, running transactions get nonrepeatable reads from the restored data. This means that the state of the data is inconsistent while the restore is in progress.

18.5.4 MySQL Server Usage for NDB Cluster

mysqld is the traditional MySQL server process. To be used with NDB Cluster, mysqld needs to be built with support for the NDB storage engine, as it is in the precompiled binaries available from https://dev.mysql.com/downloads/. If you build MySQL from source, you must invoke CMake with the --DWITH_NDBCLUSTER=1 option to include support for NDB.

For more information about compiling NDB Cluster from source, see Section 18.2.1.4, “Building NDB Cluster from Source on Linux”, and Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”.

(For information about mysqld options and variables, in addition to those discussed in this section, which are relevant to NDB Cluster, see Section 18.3.3.8, “MySQL Server Options and Variables for NDB Cluster”.)

If the mysqld binary has been built with Cluster support, the NDBCLUSTER storage engine is still disabled by default. You can use either of two possible options to enable this engine:

• Use --ndbcluster as a startup option on the command line when starting mysqld.
• Insert a line containing ndbcluster in the [mysqld] section of your my.cnf file.

An easy way to verify that your server is running with the NDBCLUSTER storage engine enabled is to issue the SHOW ENGINES statement in the MySQL Monitor (mysql). You should see the value YES as the Support value in the row for NDBCLUSTER. If you see NO in this row or if there is no such row displayed in the output, you are not running an NDB-enabled version of MySQL. If you see DISABLED in this row, you need to enable it in either one of the two ways just described.

To read cluster configuration data, the MySQL server requires at a minimum three pieces of information:

• The MySQL server’s own cluster node ID
• The host name or IP address for the management server (MGM node)
Performing a Rolling Restart of an NDB Cluster

- The number of the TCP/IP port on which it can connect to the management server

Node IDs can be allocated dynamically, so it is not strictly necessary to specify them explicitly.

The `mysqld` parameter `ndb-connectstring` is used to specify the connection string either on the command line when starting `mysqld` or in `my.cnf`. The connection string contains the host name or IP address where the management server can be found, as well as the TCP/IP port it uses.

In the following example, `ndb_mgmd.mysql.com` is the host where the management server resides, and the management server listens for cluster messages on port 1186:

```
shell> mysqld --ndbcluster --ndb-connectstring=ndb_mgmd.mysql.com:1186
```

See Section 18.3.3.3, “NDB Cluster Connection Strings”, for more information on connection strings.

Given this information, the MySQL server will be a full participant in the cluster. (We often refer to a `mysqld` process running in this manner as an SQL node.) It will be fully aware of all cluster data nodes as well as their status, and will establish connections to all data nodes. In this case, it is able to use any data node as a transaction coordinator and to read and update node data.

You can see in the `mysql` client whether a MySQL server is connected to the cluster using `SHOW PROCESSLIST`. If the MySQL server is connected to the cluster, and you have the `PROCESS` privilege, then the first row of the output is as shown here:

```
mysql> SHOW PROCESSLIST \G
*************************** 1. row ***************************
    Id: 1
    User: system user
    Host: db:
    Command: Daemon
    db:
    Time: 1
    State: Waiting for event from ndbcluster
    Info: NULL
```

---

**Important**

To participate in an NDB Cluster, the `mysqld` process must be started with both the options `--ndbcluster` and `--ndb-connectstring` (or their equivalents in `my.cnf`). If `mysqld` is started with only the `--ndbcluster` option, or if it is unable to contact the cluster, it is not possible to work with NDB tables, nor is it possible to create any new tables regardless of storage engine. The latter restriction is a safety measure intended to prevent the creation of tables having the same names as NDB tables while the SQL node is not connected to the cluster. If you wish to create tables using a different storage engine while the `mysqld` process is not participating in an NDB Cluster, you must restart the server without the `--ndbcluster` option.

---

18.5.5 Performing a Rolling Restart of an NDB Cluster

This section discusses how to perform a rolling restart of an NDB Cluster installation, so called because it involves stopping and starting (or restarting) each node in turn, so that the cluster itself remains operational. This is often done as part of a rolling upgrade or rolling downgrade, where high availability of the cluster is mandatory and no downtime of the cluster as a whole is permissible. Where we refer to upgrades, the information provided here also generally applies to downgrades as well.

There are a number of reasons why a rolling restart might be desirable. These are described in the next few paragraphs.

**Configuration change.**
Performing a Rolling Restart of an NDB Cluster

To make a change in the cluster’s configuration, such as adding an SQL node to the cluster, or setting a configuration parameter to a new value.

**NDB Cluster software upgrade or downgrade.** To upgrade the cluster to a newer version of the NDB Cluster software (or to downgrade it to an older version). This is usually referred to as a “rolling upgrade” (or “rolling downgrade”, when reverting to an older version of NDB Cluster).

**Change on node host.** To make changes in the hardware or operating system on which one or more NDB Cluster node processes are running.

**System reset (cluster reset).** To reset the cluster because it has reached an undesirable state. In such cases it is often desirable to reload the data and metadata of one or more data nodes. This can be done in any of three ways:

- Start each data node process (ndbd or possibly ndbmtd) with the `--initial` option, which forces the data node to clear its file system and to reload all NDB Cluster data and metadata from the other data nodes.

- Create a backup using the ndb_mgm client `START_BACKUP` command prior to performing the restart. Following the upgrade, restore the node or nodes using ndb_restore.

  See Section 18.5.3, “Online Backup of NDB Cluster”, and Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”, for more information.

- Use mysql to create a backup prior to the upgrade; afterward, restore the dump using LOAD DATA.

**Resource Recovery.** To free memory previously allocated to a table by successive INSERT and DELETE operations, for re-use by other NDB Cluster tables.

The process for performing a rolling restart may be generalized as follows:

1. Stop all cluster management nodes (ndb_mgmd processes), reconfigure them, then restart them. (See Rolling restarts with multiple management servers.)

2. Stop, reconfigure, then restart each cluster data node (ndbd process) in turn.

   Some node configuration parameters can be updated by issuing `RESTART` for each of the data nodes in the ndb_mgm client following the previous step; others require that the data node be stopped completely using a shell command (such as `kill` on most Unix systems) or the management client `STOP` command, then started again from a system shell by invoking the ndbd or ndbmtd executable as appropriate.

   **Note**

   On Windows, you can also use `SC_STOP` and `SC_START` commands, `NET STOP` and `NET START` commands, or the Windows Service Manager to stop and start nodes which have been installed as Windows services (see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”).

   The type of restart required is indicated in the documentation for each node configuration parameter. See Section 18.3.3, “NDB Cluster Configuration Files”.

3. Stop, reconfigure, then restart each cluster SQL node (mysqld process) in turn.

   NDB Cluster supports a somewhat flexible order for upgrading nodes. When upgrading an NDB Cluster, you may upgrade API nodes (including SQL nodes) before upgrading the management nodes, data nodes,
or both. In other words, you are permitted to upgrade the API and SQL nodes in any order. This is subject to the following provisions:

- This functionality is intended for use as part of an online upgrade only. A mix of node binaries from different NDB Cluster releases is neither intended nor supported for continuous, long-term use in a production setting.
- All management nodes must be upgraded before any data nodes are upgraded. This remains true regardless of the order in which you upgrade the cluster's API and SQL nodes.
- Features specific to the “new” version must not be used until all management nodes and data nodes have been upgraded.

This also applies to any MySQL Server version change that may apply, in addition to the NDB engine version change, so do not forget to take this into account when planning the upgrade. (This is true for online upgrades of NDB Cluster in general.)

It is not possible for any API node to perform schema operations (such as data definition statements) during a node restart. Due in part to this limitation, schema operations are also not supported during an online upgrade or downgrade.

Rolling restarts with multiple management servers. When performing a rolling restart of an NDB Cluster with multiple management nodes, you should keep in mind that ndb_mgmd checks to see if any other management node is running, and, if so, tries to use that node's configuration data. To keep this from occurring, and to force ndb_mgmd to reread its configuration file, perform the following steps:

1. Stop all NDB Cluster ndb_mgmd processes.
2. Update all config.ini files.
3. Start a single ndb_mgmd with --reload, --initial, or both options as desired.
4. If you started the first ndb_mgmd with the --initial option, you must also start any remaining ndb_mgmd processes using --initial.

Regardless of any other options used when starting the first ndb_mgmd, you should not start any remaining ndb_mgmd processes after the first one using --reload.
5. Complete the rolling restarts of the data nodes and API nodes as normal.

When performing a rolling restart to update the cluster's configuration, you can use the config_generation column of the ndbinfo.nodes table to keep track of which data nodes have been successfully restarted with the new configuration. See Section 18.5.10.13, “The ndbinfo nodes Table”.

18.5.6 Event Reports Generated in NDB Cluster

In this section, we discuss the types of event logs provided by NDB Cluster, and the types of events that are logged.

NDB Cluster provides two types of event log:

- The cluster log, which includes events generated by all cluster nodes. The cluster log is the log recommended for most uses because it provides logging information for an entire cluster in a single location.

By default, the cluster log is saved to a file named ndb_node_id_cluster.log, (where node_id is the node ID of the management server) in the management server's DataDir.
Event Reports Generated in NDB Cluster

Cluster logging information can also be sent to stdout or a syslog facility in addition to or instead of being saved to a file, as determined by the values set for the DataDir and LogDestination configuration parameters. See Section 18.3.3.5, “Defining an NDB Cluster Management Server”, for more information about these parameters.

- **Node logs** are local to each node.

Output generated by node event logging is written to the file ndb_node_id_out.log (where node_id is the node’s node ID) in the node’s DataDir. Node event logs are generated for both management nodes and data nodes.

Node logs are intended to be used only during application development, or for debugging application code.

Both types of event logs can be set to log different subsets of events.

Each reportable event can be distinguished according to three different criteria:

- **Category**: This can be any one of the following values: STARTUP, SHUTDOWN, STATISTICS, CHECKPOINT, NODERESTART, CONNECTION, ERROR, or INFO.

- **Priority**: This is represented by one of the numbers from 0 to 15 inclusive, where 0 indicates “most important” and 15 “least important.”

- **Severity Level**: This can be any one of the following values: ALERT, CRITICAL, ERROR, WARNING, INFO, or DEBUG.

Both the cluster log and the node log can be filtered on these properties.

The format used in the cluster log is as shown here:

```
2007-01-26 19:35:55 [MgmSrvr] INFO -- Node 1: Data usage is 2%(60 32K pages of total 2560)
```

Each line in the cluster log contains the following information:

- A timestamp in **YYYY-MM-DD HH:MM:SS** format.
- The type of node which is performing the logging. In the cluster log, this is always [MgmSrvr].
- The severity of the event.
• The ID of the node reporting the event.

• A description of the event. The most common types of events to appear in the log are connections and disconnections between different nodes in the cluster, and when checkpoints occur. In some cases, the description may contain status information.

### 18.5.6.1 NDB Cluster Logging Management Commands

`ndb_mgm` supports a number of management commands related to the cluster log. In the listing that follows, `node_id` denotes either a storage node ID or the keyword `ALL`, which indicates that the command should be applied to all of the cluster's data nodes.

- **CLUSTERLOG ON**
  
  Turns the cluster log on.

- **CLUSTERLOG OFF**
  
  Turns the cluster log off.

- **CLUSTERLOG INFO**
  
  Provides information about cluster log settings.

- **node_id CLUSTERLOG category=threshold**

  Logs `category` events with priority less than or equal to `threshold` in the cluster log.

- **CLUSTERLOG FILTER severity_level**

  Toggles cluster logging of events of the specified `severity_level`.

The following table describes the default setting (for all data nodes) of the cluster log category threshold. If an event has a priority with a value lower than or equal to the priority threshold, it is reported in the cluster log.

#### Note

Events are reported per data node, and that the threshold can be set to different values on different nodes.

<table>
<thead>
<tr>
<th>Category</th>
<th>Default threshold (All data nodes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTUP</td>
<td>7</td>
</tr>
<tr>
<td>SHUTDOWN</td>
<td>7</td>
</tr>
<tr>
<td>STATISTICS</td>
<td>7</td>
</tr>
<tr>
<td>CHECKPOINT</td>
<td>7</td>
</tr>
<tr>
<td>NODERESTART</td>
<td>7</td>
</tr>
<tr>
<td>CONNECTION</td>
<td>7</td>
</tr>
<tr>
<td>ERROR</td>
<td>15</td>
</tr>
<tr>
<td>INFO</td>
<td>7</td>
</tr>
</tbody>
</table>

The `STATISTICS` category can provide a great deal of useful data. See Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”, for more information.
Thresholds are used to filter events within each category. For example, a **STARTUP** event with a priority of 3 is not logged unless the threshold for **STARTUP** is set to 3 or higher. Only events with priority 3 or lower are sent if the threshold is 3.

The following table shows the event severity levels.

<table>
<thead>
<tr>
<th>Severity Level Value</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ALERT</td>
<td>A condition that should be corrected immediately, such as a corrupted system database</td>
</tr>
<tr>
<td>2</td>
<td>CRITICAL</td>
<td>Critical conditions, such as device errors or insufficient resources</td>
</tr>
<tr>
<td>3</td>
<td>ERROR</td>
<td>Conditions that should be corrected, such as configuration errors</td>
</tr>
<tr>
<td>4</td>
<td>WARNING</td>
<td>Conditions that are not errors, but that might require special handling</td>
</tr>
<tr>
<td>5</td>
<td>INFO</td>
<td>Informational messages</td>
</tr>
<tr>
<td>6</td>
<td>DEBUG</td>
<td>Debugging messages used for <strong>NDBCLUSTER</strong> development</td>
</tr>
</tbody>
</table>

Event severity levels can be turned on or off (using `CLUSTERLOG FILTER`—see above). If a severity level is turned on, then all events with a priority less than or equal to the category thresholds are logged. If the severity level is turned off then no events belonging to that severity level are logged.

**Important**

Cluster log levels are set on a per **ndb_mgmd**, per subscriber basis. This means that, in an NDB Cluster with multiple management servers, using a `CLUSTERLOG` command in an instance of **ndb_mgm** connected to one management server affects only logs generated by that management server but not by any of the others. This also means that, should one of the management servers be restarted, only logs generated by that management server are affected by the resetting of log levels caused by the restart.

### 18.5.6.2 NDB Cluster Log Events

An event report reported in the event logs has the following format:

```
datetime [string] severity -- message
```

For example:

```
```

This section discusses all reportable events, ordered by category and severity level within each category. In the event descriptions, **GCP** and **LCP** mean “Global Checkpoint” and “Local Checkpoint”, respectively.

#### CONNECTION Events

These events are associated with connections between Cluster nodes.
Table 18.249 Events associated with connections between cluster nodes

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected</td>
<td>8</td>
<td>INFO</td>
<td>Data nodes connected</td>
</tr>
<tr>
<td>Disconnected</td>
<td>8</td>
<td>ALERT</td>
<td>Data nodes disconnected</td>
</tr>
<tr>
<td>CommunicationClosed</td>
<td>8</td>
<td>INFO</td>
<td>SQL node or data node connection closed</td>
</tr>
<tr>
<td>CommunicationOpened</td>
<td>8</td>
<td>INFO</td>
<td>SQL node or data node connection open</td>
</tr>
<tr>
<td>ConnectedApiVersion</td>
<td>8</td>
<td>INFO</td>
<td>Connection using API version</td>
</tr>
</tbody>
</table>

CHECKPOINT Events

The logging messages shown here are associated with checkpoints.

Table 18.250 Events associated with checkpoints

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GlobalCheckpointStarted</td>
<td>9</td>
<td>INFO</td>
<td>Start of GCP: REDO log is written to disk</td>
</tr>
<tr>
<td>GlobalCheckpointCompleted</td>
<td>10</td>
<td>INFO</td>
<td>GCP finished</td>
</tr>
<tr>
<td>LocalCheckpointStarted</td>
<td>7</td>
<td>INFO</td>
<td>Start of LCP: data written to disk</td>
</tr>
<tr>
<td>LocalCheckpointCompleted</td>
<td>7</td>
<td>INFO</td>
<td>LCP completed normally</td>
</tr>
<tr>
<td>LCPStoppedInCalcKeepGci</td>
<td>0</td>
<td>ALERT</td>
<td>LCP stopped</td>
</tr>
<tr>
<td>LCPFragmentCompleted</td>
<td>11</td>
<td>INFO</td>
<td>LCP on a fragment has been completed</td>
</tr>
<tr>
<td>UndoLogBlocked</td>
<td>7</td>
<td>INFO</td>
<td>UNDO logging blocked; buffer near overflow</td>
</tr>
<tr>
<td>RedoStatus</td>
<td>7</td>
<td>INFO</td>
<td>Redo status</td>
</tr>
</tbody>
</table>

STARTUP Events

The following events are generated in response to the startup of a node or of the cluster and of its success or failure. They also provide information relating to the progress of the startup process, including information concerning logging activities.

Table 18.251 Events relating to the startup of a node or cluster

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDBStartStarted</td>
<td>1</td>
<td>INFO</td>
<td>Data node start phases initiated (all nodes starting)</td>
</tr>
<tr>
<td>NDBStartCompleted</td>
<td>1</td>
<td>INFO</td>
<td>Start phases completed, all data nodes</td>
</tr>
<tr>
<td>STTORRYRecieved</td>
<td>15</td>
<td>INFO</td>
<td>Blocks received after completion of restart</td>
</tr>
<tr>
<td>StartPhaseCompleted</td>
<td>4</td>
<td>INFO</td>
<td>Data node start phase X completed</td>
</tr>
<tr>
<td>CM_REGCONF</td>
<td>3</td>
<td>INFO</td>
<td>Node has been successfully included into the cluster; shows the node, managing node, and dynamic ID</td>
</tr>
<tr>
<td>CM_REGREF</td>
<td>8</td>
<td>INFO</td>
<td>Node has been refused for inclusion in the cluster; cannot be included in cluster due to misconfiguration, inability to establish communication, or other problem</td>
</tr>
</tbody>
</table>
Event Reports Generated in NDB Cluster

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIND_NEIGHBOURS</td>
<td>8</td>
<td>INFO</td>
<td>Shows neighboring data nodes</td>
</tr>
<tr>
<td>NDBStopStarted</td>
<td>1</td>
<td>INFO</td>
<td>Data node shutdown initiated</td>
</tr>
<tr>
<td>NDBStopCompleted</td>
<td>1</td>
<td>INFO</td>
<td>Data node shutdown complete</td>
</tr>
<tr>
<td>NDBStopForced</td>
<td>1</td>
<td>ALERT</td>
<td>Forced shutdown of data node</td>
</tr>
<tr>
<td>NDBStopAborted</td>
<td>1</td>
<td>INFO</td>
<td>Unable to shut down data node normally</td>
</tr>
<tr>
<td>StartREDOLog</td>
<td>4</td>
<td>INFO</td>
<td>New redo log started; GCI keep X, newest restorable GCI Y</td>
</tr>
<tr>
<td>StartLog</td>
<td>10</td>
<td>INFO</td>
<td>New log started; log part X, start MB Y, stop MB Z</td>
</tr>
<tr>
<td>UNDORecordsExecuted</td>
<td>15</td>
<td>INFO</td>
<td>Undo records executed</td>
</tr>
<tr>
<td>StartReport</td>
<td>4</td>
<td>INFO</td>
<td>Report started</td>
</tr>
<tr>
<td>LogFileInitStatus</td>
<td>7</td>
<td>INFO</td>
<td>Log file initialization status</td>
</tr>
<tr>
<td>LogFileInitCompStatus</td>
<td>7</td>
<td>INFO</td>
<td>Log file completion status</td>
</tr>
<tr>
<td>StartReadLCP</td>
<td>10</td>
<td>INFO</td>
<td>Start read for local checkpoint</td>
</tr>
<tr>
<td>ReadLCPComplete</td>
<td>10</td>
<td>INFO</td>
<td>Read for local checkpoint completed</td>
</tr>
<tr>
<td>RunRedo</td>
<td>8</td>
<td>INFO</td>
<td>Running the redo log</td>
</tr>
<tr>
<td>RebuildIndex</td>
<td>10</td>
<td>INFO</td>
<td>Rebuilding indexes</td>
</tr>
</tbody>
</table>

**NODERESTART Events**

The following events are generated when restarting a node and relate to the success or failure of the node restart process.

**Table 18.252 Events relating to restarting a node**

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR_CopyDict</td>
<td>7</td>
<td>INFO</td>
<td>Completed copying of dictionary information</td>
</tr>
<tr>
<td>NR_CopyDistr</td>
<td>7</td>
<td>INFO</td>
<td>Completed copying distribution information</td>
</tr>
<tr>
<td>NR_CopyFragsStarted</td>
<td>7</td>
<td>INFO</td>
<td>Starting to copy fragments</td>
</tr>
<tr>
<td>NR_CopyFragDone</td>
<td>10</td>
<td>INFO</td>
<td>Completed copying a fragment</td>
</tr>
<tr>
<td>NR_CopyFragsCompleted</td>
<td>7</td>
<td>INFO</td>
<td>Completed copying all fragments</td>
</tr>
<tr>
<td>NodeFailCompleted</td>
<td>8</td>
<td>ALERT</td>
<td>Node failure phase completed</td>
</tr>
<tr>
<td>NODE_FAILREP</td>
<td>8</td>
<td>ALERT</td>
<td>Reports that a node has failed</td>
</tr>
<tr>
<td>ArbitState</td>
<td>6</td>
<td>INFO</td>
<td>Report whether an arbitrator is found or not; there are seven different possible outcomes when seeking an arbitrator, listed here:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Management server restarts arbitration thread [state=X]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Prepare arbitrator node X [ticket=Y]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Receive arbitrator node X [ticket=Y]</td>
</tr>
</tbody>
</table>
### Event Reports Generated in NDB Cluster

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArbitResult</td>
<td></td>
<td>ALERT</td>
<td>Report arbitrator results; there are eight different possible results for arbitration attempts, listed here:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Arbitration check failed: less than 1/2 nodes left</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Arbitration check succeeded: node group majority</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Arbitration check failed: missing node group</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Network partitioning: arbitration required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Arbitration succeeded: affirmative response from node X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Arbitration failed: negative response from node X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Network partitioning: no arbitrator available</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Network partitioning: no arbitrator configured</td>
</tr>
<tr>
<td>TransReportCounters</td>
<td>8</td>
<td>INFO</td>
<td>Report transaction statistics, including numbers of transactions, commits, reads,</td>
</tr>
</tbody>
</table>

### STATISTICS Events

The following events are of a statistical nature. They provide information such as numbers of transactions and other operations, amount of data sent or received by individual nodes, and memory usage.

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCP_TakeoverStarted</td>
<td>7</td>
<td>INFO</td>
<td>GCP takeover started</td>
</tr>
<tr>
<td>GCP_TakeoverCompleted</td>
<td>7</td>
<td>INFO</td>
<td>GCP takeover complete</td>
</tr>
<tr>
<td>LCP_TakeoverStarted</td>
<td>7</td>
<td>INFO</td>
<td>LCP takeover started</td>
</tr>
<tr>
<td>LCP_TakeoverCompleted</td>
<td>7</td>
<td>INFO</td>
<td>LCP takeover complete (state = X)</td>
</tr>
<tr>
<td>ConnectCheckStarted</td>
<td>6</td>
<td>INFO</td>
<td>Connection check started</td>
</tr>
<tr>
<td>ConnectCheckCompleted</td>
<td>6</td>
<td>INFO</td>
<td>Connection check completed</td>
</tr>
<tr>
<td>NodeFailRejected</td>
<td>6</td>
<td>ALERT</td>
<td>Node failure phase failed</td>
</tr>
</tbody>
</table>
Event Reports Generated in NDB Cluster

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple reads, writes, concurrent operations, attribute information, and aborts</td>
<td>8</td>
<td>INFO</td>
<td>OperationReportCounters</td>
</tr>
<tr>
<td>operation number</td>
<td>7</td>
<td>INFO</td>
<td>TableCreated</td>
</tr>
<tr>
<td>Number of thread configuration loops</td>
<td>9</td>
<td>INFO</td>
<td>JobStatistic</td>
</tr>
<tr>
<td>Number of thread configuration loops</td>
<td>9</td>
<td>INFO</td>
<td>ThreadConfigLoop</td>
</tr>
<tr>
<td>Mean number of bytes sent to node X</td>
<td>9</td>
<td>INFO</td>
<td>SendBytesStatistic</td>
</tr>
<tr>
<td>Mean number of bytes received from node X</td>
<td>9</td>
<td>INFO</td>
<td>ReceiveBytesStatistic</td>
</tr>
<tr>
<td>Data and index memory usage (80%, 90%, and 100%)</td>
<td>5</td>
<td>INFO</td>
<td>MemoryUsage</td>
</tr>
<tr>
<td>Multithreaded signals</td>
<td>9</td>
<td>INFO</td>
<td>MTSignalStatistics</td>
</tr>
</tbody>
</table>

**SCHEMA Events**

These events relate to NDB Cluster schema operations.

**Table 18.254 Events relating to NDB Cluster schema operations**

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CreateSchemaObject</td>
<td>8</td>
<td>INFO</td>
<td>Schema object created</td>
</tr>
<tr>
<td>AlterSchemaObject</td>
<td>8</td>
<td>INFO</td>
<td>Schema object updated</td>
</tr>
<tr>
<td>DropSchemaObject</td>
<td>8</td>
<td>INFO</td>
<td>Schema object dropped</td>
</tr>
</tbody>
</table>

**ERROR Events**

These events relate to Cluster errors and warnings. The presence of one or more of these generally indicates that a major malfunction or failure has occurred.

**Table 18.255 Events relating to cluster errors and warnings**

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TransporterError</td>
<td>2</td>
<td>ERROR</td>
<td>Transporter error</td>
</tr>
<tr>
<td>TransporterWarning</td>
<td>8</td>
<td>WARNING</td>
<td>Transporter warning</td>
</tr>
<tr>
<td>MissedHeartbeat</td>
<td>8</td>
<td>WARNING</td>
<td>Node X missed heartbeat number Y</td>
</tr>
<tr>
<td>DeadDueToHeartbeat</td>
<td>8</td>
<td>ALERT</td>
<td>Node X declared “dead” due to missed heartbeat</td>
</tr>
<tr>
<td>WarningEvent</td>
<td>2</td>
<td>WARNING</td>
<td>General warning event</td>
</tr>
<tr>
<td>SubscriptionStatus</td>
<td>4</td>
<td>WARNING</td>
<td>Change in subscription status</td>
</tr>
</tbody>
</table>

**INFO Events**

These events provide general information about the state of the cluster and activities associated with Cluster maintenance, such as logging and heartbeat transmission.
Table 18.256 Information events

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SentHeartbeat</td>
<td>12</td>
<td>INFO</td>
<td>Sent heartbeat</td>
</tr>
<tr>
<td>CreateLogBytes</td>
<td>11</td>
<td>INFO</td>
<td>Create log: Log part, log file, size in MB</td>
</tr>
<tr>
<td>InfoEvent</td>
<td>2</td>
<td>INFO</td>
<td>General informational event</td>
</tr>
<tr>
<td>EventBufferStatus</td>
<td>7</td>
<td>INFO</td>
<td>Event buffer status</td>
</tr>
</tbody>
</table>

Note

SentHeartbeat events are available only if NDB Cluster was compiled with VM_TRACE enabled.

SINGLEUSER Events

These events are associated with entering and exiting single user mode.

Table 18.257 Events relating to single user mode

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SingleUser</td>
<td>7</td>
<td>INFO</td>
<td>Entering or exiting single user mode</td>
</tr>
</tbody>
</table>

BACKUP Events

These events provide information about backups being created or restored.

Table 18.258 Backup events

<table>
<thead>
<tr>
<th>Event</th>
<th>Priority</th>
<th>Severity Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BackupStarted</td>
<td>7</td>
<td>INFO</td>
<td>Backup started</td>
</tr>
<tr>
<td>BackupStatus</td>
<td>7</td>
<td>INFO</td>
<td>Backup status</td>
</tr>
<tr>
<td>BackupCompleted</td>
<td>7</td>
<td>INFO</td>
<td>Backup completed</td>
</tr>
<tr>
<td>BackupFailedToStart</td>
<td>7</td>
<td>ALERT</td>
<td>Backup failed to start</td>
</tr>
<tr>
<td>BackupAborted</td>
<td>7</td>
<td>ALERT</td>
<td>Backup aborted by user</td>
</tr>
<tr>
<td>RestoreStarted</td>
<td>7</td>
<td>INFO</td>
<td>Started restoring from backup</td>
</tr>
<tr>
<td>RestoreMetaData</td>
<td>7</td>
<td>INFO</td>
<td>Restoring metadata</td>
</tr>
<tr>
<td>RestoreData</td>
<td>7</td>
<td>INFO</td>
<td>Restoring data</td>
</tr>
<tr>
<td>RestoreLog</td>
<td>7</td>
<td>INFO</td>
<td>Restoring log files</td>
</tr>
<tr>
<td>RestoreCompleted</td>
<td>7</td>
<td>INFO</td>
<td>Completed restoring from backup</td>
</tr>
<tr>
<td>SavedEvent</td>
<td>7</td>
<td>INFO</td>
<td>Event saved</td>
</tr>
</tbody>
</table>

18.5.6.3 Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client

The NDB management client's CLUSTERLOG STATISTICS command can provide a number of useful statistics in its output. Counters providing information about the state of the cluster are updated at 5-second reporting intervals by the transaction coordinator (TC) and the local query handler (LQH), and written to the cluster log.
Transaction coordinator statistics. Each transaction has one transaction coordinator, which is chosen by one of the following methods:

- In a round-robin fashion
- By communication proximity
- By supplying a data placement hint when the transaction is started

Note
You can determine which TC selection method is used for transactions started from a given SQL node using the `ndb_optimized_node_selection` system variable.

All operations within the same transaction use the same transaction coordinator, which reports the following statistics:

- **Trans count.** This is the number transactions started in the last interval using this TC as the transaction coordinator. Any of these transactions may have committed, have been aborted, or remain uncommitted at the end of the reporting interval.

  Note
  Transactions do not migrate between TCs.

- **Commit count.** This is the number of transactions using this TC as the transaction coordinator that were committed in the last reporting interval. Because some transactions committed in this reporting interval may have started in a previous reporting interval, it is possible for Commit count to be greater than Trans count.

- **Read count.** This is the number of primary key read operations using this TC as the transaction coordinator that were started in the last reporting interval, including simple reads. This count also includes reads performed as part of unique index operations. A unique index read operation generates 2 primary key read operations—1 for the hidden unique index table, and 1 for the table on which the read takes place.

- **Simple read count.** This is the number of simple read operations using this TC as the transaction coordinator that were started in the last reporting interval.

- **Write count.** This is the number of primary key write operations using this TC as the transaction coordinator that were started in the last reporting interval. This includes all inserts, updates, writes and deletes, as well as writes performed as part of unique index operations.

  Note
  A unique index update operation can generate multiple PK read and write operations on the index table and on the base table.

- **AttrInfoCount.** This is the number of 32-bit data words received in the last reporting interval for primary key operations using this TC as the transaction coordinator. For reads, this is proportional to the number of columns requested. For inserts and updates, this is proportional to the number of columns written, and the size of their data. For delete operations, this is usually zero.

  Unique index operations generate multiple PK operations and so increase this count. However, data words sent to describe the PK operation itself, and the key information sent, are *not* counted here. Attribute information sent to describe columns to read for scans, or to describe ScanFilters, is also not counted in AttrInfoCount.
Event Reports Generated in NDB Cluster

- **Concurrent Operations.** This is the number of primary key or scan operations using this TC as the transaction coordinator that were started during the last reporting interval but that were not completed. Operations increment this counter when they are started and decrement it when they are completed; this occurs after the transaction commits. Dirty reads and writes—as well as failed operations—decrement this counter.

  The maximum value that Concurrent Operations can have is the maximum number of operations that a TC block can support; currently, this is \((2 \times \text{MaxNoOfConcurrentOperations}) + 16 + \text{MaxNoOfConcurrentTransactions}\). (For more information about these configuration parameters, see the Transaction Parameters section of Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.)

- **Abort count.** This is the number of transactions using this TC as the transaction coordinator that were aborted during the last reporting interval. Because some transactions that were aborted in the last reporting interval may have started in a previous reporting interval, Abort count can sometimes be greater than Trans count.

- **Scans.** This is the number of table scans using this TC as the transaction coordinator that were started during the last reporting interval. This does not include range scans (that is, ordered index scans).

- **Range scans.** This is the number of ordered index scans using this TC as the transaction coordinator that were started in the last reporting interval.

- **Local reads.** This is the number of primary-key read operations performed using a transaction coordinator on a node that also holds the primary replica of the record. This count can also be obtained from the LOCAL_READS counter in the ndbinfo.counters table.

- **Local writes.** This contains the number of primary-key read operations that were performed using a transaction coordinator on a node that also holds the primary replica of the record. This count can also be obtained from the LOCAL_WRITES counter in the ndbinfo.counters table.

**Local query handler statistics (Operations).** There is 1 cluster event per local query handler block (that is, 1 per data node process). Operations are recorded in the LQH where the data they are operating on resides.

Note

A single transaction may operate on data stored in multiple LQH blocks.

The Operations statistic provides the number of local operations performed by this LQH block in the last reporting interval, and includes all types of read and write operations (insert, update, write, and delete operations). This also includes operations used to replicate writes. For example, in a 2-replica cluster, the write to the primary replica is recorded in the primary LQH, and the write to the backup will be recorded in the backup LQH. Unique key operations may result in multiple local operations; however, this does not include local operations generated as a result of a table scan or ordered index scan, which are not counted.

**Process scheduler statistics.** In addition to the statistics reported by the transaction coordinator and local query handler, each ndbd process has a scheduler which also provides useful metrics relating to the performance of an NDB Cluster. This scheduler runs in an infinite loop; during each loop the scheduler performs the following tasks:

1. Read any incoming messages from sockets into a job buffer.

2. Check whether there are any timed messages to be executed; if so, put these into the job buffer as well.
3. Execute (in a loop) any messages in the job buffer.
4. Send any distributed messages that were generated by executing the messages in the job buffer.
5. Wait for any new incoming messages.

Process scheduler statistics include the following:

- **Mean Loop Counter.** This is the number of loops executed in the third step from the preceding list. This statistic increases in size as the utilization of the TCP/IP buffer improves. You can use this to monitor changes in performance as you add new data node processes.

- **Mean send size and Mean receive size.** These statistics enable you to gauge the efficiency of, respectively, writes and reads between nodes. The values are given in bytes. Higher values mean a lower cost per byte sent or received; the maximum value is 64K.

To cause all cluster log statistics to be logged, you can use the following command in the NDB management client:

```bash
ndb_mgm> ALL CLUSTERLOG STATISTICS=15
```

**Note**
Setting the threshold for `STATISTICS` to 15 causes the cluster log to become very verbose, and to grow quite rapidly in size, in direct proportion to the number of cluster nodes and the amount of activity in the NDB Cluster.

For more information about NDB Cluster management client commands relating to logging and reporting, see Section 18.5.6.1, “NDB Cluster Logging Management Commands”.

### 18.5.7 NDB Cluster Log Messages

This section contains information about the messages written to the cluster log in response to different cluster log events. It provides additional, more specific information on NDB transporter errors.

#### 18.5.7.1 NDB Cluster: Messages in the Cluster Log

The following table lists the most common NDB cluster log messages. For information about the cluster log, log events, and event types, see Section 18.5.6, “Event Reports Generated in NDB Cluster”. These log messages also correspond to log event types in the MGM API; see The *Ndb_logevent_type* Type, for related information of interest to Cluster API developers.

<table>
<thead>
<tr>
<th>Log Message</th>
<th>Description</th>
<th>Event Name</th>
<th>Event Type</th>
<th>Priority</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node <code>mgm_node_id</code>: Node <code>data_node_id</code> Connected</td>
<td>The data node having node ID <code>node_id</code> has connected to the management server (node <code>mgm_node_id</code>).</td>
<td>Connected</td>
<td>Connection</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <code>mgm_node_id</code>: Node <code>data_node_id</code> Disconnected</td>
<td>The data node having node ID <code>data_node_id</code> has disconnected from the management</td>
<td>Disconnected</td>
<td>Connection</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
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</tr>
<tr>
<td>Node <em>data_node_id</em>: Communication to Node <em>api_node_id</em> closed</td>
<td>The API node or SQL node having node ID <em>api_node_id</em> is no longer communicating with data node <em>data_node_id</em>.</td>
<td>CommunicationClosed</td>
<td>Connection</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <em>data_node_id</em>: Communication to Node <em>api_node_id</em> opened</td>
<td>The API node or SQL node having node ID <em>api_node_id</em> is now communicating with data node <em>data_node_id</em>.</td>
<td>CommunicationOpened</td>
<td>Connection</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <em>mgm_node_id</em>: Node <em>api_node_id</em>: API version</td>
<td>The API node having node ID <em>api_node_id</em> has connected to management node <em>mgm_node_id</em> using NDB API version <em>version</em> (generally the same as the MySQL version number).</td>
<td>ConnectedApiVersion</td>
<td>Connection</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <em>node_id</em>: Global checkpoint <em>gci</em> started</td>
<td>A global checkpoint with the ID <em>gci</em> has been started; node <em>node_id</em> is the master responsible for this global checkpoint.</td>
<td>GlobalCheckpointStart</td>
<td>Checkpoint</td>
<td>9</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <em>node_id</em>: Global checkpoint <em>gci</em> completed</td>
<td>The global checkpoint having the ID <em>gci</em> has been completed; node <em>node_id</em> was the master responsible for this global checkpoint.</td>
<td>GlobalCheckpointComp</td>
<td>Checkpoint</td>
<td>10</td>
<td>INFO</td>
</tr>
<tr>
<td>Node <em>node_id</em>: Local checkpoint <em>lcp</em> started. Keep GCI = current_gci oldest</td>
<td>The local checkpoint having sequence ID <em>lcp</em> has been started on node <em>node_id</em>. The most recent GCI that can be</td>
<td>LocalCheckpointStart</td>
<td>Checkpoint</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
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</tr>
<tr>
<td><code>restorable GCI = old_gci</code></td>
<td>used has the index <code>current_gci</code>, and the oldest GCI from which the cluster can be restored has the index <code>old_gci</code>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node_id: Local checkpoint lcp completed</td>
<td>The local checkpoint having sequence ID <code>lcp</code> on node <code>node_id</code> has been completed.</td>
<td>LocalCheckpointCompleted</td>
<td>Checkpoint</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Local Checkpoint stopped in CALCULATED_KEEP_GCI</td>
<td>The node was unable to determine the most recent usable GCI.</td>
<td>LCPStoppedInCalcKeepGci</td>
<td>Checkpoint</td>
<td>0</td>
<td>ALERT</td>
</tr>
<tr>
<td>Node node_id: Table ID = <code>table_id</code>, fragment ID = <code>fragment_id</code> has completed LCP on Node node_id maxGciStarted: <code>started_gci</code> maxGciCompleted: <code>completed_gci</code></td>
<td>A table fragment has been checkpointed to disk on node <code>node_id</code>. The GCI in progress has the index <code>started_gci</code>, and the most recent GCI to have been completed has the index <code>completed_gci</code>.</td>
<td>LCPFragmentCompletedCheckpoint</td>
<td>Checkpoint</td>
<td>11</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: ACC Blocked <code>num_1</code> and TUP Blocked <code>num_2</code> times last second</td>
<td>Undo logging is blocked because the log buffer is close to overflowing.</td>
<td>UndoLogBlocked</td>
<td>Checkpoint</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Start initiated version</td>
<td>Data node <code>node_id</code>, running NDB version <code>version</code>, is beginning its startup process.</td>
<td>NDBStartStarted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Started version</td>
<td>Data node <code>node_id</code>, running NDB version <code>version</code>, has started successfully.</td>
<td>NDBStartCompleted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: STTORY</td>
<td>The node has received a signal</td>
<td>STTORYRecieved</td>
<td>StartUp</td>
<td>15</td>
<td>INFO</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>received after restart finished</td>
<td>indicating that a cluster restart has completed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node_id: Start phase phase completed (type)</td>
<td>The node has completed start phase phase of a type start. For a listing of start phases, see Section 18.5.1, “Summary of NDB Cluster Start Phases”. (type is one of initial, system, node, initial node, or &lt;Unknown&gt;.)</td>
<td>StartPhaseCompleted</td>
<td>StartUp</td>
<td>4</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: CM_REGCONF president = president_id, own Node = own_id, our dynamic id = dynamic_id</td>
<td>Node president_id has been selected as “president”. own_id and dynamic_id should always be the same as the ID (node_id) of the reporting node.</td>
<td>CM_REGCONF</td>
<td>StartUp</td>
<td>3</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: CM_REGREF from Node president_id to our Node node_id. Cause = cause</td>
<td>The reporting node (ID node_id) was unable to accept node president_id as president. The cause of the problem is given as one of Busy, Election with wait = false, Not president, Election without selecting new candidate, or No such cause.</td>
<td>CM_REGREF</td>
<td>StartUp</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: We are Node own_id with dynamic ID dynamic_id, our left neighbor is Node id_1,</td>
<td>The node has discovered its neighboring nodes in the cluster (node id_1 and node id_2). node_id, own_id, and</td>
<td>FIND_NEIGHBOURS</td>
<td>StartUp</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>our right is Node id_2</td>
<td>dynamic_id should always be the same; if they are not, this indicates a serious misconfiguration of the cluster nodes.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Node node_id: type shutdown initiated</td>
<td>The node has received a shutdown signal. The type of shutdown is either Cluster or Node.</td>
<td>NDBStopStarted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node shutdown completed [, action] [Initiated by signal signal.]</td>
<td>The node has been shut down. This report may include an action, which if present is one of restarting, no start, or initial. The report may also include a reference to an NDB Protocol signal; for possible signals, refer to Operations and Signals.</td>
<td>NDBStopCompleted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Forced node shutdown completed [, action]. [Occurred during startphase start_phase.] [Initiated by signal.] [Caused by error error_code: 'error_message(error_classification)'. [extra info extra_code]]</td>
<td>The node has been forcibly shut down. The action (one of restarting, no start, or initial) subsequently being taken, if any, is also reported. If the shutdown occurred while the node was starting, the report includes the start_phase during which the node failed. If this was a result of a signal sent to the node, this information is also provided (see Operations and Signals, for more</td>
<td>NDBStopForced</td>
<td>StartUp</td>
<td>1</td>
<td>ALERT</td>
</tr>
</tbody>
</table>
### Log Messages

<table>
<thead>
<tr>
<th>Log Message</th>
<th>Description</th>
<th>Event Name</th>
<th>Event Type</th>
<th>Priority</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDB Cluster Log Messages</td>
<td>information). If the error causing the failure is known, this is also included; for more information about NDB error messages and classifications, see NDB Cluster API Errors.</td>
<td>NDBStopAborted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node shutdown aborted</td>
<td>The node shutdown process was aborted by the user.</td>
<td>NDBStopAborted</td>
<td>StartUp</td>
<td>1</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: StartLog: [GCI Keep: keep_pos LastCompleted: last_pos NewestRestorable: restore_pos]</td>
<td>This reports global checkpoints referenced during a node start. The redo log prior to keep_pos is dropped. last_pos is the last global checkpoint in which data node the participated; restore_pos is the global checkpoint which is actually used to restore all data nodes.</td>
<td>StartREDolog</td>
<td>StartUp</td>
<td>4</td>
<td>INFO</td>
</tr>
<tr>
<td>startup_message [Listed separately; see below.]</td>
<td>There are a number of possible startup messages that can be logged under different circumstances. These are listed separately; see Section 18.5.7.2, “NDB Cluster Log Startup Messages”.</td>
<td>StartReport</td>
<td>StartUp</td>
<td>4</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node restart completed copy of dictionary information</td>
<td>Copying of data dictionary information to the restarted node has been completed.</td>
<td>NR_CopyDict</td>
<td>NodeRestart</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node restart completed copy</td>
<td>Copying of data distribution information to the</td>
<td>NR_CopyDistr</td>
<td>NodeRestart</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
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<tr>
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</tr>
<tr>
<td>of distribution information</td>
<td>restarted node has been completed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node_id: Node restart starting to copy the fragments to Node node_id</td>
<td>Copy of fragments to starting data node node_id has begun</td>
<td>NR_CopyFfragsStarted</td>
<td>NodeRestart</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Table ID = table_id, fragment ID = fragment_id have been copied to Node node_id</td>
<td>Fragment fragment_id from table table_id has been copied to data node node_id</td>
<td>NR_CopyFragDone</td>
<td>NodeRestart</td>
<td>10</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node restart completed copying the fragments to Node node_id</td>
<td>Copying of all table fragments to restarting data node node_id has been completed</td>
<td>NR_CopyFfragsCompleted</td>
<td>NodeRestart</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Node node1_id completed failure of Node node2_id</td>
<td>Data node node1_id has detected the failure of data node node2_id</td>
<td>NodeFailCompleted</td>
<td>NodeRestart</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>All nodes completed failure of Node node_id</td>
<td>All (remaining) data nodes have detected the failure of data node node_id</td>
<td>NodeFailCompleted</td>
<td>NodeRestart</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>Node failure of node_id block completed</td>
<td>The failure of data node node_id has been detected in the blockNDB kernel block, where block is 1 of DBTC, DBDICT, DBDIH, or DBLQH; for more information, see NDB Kernel Blocks</td>
<td>NodeFailCompleted</td>
<td>NodeRestart</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>Node mgm_node_id: Node data_node_id has failed. The Node state</td>
<td>A data node has failed. Its state at the time of failure is described by an arbitration state code state_code: possible state</td>
<td>NODE_FAILREP</td>
<td>NodeRestart</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
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<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>at failure was state_code</td>
<td>code values can be found in the file include/kernel/signaldata/ArbitSignalData.hpp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>President restarts arbitration thread [state=state_code]</td>
<td>This is a report on the current state and progress of arbitration in the cluster. node_id is the node ID of the management node or SQL node selected as the arbitrator. state_code is an arbitration state code, as found in include/kernel/signaldata/ArbitSignalData.hpp. When an error has occurred, an error_message, also defined in ArbitSignalData.hpp, is provided. ticket_id is a unique identifier handed out by the arbitrator when it is selected to all the nodes that participated in its selection; this is used to ensure that each node requesting arbitration was one of the nodes that took part in the selection process.</td>
<td>ArbitState</td>
<td>NodeRestart</td>
<td>6</td>
<td>INFO</td>
</tr>
<tr>
<td>Arbitration check lost - less than 1/2 nodes left</td>
<td>This message reports on the result of arbitration. In the event of arbitration failure, an error_message and an arbitration state_code are provided; definitions</td>
<td>ArbitResult</td>
<td>NodeRestart</td>
<td>2</td>
<td>ALERT</td>
</tr>
<tr>
<td>Arbitration check won - all node groups and more than 1/2 nodes left</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
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</tr>
<tr>
<td>or Arbitration check won - node group majority or Arbitration check lost - missing node group or Network partitioning - arbitration required or Arbitration won - positive reply from node node_id or Arbitration lost - negative reply from node node_id or Network partitioning - no arbitrator available or Network partitioning - no arbitrator configured or Arbitration failure - error_message [state=state_code]</td>
<td>for both of these are found in include/kernel/signaldata/ArbitSignalData.hpp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node_id: GCP Take over started</td>
<td>This node is attempting to assume responsibility for the next global checkpoint (that is, it is becoming the master node)</td>
<td>GCP_TakeoverStarted NodeRestart</td>
<td>7</td>
<td>INFO</td>
<td></td>
</tr>
<tr>
<td>Node node_id: GCP Take over completed</td>
<td>This node has become the master, and has assumed responsibility for the next global checkpoint</td>
<td>GCP_TakeoverCompleted NodeRestart</td>
<td>7</td>
<td>INFO</td>
<td></td>
</tr>
<tr>
<td>Node node_id: LCP Take over started</td>
<td>This node is attempting to assume responsibility for the next set of local checkpoints (that is,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---------------------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>Node node_id:</strong> LCP Take over completed</td>
<td>This node has become the master, and has assumed responsibility for the next set of local checkpoints</td>
<td>LCP_TakeoverCompleted</td>
<td>NodeRestart</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td><strong>Node node_id:</strong> Trans. Count = transactions, Commit Count = commits, Read Count = reads, Simple Read Count = simple_reads, Write Count = writes, AttrInfo Count = AttrInfo_objects, Concurrent Operations = concurrent_operations, Abort Count = aborts, Scans = scans, Range scans = range_scans</td>
<td>This report of transaction activity is given approximately once every 10 seconds</td>
<td>TransReportCounters</td>
<td>Statistic</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td><strong>Node node_id:</strong> Operations=operations</td>
<td>Number of operations performed by this node, provided approximately once every 10 seconds</td>
<td>OperationReportCounters</td>
<td>Statistic</td>
<td>8</td>
<td>INFO</td>
</tr>
<tr>
<td><strong>Node node_id:</strong> Table with ID = table_id created</td>
<td>A table having the table ID shown has been created</td>
<td>TableCreated</td>
<td>Statistic</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td><strong>Node node_id:</strong> Mean loop Counter in doJob last 8192 times = count</td>
<td></td>
<td>JobStatistic</td>
<td>Statistic</td>
<td>9</td>
<td>INFO</td>
</tr>
<tr>
<td><strong>Mean send size to Node = node_id last 4096 sends = bytes per send to node node_id</strong></td>
<td>This node is sending an average of bytes per send to node node_id</td>
<td>SendBytesStatistic</td>
<td>Statistic</td>
<td>9</td>
<td>INFO</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Mean receive size to Node = node_id last 4096 sends = bytes bytes</td>
<td>This node is receiving an average of bytes of data each time it receives data from node node_id</td>
<td>ReceiveBytesStatistic</td>
<td>Statistic</td>
<td>9</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id:</td>
<td>This report is generated when a DUMP 1000 command is issued in the cluster management client; for more information, see DUMP 1000, in MySQL NDB Cluster Internals Manual</td>
<td>MemoryUsage</td>
<td>Statistic</td>
<td>5</td>
<td>INFO</td>
</tr>
<tr>
<td>Data usage is data_memory_percentage % (data_pages_used / data_pages_total)</td>
<td>/Node node_id: Index usage is index_memory_percentage % (index_pages_used / index_pages_total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node1_id: Transporter to node node2_id reported error error_code:</td>
<td>A transporter error occurred while communicating with node node2_id; for a listing of transporter error codes and messages, see NDB Transporter Errors, in MySQL NDB Cluster Internals Manual</td>
<td>TransporterError</td>
<td>Error</td>
<td>2</td>
<td>ERROR</td>
</tr>
<tr>
<td>error_message</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node1_id: Transporter to node node2_id reported error error_code:</td>
<td>A warning of a potential transporter problem while communicating with node node2_id; for a listing of transporter error codes and messages, see NDB Transporter Errors, for more information</td>
<td>TransporterWarning</td>
<td>Error</td>
<td>8</td>
<td>WARNING</td>
</tr>
<tr>
<td>error_message</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node node1_id: Node node2_id missed heartbeat heartbeat_id</td>
<td>This node missed a heartbeat from node node2_id</td>
<td>MissedHeartbeat</td>
<td>Error</td>
<td>8</td>
<td>WARNING</td>
</tr>
<tr>
<td>Log Message</td>
<td>Description</td>
<td>Event Name</td>
<td>Event Type</td>
<td>Priority</td>
<td>Severity</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Node node1_id: Node node2_id declared dead due to missed heartbeat</td>
<td>This node has missed at least 3 heartbeats from node node2_id, and so has declared that node &quot;dead&quot;</td>
<td>DeadDueToHeartbeat</td>
<td>Error</td>
<td>8</td>
<td>ALERT</td>
</tr>
<tr>
<td>Node node1_id: Node Sent Heartbeat to node = node2_id</td>
<td>This node has sent a heartbeat to node node2_id</td>
<td>SentHeartbeat</td>
<td>Info</td>
<td>12</td>
<td>INFO</td>
</tr>
<tr>
<td>(NDB 7.5.0 and earlier) Node node_id: Event buffer status: used=bytes_used (percent_used%) alloc=bytes_allocated (percent_available%) max=bytes_available apply_epoch=latest_restorable_epoch latest_epoch=latest_epoch</td>
<td>This report is seen during heavy event buffer usage, for example, when many updates are being applied in a relatively short period of time; the report shows the number of bytes and the percentage of event buffer memory used, the bytes allocated and percentage still available, and the latest and latest restorable epochs</td>
<td>EventBufferStatus</td>
<td>Info</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Entering single user mode, Node node_id: Entered single user mode Node API_node_id has exclusive access, Node node_id: Entering single user mode</td>
<td>These reports are written to the cluster log when entering and exiting single user mode; API_node_id is the node ID of the API or SQL having exclusive access to the cluster (for more information, see Section 18.5.8, “NDB Cluster Single User Mode”); the message Unknown single user report API_node_id indicates an error has taken place and should never be seen in normal operation</td>
<td>SingleUser</td>
<td>Info</td>
<td>7</td>
<td>INFO</td>
</tr>
</tbody>
</table>
## NDB Cluster Log Messages

<table>
<thead>
<tr>
<th>Log Message</th>
<th>Description</th>
<th>Event Name</th>
<th>Event Type</th>
<th>Priority</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node node_id: Backup backup_id started from node mgm_node_id</td>
<td>A backup has been started using the management node having mgm_node_id; this message is also displayed in the cluster management client when the START BACKUP command is issued; for more information, see Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”</td>
<td>BackupStarted</td>
<td>Backup</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Backup backup_id started from node mgm_node_id completed. StartGCP: start_gcp StopGCP: stop_gcp #Records: records #LogRecords: log_records Data: data_bytes bytes Log: log_bytes bytes</td>
<td>The backup having the ID backup_id has been completed; for more information, see Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”</td>
<td>BackupCompleted</td>
<td>Backup</td>
<td>7</td>
<td>INFO</td>
</tr>
<tr>
<td>Node node_id: Backup request from mgm_node_id failed to start. Error: error_code</td>
<td>The backup failed to start; for error codes, see MGM API Errors</td>
<td>BackupFailedToStart</td>
<td>Backup</td>
<td>7</td>
<td>ALERT</td>
</tr>
<tr>
<td>Node node_id: Backup backup_id started from mgm_node_id has been</td>
<td>The backup was terminated after starting, possibly due to user intervention</td>
<td>BackupAborted</td>
<td>Backup</td>
<td>7</td>
<td>ALERT</td>
</tr>
</tbody>
</table>
### 18.5.7.2 NDB Cluster Log Startup Messages

Possible startup messages with descriptions are provided in the following list:

- **Initial start, waiting for %s to connect, nodes [ all: %s connected: %s no-wait: %s ]**
- **Waiting until nodes: %s connects, nodes [ all: %s connected: %s no-wait: %s ]**
- **Waiting %u sec for nodes %s to connect, nodes [ all: %s connected: %s no-wait: %s ]**
- **Waiting for non partitioned start, nodes [ all: %s connected: %s missing: %s no-wait: %s ]**
- **Waiting %u sec for non partitioned start, nodes [ all: %s connected: %s missing: %s no-wait: %s ]**
- **Initial start with nodes %s [ missing: %s no-wait: %s ]**
- **Start with all nodes %s**
- **Start with nodes %s [ missing: %s no-wait: %s ]**
- **Start potentially partitioned with nodes %s [ missing: %s no-wait: %s ]**
- **Unknown startreport: 0x%x [ %s %s %s %s ]**

### 18.5.7.3 NDB Cluster: NDB Transporter Errors

This section lists error codes, names, and messages that are written to the cluster log in the event of transporter errors.

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td><strong>TE_NO_ERROR</strong></td>
</tr>
<tr>
<td></td>
<td>No error</td>
</tr>
<tr>
<td>0x01</td>
<td><strong>TE_ERROR_CLOSING_SOCKET</strong></td>
</tr>
<tr>
<td></td>
<td>Error found during closing of socket</td>
</tr>
<tr>
<td>0x02</td>
<td><strong>TE_ERROR_IN_SELECT_BEFORE_ACCEPT</strong></td>
</tr>
<tr>
<td></td>
<td>Error found before accept. The transporter will retry</td>
</tr>
<tr>
<td>0x03</td>
<td><strong>TE_INVALID_MESSAGE_LENGTH</strong></td>
</tr>
<tr>
<td></td>
<td>Error found in message (invalid message length)</td>
</tr>
<tr>
<td>0x04</td>
<td><strong>TE_INVALID_CHECKSUM</strong></td>
</tr>
<tr>
<td></td>
<td>Error found in message (checksum)</td>
</tr>
<tr>
<td>0x05</td>
<td><strong>TE_COULD_NOT_CREATE_SOCKET</strong></td>
</tr>
</tbody>
</table>

2480
Error found while creating socket (can't create socket)

0x06   TE_COULD_NOT_BIND_SOCKET

Error found while binding server socket

0x07   TE_LISTEN_FAILED

Error found while listening to server socket

0x08   TE_ACCEPT_RETURN_ERROR

Error found during accept (accept return error)

0x0b   TE_SHM_DISCONNECT

The remote node has disconnected

0x0c   TE_SHM_IPC_STAT

Unable to check shm segment

0x0d   TE_SHM_UNABLE_TO_CREATE_SEGMENT

Unable to create shm segment

0x0e   TE_SHM_UNABLE_TO_ATTACH_SEGMENT

Unable to attach shm segment

0x0f   TE_SHM_UNABLE_TO_REMOVE_SEGMENT

Unable to remove shm segment

0x10   TE_TOO_SMALL_SIGID

Sig ID too small

0x11   TE_TOO_LARGE_SIGID

Sig ID too large

0x12   TE_WAIT_STACK_FULL

Wait stack was full

0x13   TE_RECEIVE_BUFFER_FULL

Receive buffer was full

0x14   TE_SIGNAL_LOST_SEND_BUFFER_FULL

Send buffer was full, and trying to force send fails

0x15   TE_SIGNAL_LOST

Send failed for unknown reason (signal lost)
0x16  
**TE_SEND_BUFFER_FULL**  
The send buffer was full, but sleeping for a while solved

0x17  
**TE_SCI_LINK_ERROR**  
There is no link from this node to the switch

0x18  
**TE_SCI_UNABLE_TO_START_SEQUENCE**  
Could not start a sequence, because system resources are exumed or no sequence has been created

0x19  
**TE_SCI_UNABLE_TO_REMOVE_SEQUENCE**  
Could not remove a sequence

0x1a  
**TE_SCI_UNABLE_TO_CREATE_SEQUENCE**  
Could not create a sequence, because system resources are exempted. Must reboot

0x1b  
**TE_SCI_UNRECOVERABLE_DATA_TFX_ERROR**  
Tried to send data on redundant link but failed

0x1c  
**TE_SCI_CANNOT_INIT_LOCALSEGMENT**  
Cannot initialize local segment

0x1d  
**TE_SCI_CANNOT_MAP_REMOTESEGMENT**  
Cannot map remote segment

0x1e  
**TE_SCI_UNABLE_TO_UNMAP_SEGMENT**  
Cannot free the resources used by this segment (step 1)

0x1f  
**TE_SCI_UNABLE_TO_REMOVE_SEGMENT**  
Cannot free the resources used by this segment (step 2)

0x20  
**TE_SCI_UNABLE_TO_DISCONNECT_SEGMENT**  
Cannot disconnect from a remote segment

0x21  
**TE_SHM_IPC_PERMANENT**  
Shm ipc Permanent error

0x22  
**TE_SCI_UNABLE_TO_CLOSE_CHANNEL**  
Unable to close the sci channel and the resources allocated

---

**18.5.8 NDB Cluster Single User Mode**
Single user mode enables the database administrator to restrict access to the database system to a single API node, such as a MySQL server (SQL node) or an instance of ndb_restore. When entering single user mode, connections to all other API nodes are closed gracefully and all running transactions are aborted. No new transactions are permitted to start.

Once the cluster has entered single user mode, only the designated API node is granted access to the database.

You can use the ALL_STATUS command in the ndb_mgm client to see when the cluster has entered single user mode. You can also check the status column of the ndbinfo.nodes table (see Section 18.5.10.13, “The ndbinfo nodes Table”, for more information).

Example:

```
ndb_mgm> ENTER SINGLE USER MODE 5
```

After this command has executed and the cluster has entered single user mode, the API node whose node ID is 5 becomes the cluster's only permitted user.

The node specified in the preceding command must be an API node; attempting to specify any other type of node will be rejected.

**Note**

When the preceding command is invoked, all transactions running on the designated node are aborted, the connection is closed, and the server must be restarted.

The command EXIT SINGLE USER MODE changes the state of the cluster's data nodes from single user mode to normal mode. API nodes—such as MySQL Servers—waiting for a connection (that is, waiting for the cluster to become ready and available), are again permitted to connect. The API node denoted as the single-user node continues to run (if still connected) during and after the state change.

Example:

```
ndb_mgm> EXIT SINGLE USER MODE
```

There are two recommended ways to handle a node failure when running in single user mode:

- **Method 1:**
  1. Finish all single user mode transactions
  2. Issue the EXIT SINGLE USER MODE command
  3. Restart the cluster's data nodes

- **Method 2:**
  Restart storage nodes prior to entering single user mode.

**18.5.9 Quick Reference: NDB Cluster SQL Statements**

This section discusses several SQL statements that can prove useful in managing and monitoring a MySQL server that is connected to an NDB Cluster, and in some cases provide information about the cluster itself.

- SHOW ENGINE NDB STATUS, SHOW ENGINE NDBCLUSTER STATUS
The output of this statement contains information about the server’s connection to the cluster, creation and usage of NDB Cluster objects, and binary logging for NDB Cluster replication.

See Section 13.7.5.16, “SHOW ENGINE Statement”, for a usage example and more detailed information.

• **SHOW ENGINES**

This statement can be used to determine whether or not clustering support is enabled in the MySQL server, and if so, whether it is active.

See Section 13.7.5.17, “SHOW ENGINES Statement”, for more detailed information.

**Note**

In MySQL 5.1 and later, this statement does not support a `LIKE` clause. However, you can use `LIKE` to filter queries against the `INFORMATION_SCHEMA.ENGINES` table, as discussed in the next item.

• **SELECT * FROM INFORMATION_SCHEMA.ENGINES [WHERE ENGINE LIKE 'NDB%']**

This is the equivalent of `SHOW ENGINES`, but uses the `ENGINES` table of the `INFORMATION_SCHEMA` database. Unlike the case with the `SHOW ENGINES` statement, it is possible to filter the results using a `LIKE` clause, and to select specific columns to obtain information that may be of use in scripts. For example, the following query shows whether the server was built with NDB support and, if so, whether it is enabled:

```
mysql> SELECT SUPPORT FROM INFORMATION_SCHEMA.ENGINES WHERE ENGINE LIKE 'NDB%';
+---------+
| support |
+---------+
| ENABLED |
```

See Section 21.7, “The INFORMATION_SCHEMA ENGINES Table”, for more information.

• **SHOW VARIABLES LIKE 'NDB%'

This statement provides a list of most server system variables relating to the NDB storage engine, and their values, as shown here:

```
mysql> SHOW VARIABLES LIKE 'NDB%';
+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| ndb_autoincrement_prefetch_sz | 32    |
| ndb_cache_check_time    | 0     |
| ndb_extra_logging       | 0     |
| ndb_force_send          | ON    |
| ndb_index_stat_cache_entries | 32    |
| ndb_index_stat_enable   | OFF   |
| ndb_index_stat_update_freq | 20    |
| ndb_report_thresh_binlog_epoch_slip | 3     |
| ndb_report_thresh_binlog_mem_usage | 10    |
| ndb_use_copying_alter_table | OFF   |
| ndb_use_exact_count     | ON    |
| ndb_use_transactions   | ON    |
```

2484
Quick Reference: NDB Cluster SQL Statements

See Section 5.1.7, “Server System Variables”, for more information.

• SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES WHERE VARIABLE_NAME LIKE 'NDB%';

This statement is the equivalent of the SHOW VARIABLES statement described in the previous item, and provides almost identical output, as shown here:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
-> WHERE VARIABLE_NAME LIKE 'NDB%';
+-------------------------------------+----------------+
| VARIABLE_NAME                       | VARIABLE_VALUE |
+-------------------------------------+----------------+
| NDB_AUTOINCREMENT_PREFETCH_SZ       | 32             |
| NDB_CACHE_CHECK_TIME                | 0              |
| NDB_EXTRA_LOGGING                   | 0              |
| NDB_FORCE_SEND                      | ON             |
| NDB_INDEX_STAT_CACHE_ENTRIES        | 32             |
| NDB_INDEX_STAT_ENABLE               | OFF            |
| NDB_INDEX_STAT_UPDATE_FREQ          | 20             |
| NDB_REPORT_THRESH_BINLOG_EPOCH_SLIP | 3              |
| NDB_REPORT_THRESH_BINLOG_MEM_USAGE  | 10             |
| NDB_USE_COPYING_ALTER_TABLE         | OFF            |
| NDB_USE_EXACT_COUNT                 | ON             |
| NDB_USE_TRANSACTIONS                | ON             |
+-------------------------------------+----------------+
```

Unlike the case with the SHOW VARIABLES statement, it is possible to select individual columns. For example:

```
mysql> SELECT VARIABLE_VALUE
-> FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
-> WHERE VARIABLE_NAME = 'ndb_force_send';
+----------------+
| VARIABLE_VALUE |
+----------------+
| ON             |
+----------------+
```


• SHOW STATUS LIKE 'NDB%'

This statement shows at a glance whether or not the MySQL server is acting as a cluster SQL node, and if so, it provides the MySQL server's cluster node ID, the host name and port for the cluster management server to which it is connected, and the number of data nodes in the cluster, as shown here:

```
mysql> SHOW STATUS LIKE 'NDB%';
+-------------+----------------+
| Variable_name | Value          |
+-------------+----------------+
| Ndb_cluster_node_id | 10            |
| Ndb_config_from_host | 198.51.100.103 |
| Ndb_config_from_port | 1186          |
| Ndb_number_of_data_nodes | 4             |
+-------------+----------------+
```
If the MySQL server was built with clustering support, but it is not connected to a cluster, all rows in the output of this statement contain a zero or an empty string:

```
mysql> SHOW STATUS LIKE 'NDB%';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_cluster_node_id</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_config_from_host</td>
<td></td>
</tr>
<tr>
<td>Ndb_config_from_port</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_number_of_data_nodes</td>
<td>0</td>
</tr>
</tbody>
</table>

See also Section 13.7.5.36, “SHOW STATUS Statement”.

- `SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS WHERE VARIABLE_NAME LIKE 'NDB %';`

This statement provides similar output to the `SHOW STATUS` statement discussed in the previous item. However, unlike the case with `SHOW STATUS`, it is possible using the `SELECT` to extract values in SQL for use in scripts for monitoring and automation purposes.

See Section 21.9, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”, for more information.

You can also query the tables in the `ndbinfo` information database for real-time data about many NDB Cluster operations. See Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

### 18.5.10 ndbinfo: The NDB Cluster Information Database

`ndbinfo` is a database containing information specific to NDB Cluster.

This database contains a number of tables, each providing a different sort of data about NDB Cluster node status, resource usage, and operations. You can find more detailed information about each of these tables in the next several sections.

`ndbinfo` is included with NDB Cluster support in the MySQL Server; no special compilation or configuration steps are required; the tables are created by the MySQL Server when it connects to the cluster. You can verify that `ndbinfo` support is active in a given MySQL Server instance using `SHOW PLUGINS`; if `ndbinfo` support is enabled, you should see a row containing `ndbinfo` in the `Name` column and `ACTIVE` in the `Status` column, as shown here (emphasized text):

```
mysql> SHOW PLUGINS;
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Status</th>
<th>Type</th>
<th>Library</th>
<th>License</th>
</tr>
</thead>
<tbody>
<tr>
<td>binlog</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>mysql_native_password</td>
<td>ACTIVE</td>
<td>AUTHENTICATION</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>mysql_old_password</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>CSV</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>MEMORY</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>MRG_MYISAM</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>MyISAM</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>PERFORMANCE_SCHEMA</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>BLACKHOLE</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>ARCHIVE</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>ndbcluster</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>ndbinfo</td>
<td>ACTIVE</td>
<td>STORAGE ENGINE</td>
<td>NULL</td>
<td>GPL</td>
</tr>
<tr>
<td>ndb_transid_mysql_connection_map</td>
<td>ACTIVE</td>
<td>INFORMATION_SCHEMA</td>
<td>NULL</td>
<td>GPL</td>
</tr>
</tbody>
</table>
### ndbinfo: The NDB Cluster Information Database

<table>
<thead>
<tr>
<th>Engine</th>
<th>Support</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndbcluster</td>
<td>YES</td>
<td>Clustered, fault-tolerant tables</td>
</tr>
<tr>
<td>MRG_MYISAM</td>
<td>YES</td>
<td>Collection of identical MyISAM tables</td>
</tr>
<tr>
<td>ndbinfo</td>
<td>YES</td>
<td>NDB Cluster system information storage engine</td>
</tr>
<tr>
<td>CSV</td>
<td>YES</td>
<td>CSV storage engine</td>
</tr>
<tr>
<td>MEMORY</td>
<td>YES</td>
<td>Hash based, stored in memory, useful for temporary tables</td>
</tr>
<tr>
<td>FEDERATED</td>
<td>NO</td>
<td>Federated MySQL storage engine</td>
</tr>
<tr>
<td>ARCHIVE</td>
<td>YES</td>
<td>Archive storage engine</td>
</tr>
</tbody>
</table>

You can also do this by checking the output of `SHOW ENGINES` for a line including `ndbinfo` in the **Engine** column and **YES** in the **Support** column, as shown here (emphasized text):

```sql
mysql> SHOW ENGINES
+-----------------+---------+--------------------------------------------------+
<table>
<thead>
<tr>
<th>Engine</th>
<th>Support</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndbcluster</td>
<td>YES</td>
<td>Clustered, fault-tolerant tables</td>
</tr>
<tr>
<td>MRG_MYISAM</td>
<td>YES</td>
<td>Collection of identical MyISAM tables</td>
</tr>
<tr>
<td>ndbinfo</td>
<td>YES</td>
<td>NDB Cluster system information storage engine</td>
</tr>
<tr>
<td>CSV</td>
<td>YES</td>
<td>CSV storage engine</td>
</tr>
<tr>
<td>MEMORY</td>
<td>YES</td>
<td>Hash based, stored in memory, useful for temporary tables</td>
</tr>
<tr>
<td>FEDERATED</td>
<td>NO</td>
<td>Federated MySQL storage engine</td>
</tr>
<tr>
<td>ARCHIVE</td>
<td>YES</td>
<td>Archive storage engine</td>
</tr>
<tr>
<td>InnoDB</td>
<td>YES</td>
<td></td>
</tr>
</tbody>
</table>
```
If `ndbinfo` support is enabled, then you can access `ndbinfo` using SQL statements in `mysql` or another MySQL client. For example, you can see `ndbinfo` listed in the output of `SHOW DATABASES`, as shown here (emphasized text):

```
mysql> SHOW DATABASES;
+--------------------+
| Database           |
+--------------------+
| information_schema |
| mysql              |
| ndbinfo            |
| test               |
+--------------------+
4 rows in set (0.00 sec)
```

If the `mysqld` process was not started with the `--ndbcluster` option, `ndbinfo` is not available and is not displayed by `SHOW DATABASES`. If `mysqld` was formerly connected to an NDB Cluster but the cluster becomes unavailable (due to events such as cluster shutdown, loss of network connectivity, and so forth), `ndbinfo` and its tables remain visible, but an attempt to access any tables (other than `blocks` or `config_params`) fails with `Got error 157 'Connection to NDB failed' from NDBINFO`.

With the exception of the `blocks` and `config_params` tables, what we refer to as `ndbinfo` "tables" are actually views generated from internal NDB tables not normally visible to the MySQL Server.

All `ndbinfo` tables are read-only, and are generated on demand when queried. Because many of them are generated in parallel by the data nodes while other are specific to a given SQL node, they are not guaranteed to provide a consistent snapshot.

In addition, pushing down of joins is not supported on `ndbinfo` tables; so joining large `ndbinfo` tables can require transfer of a large amount of data to the requesting API node, even when the query makes use of a `WHERE` clause.

`ndbinfo` tables are not included in the query cache. (Bug #59831)

You can select the `ndbinfo` database with a `USE` statement, and then issue a `SHOW TABLES` statement to obtain a list of tables, just as for any other database, like this:

```
mysql> USE ndbinfo;
Database changed
mysql> SHOW TABLES;
```

2488
The `cluster_operations`, `cluster_transactions`, `server_operations`, `server_transactions`, `threadblocks`, and `threadstat` tables were added in NDB 7.2.2. The `arbitrator_validity_detail`, `arbitrator_validity_summary`, and `membership` tables were added in NDB 7.2.10.

You can execute `SELECT` statements against these tables, just as you would normally expect:

```sql
mysql> SELECT * FROM memoryusage;
```

<table>
<thead>
<tr>
<th>node_id</th>
<th>memory_type</th>
<th>used</th>
<th>used_pages</th>
<th>total</th>
<th>total_pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Data memory</td>
<td>753664</td>
<td>23</td>
<td>1073741824</td>
<td>32768</td>
</tr>
<tr>
<td>5</td>
<td>Index memory</td>
<td>163840</td>
<td>20</td>
<td>1074003968</td>
<td>131104</td>
</tr>
<tr>
<td>5</td>
<td>Long message buffer</td>
<td>2304</td>
<td>9</td>
<td>67108864</td>
<td>262144</td>
</tr>
<tr>
<td>6</td>
<td>Data memory</td>
<td>753664</td>
<td>23</td>
<td>1073741824</td>
<td>32768</td>
</tr>
<tr>
<td>6</td>
<td>Index memory</td>
<td>163840</td>
<td>20</td>
<td>1074003968</td>
<td>131104</td>
</tr>
<tr>
<td>6</td>
<td>Long message buffer</td>
<td>2304</td>
<td>9</td>
<td>67108864</td>
<td>262144</td>
</tr>
</tbody>
</table>

6 rows in set (0.02 sec)

More complex queries, such as the two following `SELECT` statements using the `memoryusage` table, are possible:

```sql
mysql> SELECT SUM(used) as 'Data Memory Used, All Nodes'
       > FROM memoryusage
       > WHERE memory_type = 'Data memory';
```

```
<table>
<thead>
<tr>
<th>Data Memory Used, All Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>6460</td>
</tr>
</tbody>
</table>
```

1 row in set (0.37 sec)

```sql
mysql> SELECT SUM(max) as 'Total IndexMemory Available'
       > FROM memoryusage
       > WHERE memory_type = 'Index memory';
```

```
<table>
<thead>
<tr>
<th>Total IndexMemory Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>25664</td>
</tr>
</tbody>
</table>
```
ndbinfo: The NDB Cluster Information Database

The ndbinfo table and column names are case-sensitive (as is the name of the ndbinfo database itself). These identifiers are in lowercase. Trying to use the wrong lettercase results in an error, as shown in this example:

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+
| node_id | uptime | status  | start_phase |
+---------+--------+---------+-------------+
|       1 |  13602 | STARTED |           0 |
|       2 |     16 | STARTED |           0 |
+---------+--------+---------+-------------+
2 rows in set (0.04 sec)
```

```
mysql> SELECT * FROM Nodes;
ERROR 1146 (42S02): Table 'ndbinfo.Nodes' doesn't exist
```

mysqldump ignores the ndbinfo database entirely, and excludes it from any output. This is true even when using the `--databases` or `--all-databases` option.

NDB Cluster also maintains tables in the INFORMATION_SCHEMA information database, including the FILES table which contains information about files used for NDB Cluster Disk Data storage. For more information, see Section 21.30, “INFORMATION_SCHEMA NDB Cluster Tables”.

### 18.5.10.1 The ndbinfo arbitrator_validity_detail Table

The arbitrator_validity_detail table shows the view that each data node in the cluster has of the arbitrator. It is a subset of the membership table.

The following table provides information about the columns in the arbitrator_validity_detail table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>This node's node ID</td>
</tr>
<tr>
<td>arbitrator</td>
<td>integer</td>
<td>Node ID of arbitrator</td>
</tr>
<tr>
<td>arb_ticket</td>
<td>string</td>
<td>Internal identifier used to track arbitration</td>
</tr>
<tr>
<td>arb_connected</td>
<td>Yes or No</td>
<td>Whether this node is connected to the arbitrator</td>
</tr>
<tr>
<td>arb_state</td>
<td>Enumeration (see text)</td>
<td>Arbitration state</td>
</tr>
</tbody>
</table>

The node ID is the same as that reported by ndb_mgm -e "SHOW".

All nodes should show the same arbitrator and arb_ticket values as well as the same arb_state value. Possible arb_state values are ARBIT_NULL, ARBIT_INIT, ARBIT_FIND, ARBIT_PREP1, ARBIT_PREP2, ARBIT_START, ARBIT_RUN, ARBIT_CHOOSE, ARBIT_CRASH, and UNKNOWN.

arb_connected shows whether the current node is connected to the arbitrator.

Like the membership and arbitrator_validity_summary tables, this table was added in NDB 7.2.10.
18.5.10.2 The ndbinfo arbitrator_validity_summary Table

The arbitrator_validity_summary table provides a composite view of the arbitrator with regard to the cluster's data nodes.

The following table provides information about the columns in the arbitrator_validity_summary table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>arbitrator</td>
<td>integer</td>
<td>Node ID of arbitrator</td>
</tr>
<tr>
<td>arb_ticket</td>
<td>string</td>
<td>Internal identifier used to track arbitration</td>
</tr>
<tr>
<td>arb_connected</td>
<td>Yes or No</td>
<td>Whether this arbitrator is connected to the cluster</td>
</tr>
<tr>
<td>consensus_count</td>
<td>integer</td>
<td>Number of data nodes that see this node as arbitrator</td>
</tr>
</tbody>
</table>

In normal operations, this table should have only 1 row for any appreciable length of time. If it has more than 1 row for longer than a few moments, then either not all nodes are connected to the arbitrator, or all nodes are connected, but do not agree on the same arbitrator.

The arbitrator column shows the arbitrator's node ID.

arb_ticket is the internal identifier used by this arbitrator.

arb_connected shows whether this node is connected to the cluster as an arbitrator.

Like the membership and arbitrator_validity_detail tables, this table was added in NDB 7.2.10.

18.5.10.3 The ndbinfo blocks Table

The blocks table is a static table which simply contains the names and internal IDs of all NDB kernel blocks (see NDB Kernel Blocks). It is for use by the other ndbinfo tables (most of which are actually views) in mapping block numbers to block names for producing human-readable output.

The following table provides information about the columns in the blocks table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>block_number</td>
<td>integer</td>
<td>Block number</td>
</tr>
<tr>
<td>block_name</td>
<td>string</td>
<td>Block name</td>
</tr>
</tbody>
</table>

To obtain a list of all block names, simply execute SELECT block_name FROM ndbinfo.blocks. Although this is a static table, its content can vary between different NDB Cluster releases.

18.5.10.4 The ndbinfo cluster_operations Table
The `cluster_operations` table provides a per-operation (stateful primary key op) view of all activity in the NDB Cluster from the point of view of the local data management (LQH) blocks (see The DBLQH Block).

The following table provides information about the columns in the `cluster_operations` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

### Table 18.263 Columns of the cluster_operations table

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>Node ID of reporting LQH block</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>LQH block instance</td>
</tr>
<tr>
<td>transid</td>
<td>integer</td>
<td>Transaction ID</td>
</tr>
<tr>
<td>operation_type</td>
<td>string</td>
<td>Operation type (see text for possible values)</td>
</tr>
<tr>
<td>state</td>
<td>string</td>
<td>Operation state (see text for possible values)</td>
</tr>
<tr>
<td>tableid</td>
<td>integer</td>
<td>Table ID</td>
</tr>
<tr>
<td>fragmented</td>
<td>integer</td>
<td>Fragment ID</td>
</tr>
<tr>
<td>client_node_id</td>
<td>integer</td>
<td>Client node ID</td>
</tr>
<tr>
<td>client_block_ref</td>
<td>integer</td>
<td>Client block reference</td>
</tr>
<tr>
<td>tc_node_id</td>
<td>integer</td>
<td>Transaction coordinator node ID</td>
</tr>
<tr>
<td>tc_block_no</td>
<td>integer</td>
<td>Transaction coordinator block number</td>
</tr>
<tr>
<td>tc_block_instance</td>
<td>integer</td>
<td>Transaction coordinator block instance</td>
</tr>
</tbody>
</table>

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `operation_type` column can take any one of the values `READ`, `READ-SH`, `READ-EX`, `INSERT`, `UPDATE`, `DELETE`, `WRITE`, `UNLOCK`, `REFRESH`, `SCAN`, `SCAN-SH`, `SCAN-EX`, or `<unknown>`.

The `state` column can have any one of the values `ABORT_QUEUED`, `ABORT_STOPPED`, `COMMITTED`, `COMMIT_QUEUED`, `COMMIT_STOPPED`, `COPY_CLOSE_STOPPED`, `COPY_FIRST_STOPPED`, `COPY_STOPPED`, `COPY_TUPKEY`, `IDLE`, `LOG_ABORT_QUEUED`, `LOG_COMMIT_QUEUED`, `LOG_COMMIT_QUEUED_WAIT_SIGNAL`, `LOG_COMMIT_WRITTEN`, `LOG_COMMIT_WRITTEN_WAIT_SIGNAL`, `LOG_STOPPED`, `LOG_STOPPED_STOPPED`, `LOG_STOPPED_WAIT_SIGNAL`, `LOG_STOPPED_WAIT_SIGNAL`, `SCAN_CLOSE_STOPPED`, `SCANCLOSE_STOPPED`, `SCAN_FIRST_STOPPED`, `SCAN_RELEASE_STOPPED`, `SCAN_STATE_USED`, `SCAN_STOPPED`, `SCAN_TUPKEY`, `STOPPED`, `TC_NOT_CONNECTED`, `WAIT_ACC`, `WAIT_ACC_ABORT`, `WAIT_AI_AFTER_ABORT`, `WAIT_ATTR`, `WAIT_SCAN_AI`, `WAIT_TUP`, `WAIT_TUP_KEYINFO`, `WAIT_TUP_COMMIT`, or `WAIT_TUP_TO_ABORT`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb $dblqh_tconnect_state` table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of `ndb_show_tables`.

The `fragid` is the same as the partition number seen in the output of `ndb_desc --extra-partition-info` (short form `-p`).

In `client_node_id` and `client_block_ref`, `client` refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).
The block_instance and tc_block_instance column provide, respectively, the DBLQH and DBTC block instance numbers. You can use these along with the block names to obtain information about specific threads from the threadblocks table.

This table was added in NDB 7.2.2.

### 18.5.10.5 The ndbinfo cluster_transactions Table

The cluster_transactions table shows information about all ongoing transactions in an NDB Cluster.

The following table provides information about the columns in the cluster_transactions table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>Node ID of transaction coordinator</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>TC block instance</td>
</tr>
<tr>
<td>transid</td>
<td>integer</td>
<td>Transaction ID</td>
</tr>
<tr>
<td>state</td>
<td>string</td>
<td>Operation state (see text for possible values)</td>
</tr>
<tr>
<td>count_operations</td>
<td>integer</td>
<td>Number of stateful primary key operations in transaction (includes reads with locks, as well as DML operations)</td>
</tr>
<tr>
<td>outstanding_operations</td>
<td>integer</td>
<td>Operations still being executed in local data management blocks</td>
</tr>
<tr>
<td>inactive_seconds</td>
<td>integer</td>
<td>Time spent waiting for API</td>
</tr>
<tr>
<td>client_node_id</td>
<td>integer</td>
<td>Client node ID</td>
</tr>
<tr>
<td>client_block_ref</td>
<td>integer</td>
<td>Client block reference</td>
</tr>
</tbody>
</table>

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's getTransactionId() method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

block_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the threadblocks table.

The state column can have any one of the values CS_ABORTING, CS_COMMITTING, CS_COMMIT_SENT, CS_COMPLETE_SENT, CS_COMPLETED, CS_DISCONNECTED, CS_FAIL_ABORTED, CS_FAIL_ABORTING, CS_FAIL_COMMITTED, CS_FAIL_COMMITTING, CS_FAIL_COMPLETED, CS_FAIL_PREPARED, CS_PREPARE_TO_COMMIT, CS_RECEIVING, CS_REC_COMMITTING, CS_RESTART, CS_SEND_FIRE_TRIG_REQ, CS_STARTED, CS_START_COMMITTING, CS_START_SCAN, CS_WAIT_ABORT_CONF, CS_WAIT_COMMIT_CONF, CS_WAIT_COMPLETE_CONF, CS_WAIT_FIRE_TRIG_REQ. (If the MySQL Server is running with ndbinfo_show_hidden enabled, you can view this list of states by selecting from the ndb$dbtc$apiconnect_state table, which is normally hidden.)

In client_node_id and client_block_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The tc_block_instance column provides the DBTC block instance number. You can use this along with the block name to obtain information about specific threads from the threadblocks table.
This table was added in NDB 7.2.2.

18.5.10.6 The ndbinfo config_params Table

The `config_params` table is a static table which provides the names and internal ID numbers of and other information about NDB Cluster configuration parameters.

The following table provides information about the columns in the `config_params` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>param_number</td>
<td>integer</td>
<td>The parameter's internal ID number</td>
</tr>
<tr>
<td>param_name</td>
<td>string</td>
<td>The name of the parameter</td>
</tr>
</tbody>
</table>

Although this is a static table, its content can vary between NDB Cluster installations, since supported parameters can vary due to differences between software releases, cluster hardware configurations, and other factors.

18.5.10.7 The ndbinfo counters Table

The `counters` table provides running totals of events such as reads and writes for specific kernel blocks and data nodes. Counts are kept from the most recent node start or restart; a node start or restart resets all counters on that node. Not all kernel blocks have all types of counters.

The following table provides information about the columns in the `counters` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The data node ID</td>
</tr>
<tr>
<td>block_name</td>
<td>string</td>
<td>Name of the associated NDB kernel block (see NDB Kernel Blocks)</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>Block instance</td>
</tr>
<tr>
<td>counter_id</td>
<td>integer</td>
<td>The counter's internal ID number; normally an integer between 1 and 10, inclusive.</td>
</tr>
<tr>
<td>counter_name</td>
<td>string</td>
<td>The name of the counter. See text for names of individual counters and the NDB kernel block with which each counter is associated.</td>
</tr>
<tr>
<td>val</td>
<td>integer</td>
<td>The counter's value</td>
</tr>
</tbody>
</table>

Each counter is associated with a particular NDB kernel block. Prior to NDB 7.2.0, this was limited to either the DBLQH kernel block or the DBTC kernel block. In NDB 7.2.0 and later, a number of counters relating to the DBSPJ kernel block are also available; these counters are described later in this section.

The OPERATIONS counter is associated with the DBLQH (local query handler) kernel block (see The DBLQH Block). A primary-key read counts as one operation, as does a primary-key update. For reads,
there is one operation in DBLQH per operation in DBTC. For writes, there is one operation counted per replica.

The ATTRINFO, TRANSACTIONS, COMMITS, READS, LOCAL_READS, SIMPLE_READS, WRITES, LOCAL_WRITES, ABORTS, TABLE_SCANS, and RANGE_SCANS counters are associated with the DBTC (transaction co-ordinator) kernel block (see The DBTC Block).

LOCAL_WRITES and LOCAL_READS are primary-key operations using a transaction coordinator in a node that also holds the primary replica of the record.

The READS counter includes all reads. LOCAL_READS includes only those reads of the primary replica on the same node as this transaction coordinator. SIMPLE_READS includes only those reads in which the read operation is the beginning and ending operation for a given transaction. Simple reads do not hold locks but are part of a transaction, in that they observe uncommitted changes made by the transaction containing them but not of any other uncommitted transactions. Such reads are “simple” from the point of view of the TC block; since they hold no locks they are not durable, and once DBTC has routed them to the relevant LQH block, it holds no state for them.

ATTRINFO keeps a count of the number of times an interpreted program is sent to the data node. See NDB Protocol Messages, for more information about ATTRINFO messages in the NDB kernel.

NDB 7.2.0, as part of its implementation of distributed pushed-down joins, adds the LOCAL_TABLE_SCANS_SENT, READS_RECEIVED, PRUNED_RANGE_SCANS_RECEIVED, RANGE_SCANS_RECEIVED, LOCAL_READS_SENT, CONST_PRUNED_RANGE_SCANS_RECEIVED, LOCAL_RANGE_SCANS_SENT, REMOTE_READS_SENT, REMOTE_RANGE_SCANS_SENT, READS_NOT_FOUND, SCAN_BATCHES_RETURNED, TABLE_SCANS_RECEIVED, and SCAN_ROWS_RETURNED counters. These counters are associated with the DBSPJ (select push-down join) kernel block (see The DBSPJ Block).

The block_name and block_instance columns provide, respectively, the applicable NDB kernel block name and instance number. You can use these to obtain information about specific threads from the threadblocks table.

A number of counters increasing the visibility of transporter overload and send buffer sizing when troubleshooting such issues were added in NDB 7.2.10. (Bug #15935206) For each LQH instance, there is one instance of each counter in the following list:

- **LQHKEY_OVERLOAD**: Number of primary key requests rejected at the LQH block instance due to transporter overload
- **LQHKEY_OVERLOAD_TC**: Count of instances of LQHKEY_OVERLOAD where the TC node transporter was overloaded
- **LQHKEY_OVERLOAD_READER**: Count of instances of LQHKEY_OVERLOAD where the API reader (reads only) node was overloaded.
- **LQHKEY_OVERLOAD_NODE_PEER**: Count of instances of LQHKEY_OVERLOAD where the next backup data node (writes only) was overloaded.
- **LQHKEY_OVERLOAD_SUBSCRIBER**: Count of instances of LQHKEY_OVERLOAD where a event subscriber (writes only) was overloaded.
- **LQHSCAN_SLOWDOWNS**: Count of instances where a fragment scan batch size was reduced due to scanning API transporter overload.

18.5.10.8 The ndbinfo diskpagebuffer Table
The `diskpagebuffer` table provides statistics about disk page buffer usage by NDB Cluster Disk Data tables.

The following table provides information about the columns in the `diskpagebuffer` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

**Table 18.267 Columns of the `diskpagebuffer` table**

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The data node ID</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>Block instance</td>
</tr>
<tr>
<td>pages_written</td>
<td>integer</td>
<td>Number of pages written to disk.</td>
</tr>
<tr>
<td>pages_written_lcp</td>
<td>integer</td>
<td>Number of pages written by local checkpoints.</td>
</tr>
<tr>
<td>pages_read</td>
<td>integer</td>
<td>Number of pages read from disk</td>
</tr>
<tr>
<td>log_waits</td>
<td>integer</td>
<td>Number of page writes waiting for log to be written to disk</td>
</tr>
<tr>
<td>page_requests_direct_return</td>
<td>integer</td>
<td>Number of requests for pages that were available in buffer</td>
</tr>
<tr>
<td>page_requests_wait_queue</td>
<td>integer</td>
<td>Number of requests that had to wait for pages to become available in buffer</td>
</tr>
<tr>
<td>page_requests_wait_io</td>
<td>integer</td>
<td>Number of requests that had to be read from pages on disk (pages were unavailable in buffer)</td>
</tr>
</tbody>
</table>

You can use this table with NDB Cluster Disk Data tables to determine whether `DiskPageBufferMemory` is sufficiently large to allow data to be read from the buffer rather than from disk; minimizing disk seeks can help improve performance of such tables.

You can determine the proportion of reads from `DiskPageBufferMemory` to the total number of reads using a query such as this one, which obtains this ratio as a percentage:

```sql
SELECT node_id, 100 * page_requests_direct_return / (page_requests_direct_return + page_requests_wait_io) AS hit_ratio FROM ndbinfo.diskpagebuffer;
```

The result from this query should be similar to what is shown here, with one row for each data node in the cluster (in this example, the cluster has 4 data nodes):

```
+---------+-----------+
<table>
<thead>
<tr>
<th>node_id</th>
<th>hit_ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>97.6744</td>
</tr>
<tr>
<td>6</td>
<td>97.6879</td>
</tr>
<tr>
<td>7</td>
<td>98.1776</td>
</tr>
<tr>
<td>8</td>
<td>98.1343</td>
</tr>
</tbody>
</table>
+---------+-----------+
4 rows in set (0.00 sec)
```

`hit_ratio` values approaching 100% indicate that only a very small number of reads are being made from disk rather than from the buffer, which means that Disk Data read performance is approaching an optimum level. If any of these values are less than 95%, this is a strong indicator that the setting for `DiskPageBufferMemory` needs to be increased in the `config.ini` file.
Note

A change in `DiskPageBufferMemory` requires a rolling restart of all of the cluster’s data nodes before it takes effect.

The `block_instance` column provides the NDB kernel block instance number. You can use this to obtain information about specific threads from the `threadblocks` table.

### 18.5.10.9 The ndbinfo logbuffers Table

The `logbuffer` table provides information on NDB Cluster log buffer usage.

The following table provides information about the columns in the `logbuffers` table. For each column, the table shows the name, data type, and a brief description.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The ID of this data node.</td>
</tr>
<tr>
<td>log_type</td>
<td>string</td>
<td>Type of log, one of: <code>REDO</code> or <code>DD-UNDO</code>.</td>
</tr>
<tr>
<td>log_id</td>
<td>integer</td>
<td>The log ID.</td>
</tr>
<tr>
<td>log_part</td>
<td>integer</td>
<td>The log part number.</td>
</tr>
<tr>
<td>total</td>
<td>integer</td>
<td>Total space available for this log.</td>
</tr>
<tr>
<td>used</td>
<td>integer</td>
<td>Space used by this log.</td>
</tr>
</tbody>
</table>

### 18.5.10.10 The ndbinfo logspaces Table

This table provides information about NDB Cluster log space usage.

The following table provides information about the columns in the `logspaces` table. For each column, the table shows the name, data type, and a brief description.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The ID of this data node.</td>
</tr>
<tr>
<td>log_type</td>
<td>string</td>
<td>Type of log; one of: <code>REDO</code> or <code>DD-UNDO</code>.</td>
</tr>
<tr>
<td>log_id</td>
<td>integer</td>
<td>The log ID.</td>
</tr>
<tr>
<td>log_part</td>
<td>integer</td>
<td>The log part number.</td>
</tr>
<tr>
<td>total</td>
<td>integer</td>
<td>Total space available for this log.</td>
</tr>
<tr>
<td>used</td>
<td>integer</td>
<td>Space used by this log.</td>
</tr>
</tbody>
</table>

### 18.5.10.11 The ndbinfo membership Table

The `membership` table describes the view that each data node has of all the others in the cluster, including node group membership, president node, arbitrator, arbitrator successor, arbitrator connection states, and other information.

The following table provides information about the columns in the `membership` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.
Table 18.270 Columns of the membership table

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>This node's node ID</td>
</tr>
<tr>
<td>group_id</td>
<td>integer</td>
<td>Node group to which this node belongs</td>
</tr>
<tr>
<td>left_node</td>
<td>integer</td>
<td>Node ID of the previous node</td>
</tr>
<tr>
<td>right_node</td>
<td>integer</td>
<td>Node ID of the next node</td>
</tr>
<tr>
<td>president</td>
<td>integer</td>
<td>President's node ID</td>
</tr>
<tr>
<td>successor</td>
<td>integer</td>
<td>Node ID of successor to president</td>
</tr>
<tr>
<td>succession_order</td>
<td>integer</td>
<td>Order in which this node succeeds to presidency</td>
</tr>
<tr>
<td>Conf_HB_order</td>
<td>integer</td>
<td>-</td>
</tr>
<tr>
<td>arbitrator</td>
<td>integer</td>
<td>Node ID of arbitrator</td>
</tr>
<tr>
<td>arb_ticket</td>
<td>string</td>
<td>Internal identifier used to track arbitration</td>
</tr>
<tr>
<td>arb_state</td>
<td>Enumeration (see text)</td>
<td>Arbitration state</td>
</tr>
<tr>
<td>arb_connected</td>
<td>Yes or No</td>
<td>Whether this node is connected to the arbitrator</td>
</tr>
<tr>
<td>connected_rank1_arbs</td>
<td>List of node IDs</td>
<td>Connected arbitrators of rank 1</td>
</tr>
<tr>
<td>connected_rank2_arbs</td>
<td>List of node IDs</td>
<td>Connected arbitrators of rank 1</td>
</tr>
</tbody>
</table>

The node ID and node group ID are the same as reported by `ndb_mgm -e "SHOW"`.

`left_node` and `right_node` are defined in terms of a model that connects all data nodes in a circle, in order of their node IDs, similar to the ordering of the numbers on a clock dial, as shown here:

Figure 18.6 Circular Arrangement of NDB Cluster Nodes

In this example, we have 8 data nodes, numbered 5, 6, 7, 8, 12, 13, 14, and 15, ordered clockwise in a circle. We determine “left” and “right” from the interior of the circle. The node to the left of node 5 is node 15, and the node to the right of node 5 is node 6. You can see all these relationships by running the following query and observing the output:

```
mysql> SELECT node_id, left_node, right_node
  -> FROM ndbinfo.membership;
+---------+-----------+------------+
<table>
<thead>
<tr>
<th>node_id</th>
<th>left_node</th>
<th>right_node</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>14</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>
```
The designations “left” and “right” are used in the event log in the same way.

The president node is the node viewed by the current node as responsible for setting an arbitrator (see NDB Cluster Start Phases). If the president fails or becomes disconnected, the current node expects the node whose ID is shown in the successor column to become the new president. The succession_order column shows the place in the succession queue that the current node views itself as having.

In a normal NDB Cluster, all data nodes should see the same node as president, and the same node (other than the president) as its successor. In addition, the current president should see itself as 1 in the order of succession, the successor node should see itself as 2, and so on.

All nodes should show the same arb_ticket values as well as the same arb_state values. Possible arb_state values are ARBIT_NULL, ARBIT_INIT, ARBIT_FIND, ARBIT_PREP1, ARBIT_PREP2, ARBIT_START, ARBIT_RUN, ARBIT_CHOOSE, ARBIT_CRASH, and UNKNOWN.

arb_connected shows whether this node is connected to the node shown as this node's arbitrator.

The connected_rank1_arbs and connected_rank2_arbs columns each display a list of 0 or more arbitrators having an ArbitrationRank equal to 1, or to 2, respectively.

Note
Both management nodes and API nodes are eligible to become arbitrators.

Like the arbitrator_validity_detail and arbitrator_validity_summary tables, this table was added in NDB 7.2.10.

18.5.10.12 The ndbinfo memoryusage Table

Querying this table provides information similar to that provided by the ALL REPORT MemoryUsage command in the ndb_mgm client, or logged by ALL DUMP 1000.

The following table provides information about the columns in the memoryusage table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Table 18.271 Columns of the memoryusage table

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The node ID of this data node.</td>
</tr>
<tr>
<td>memory_type</td>
<td>string</td>
<td>One of Data memory, Index memory, or Long message buffer.</td>
</tr>
<tr>
<td>used</td>
<td>integer</td>
<td>Number of bytes currently used for data memory or index memory by this data node.</td>
</tr>
</tbody>
</table>
The total column represents the total amount of memory in bytes available for the given resource (data memory or index memory) on a particular data node. This number should be approximately equal to the setting of the corresponding configuration parameter in the config.ini file.

Suppose that the cluster has 2 data nodes having node IDs 5 and 6, and the config.ini file contains the following:

```
[ndbd default]
DataMemory = 1G
IndexMemory = 1G
```

Suppose also that the value of the LongMessageBuffer configuration parameter is allowed to assume its default (64 MB in NDB 7.2.16 and later).

The following query shows approximately the same values:

```
mysql> SELECT node_id, memory_type, total
    > FROM ndbinfo.memoryusage;
+---------+---------------------+------------+
<table>
<thead>
<tr>
<th>node_id</th>
<th>memory_type</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Data memory</td>
<td>1073741824</td>
</tr>
<tr>
<td>5</td>
<td>Index memory</td>
<td>1074003968</td>
</tr>
<tr>
<td>6</td>
<td>Long message buffer</td>
<td>67108864</td>
</tr>
<tr>
<td>6</td>
<td>Data memory</td>
<td>1073741824</td>
</tr>
<tr>
<td>6</td>
<td>Index memory</td>
<td>1074003968</td>
</tr>
<tr>
<td>6</td>
<td>Long message buffer</td>
<td>67108864</td>
</tr>
</tbody>
</table>
+---------+---------------------+------------+
6 rows in set (0.00 sec)
```

In this case, the total column values for index memory are slightly higher than the value set of IndexMemory due to internal rounding.

For the used_pages and total_pages columns, resources are measured in pages, which are 32K in size for DataMemory and 8K for IndexMemory. For long message buffer memory, the page size is 256 bytes.

Long message buffer information can be found in this table beginning with NDB 7.2.16; in earlier versions of NDB Cluster 7.2, only data memory and index memory were included.

### 18.5.10.13 The ndbinfo nodes Table

This table contains information on the status of data nodes. For each data node that is running in the cluster, a corresponding row in this table provides the node’s node ID, status, and uptime. For nodes that are starting, it also shows the current start phase.

The following table provides information about the columns in the nodes table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.
Table 18.272 Columns of the nodes table

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The data node's unique node ID in the cluster.</td>
</tr>
<tr>
<td>uptime</td>
<td>integer</td>
<td>Time since the node was last started, in seconds.</td>
</tr>
<tr>
<td>status</td>
<td>string</td>
<td>Current status of the data node; see text for possible values.</td>
</tr>
<tr>
<td>start_phase</td>
<td>integer</td>
<td>If the data node is starting, the current start phase.</td>
</tr>
<tr>
<td>config_generation</td>
<td>integer</td>
<td>The version of the cluster configuration file in use on this data node.</td>
</tr>
</tbody>
</table>

The `uptime` column shows the time in seconds that this node has been running since it was last started or restarted. This is a `BIGINT` value. This figure includes the time actually needed to start the node; in other words, this counter starts running the moment that `ndbd` or `ndbmtd` is first invoked; thus, even for a node that has not yet finished starting, `uptime` may show a nonzero value.

The `status` column shows the node's current status. This is one of: `NOTHING`, `CMVMI`, `STARTING`, `STARTED`, `SINGLEUSER`, `STOPPING_1`, `STOPPING_2`, `STOPPING_3`, or `STOPPING_4`. When the status is `STARTING`, you can see the current start phase in the `start_phase` column (see later in this section). `SINGLEUSER` is displayed in the `status` column for all data nodes when the cluster is in single user mode (see Section 18.5.8, “NDB Cluster Single User Mode”). Seeing one of the `STOPPING` states does not necessarily mean that the node is shutting down but can mean rather that it is entering a new state. For example, if you put the cluster in single user mode, you can sometimes see data nodes report their state briefly as `STOPPING_2` before the status changes to `SINGLEUSER`.

The `start_phase` column uses the same range of values as those used in the output of the `ndb_mgm` client `node_id STATUS` command (see Section 18.5.2, “Commands in the NDB Cluster Management Client”). If the node is not currently starting, then this column shows `0`. For a listing of NDB Cluster start phases with descriptions, see Section 18.5.1, “Summary of NDB Cluster Start Phases”.

The `config_generation` column shows which version of the cluster configuration is in effect on each data node. This can be useful when performing a rolling restart of the cluster in order to make changes in configuration parameters. For example, from the output of the following `SELECT` statement, you can see that node 3 is not yet using the latest version of the cluster configuration (6) although nodes 1, 2, and 4 are doing so:

```
mysql> USE ndbinfo;
Database changed
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 | 10462  | STARTED |           0 |                 6 |
|       2 | 10460  | STARTED |           0 |                 6 |
|       3 | 10457  | STARTED |           0 |                 5 |
|       4 | 10455  | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
2 rows in set (0.04 sec)
```

Therefore, for the case just shown, you should restart node 3 to complete the rolling restart of the cluster.

Nodes that are stopped are not accounted for in this table. Suppose that you have an NDB Cluster with 4 data nodes (node IDs 1, 2, 3 and 4), and all nodes are running normally, then this table contains 4 rows, 1 for each data node.
If you shut down one of the nodes, only the nodes that are still running are represented in the output of this `SELECT` statement, as shown here:

```
ndb_mgm> 2 STOP
Node 2: Node shutdown initiated
Node 2: Node shutdown completed.
Node 2 has shutdown.
```

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
|---------+--------+---------+-------------+-------------------|
|       1 |  11807 | STARTED |           0 |                 6 |
|       3 |  11802 | STARTED |           0 |                 6 |
|       4 |  11800 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
3 rows in set (0.02 sec)
```

### 18.5.10.14 The ndbinfo resources Table

This table provides information about data node resource availability and usage.

These resources are sometimes known as *super-pools*.

The following table provides information about the columns in the `resources` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>The unique node ID of this data node.</td>
</tr>
<tr>
<td>resource_name</td>
<td>string</td>
<td>Name of the resource; see text.</td>
</tr>
<tr>
<td>reserved</td>
<td>integer</td>
<td>The amount reserved for this resource.</td>
</tr>
<tr>
<td>used</td>
<td>integer</td>
<td>The amount actually used by this resource.</td>
</tr>
<tr>
<td>max</td>
<td>integer</td>
<td>The maximum amount of this resource used, since the node was last started.</td>
</tr>
</tbody>
</table>

The `resource_name` can be one of the names shown in the following table:

<table>
<thead>
<tr>
<th>Resource name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESERVED</td>
<td>Reserved by the system; cannot be overridden.</td>
</tr>
</tbody>
</table>
### ndbinfo: The NDB Cluster Information Database

<table>
<thead>
<tr>
<th>Resource name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISK_OPERATIONS</td>
<td>If a log file group is allocated, the size of the undo log buffer is used to set the size of this resource. This resource is used only to allocate the undo log buffer for an undo log file group; there can only be one such group. Overallocation occurs as needed by <code>CREATE LOGFILE GROUP</code>.</td>
</tr>
<tr>
<td>DISK_RECORDS</td>
<td>Records allocated for Disk Data operations.</td>
</tr>
<tr>
<td>DATA_MEMORY</td>
<td>Used for main memory tuples, indexes, and hash indexes. Sum of DataMemory and IndexMemory, plus 8 pages of 32 KB each if IndexMemory has been set. Cannot be overallocated.</td>
</tr>
<tr>
<td>JOBBUFFER</td>
<td>Used for allocating job buffers by the NDB scheduler; cannot be overallocated. This is approximately 2 MB per thread plus a 1 MB buffer in both directions for all threads that can communicate. For large configurations this consume several GB.</td>
</tr>
<tr>
<td>FILE_BUFFERS</td>
<td>Used by the redo log handler in the DBLQH kernel block; cannot be overallocated. Size is <code>NoOfFragmentLogParts * RedoBuffer</code>, plus 1 MB per log file part.</td>
</tr>
<tr>
<td>TRANSPORTER_BUFFERS</td>
<td>Used for send buffers by <code>ndbmtd</code>; the sum of <code>TotalSendBufferMemory</code> and <code>ExtraSendBufferMemory</code>. This resource that can be overallocated by up to 25 percent. <code>TotalSendBufferMemory</code> is calculated by summing the send buffer memory per node, the default value of which is 2 MB. Thus, in a system having four data nodes and eight API nodes, the data nodes have 12 * 2 MB send buffer memory. <code>ExtraSendBufferMemory</code> is used by <code>ndbmtd</code> and amounts to 2 MB extra memory per thread. Thus, with 4 LDM threads, 2 TC threads, 1 main thread, 1 replication thread, and 2 receive threads, <code>ExtraSendBufferMemory</code> is 10 * 2 MB. Overallocation of this resource can be performed by setting the <code>SharedGlobalMemory</code> data node configuration parameter.</td>
</tr>
<tr>
<td>DISK_PAGE_BUFFER</td>
<td>Used for the disk page buffer; determined by the <code>DiskPageBufferMemory</code> configuration parameter. Cannot be overallocated.</td>
</tr>
<tr>
<td>QUERY_MEMORY</td>
<td>Used by the DBSPJ kernel block.</td>
</tr>
<tr>
<td>SCHEMA_TRANS_MEMORY</td>
<td>Minimum is 2 MB; can be overallocated to use any remaining available memory.</td>
</tr>
</tbody>
</table>

#### 18.5.10.15 The ndbinfo server_operations Table

The `server_operations` table contains entries for all ongoing NDB operations that the current SQL node (MySQL Server) is currently involved in. It effectively is a subset of the `cluster_operations` table, in which operations for other SQL and API nodes are not shown.

The following table provides information about the columns in the `server_operations` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

<p>| Table 18.275 Columns of the server_operations table |</p>
<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mysql_connection_id</td>
<td>integer</td>
<td>MySQL Server connection ID</td>
</tr>
<tr>
<td>node_id</td>
<td>integer</td>
<td>Node ID</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>Block instance</td>
</tr>
<tr>
<td>Column Name</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>transid</td>
<td>integer</td>
<td>Transaction ID</td>
</tr>
<tr>
<td>operation_type</td>
<td>string</td>
<td>Operation type (see text for possible values)</td>
</tr>
<tr>
<td>state</td>
<td>string</td>
<td>Operation state (see text for possible values)</td>
</tr>
<tr>
<td>tableid</td>
<td>integer</td>
<td>Table ID</td>
</tr>
<tr>
<td>fragmentid</td>
<td>integer</td>
<td>Fragment ID</td>
</tr>
<tr>
<td>client_node_id</td>
<td>integer</td>
<td>Client node ID</td>
</tr>
<tr>
<td>client_block_ref</td>
<td>integer</td>
<td>Client block reference</td>
</tr>
<tr>
<td>tc_node_id</td>
<td>integer</td>
<td>Transaction coordinator node ID</td>
</tr>
<tr>
<td>tc_block_no</td>
<td>integer</td>
<td>Transaction coordinator block number</td>
</tr>
<tr>
<td>tc_block_instance</td>
<td>integer</td>
<td>Transaction coordinator block instance</td>
</tr>
</tbody>
</table>

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`. It is obtained from the `INFORMATION_SCHEMA` table `NDB_TRANSID_MYSQL_CONNECTION_MAP`.

`block_instance` refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the `threadblocks` table.

The transaction ID (`transid`) is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `operation_type` column can take any one of the values `READ`, `READ-SH`, `READ-EX`, `INSERT`, `UPDATE`, `DELETE`, `WRITE`, `UNLOCK`, `REFRESH`, `SCAN`, `SCAN-SH`, `SCAN-EX`, or `<unknown>`.

The `state` column can have any one of the values `ABORT_QUEUED`, `ABORT_STOPPED`, `COMMITTED`, `COMMIT_QUEUED`, `COMMIT_STOPPED`, `COPY_CLOSE_STOPPED`, `COPY_FIRST_STOPPED`, `COPY_STOPPED`, `COPY_TUPKEY`, `IDLE`, `LOG_ABORT_QUEUED`, `LOG_ABORT_WRITTEN`, `LOG_ABORT_WRITTEN_WAIT_SIGNAL`, `LOG_COMMIT_QUEUED`, `LOG_COMMIT_QUEUED_WAIT_SIGNAL`, `LOG_COMMIT_WRITTEN`, `LOG_COMMIT_WRITTEN_WAIT_SIGNAL`, `LOG_QUEUE`, `PREPARED`, `PREPARED_RECEIVED_COMMIT`, `SCAN_CHECK_STOPPED`, `SCAN_CLOSE_STOPPED`, `SCAN_FIRST_STOPPED`, `SCAN_RELEASE_STOPPED`, `SCAN_STATE_USED`, `SCAN_STOPPED`, `SCAN_TUPKEY`, `STOPPED`, `TC_NOT_CONNECTED`, `WAIT_ACC`, `WAIT_ACC_ABORT`, `WAIT_AI_AFTER_ABORT`, `WAIT_ATTR`, `WAIT_SCAN_AI`, `WAIT_TUP`, `WAIT_TUPKEYINFO`, `WAIT_TUP_COMMIT`, or `WAIT_TUP_TO_ABORT`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb $dblqh_tconnect_state` table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of `ndb_show_tables`.

The `fragid` is the same as the partition number seen in the output of `ndb_desc --extra-partition-info` (short form `-p`).

In `client_node_id` and `client_block_ref`, `client` refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The `block_instance` and `tc_block_instance` column provide NDB kernel block instance numbers. You can use these to obtain information about specific threads from the `threadblocks` table.

This table was added in NDB 7.2.2.

18.5.10.16 The `ndbinfo server_transactions` Table
The `server_transactions` table is a subset of the `cluster_transactions` table, but includes only those transactions in which the current SQL node (MySQL Server) is a participant, while including the relevant connection IDs.

The following table provides information about the columns in the `server_transactions` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

### Table 18.276 Columns of the `server_transactions` table

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>mysql_connection_id</code></td>
<td>integer</td>
<td>MySQL Server connection ID</td>
</tr>
<tr>
<td><code>node_id</code></td>
<td>integer</td>
<td>Transaction coordinator node ID</td>
</tr>
<tr>
<td><code>block_instance</code></td>
<td>integer</td>
<td>Transaction coordinator block instance</td>
</tr>
<tr>
<td><code>transid</code></td>
<td>integer</td>
<td>Transaction ID</td>
</tr>
<tr>
<td><code>state</code></td>
<td>string</td>
<td>Operation state (see text for possible values)</td>
</tr>
<tr>
<td><code>count_operations</code></td>
<td>integer</td>
<td>Number of stateful operations in the transaction</td>
</tr>
<tr>
<td><code>outstanding_operations</code></td>
<td>integer</td>
<td>Operations still being executed by local data management layer (LQH blocks)</td>
</tr>
<tr>
<td><code>inactive_seconds</code></td>
<td>integer</td>
<td>Time spent waiting for API</td>
</tr>
<tr>
<td><code>client_node_id</code></td>
<td>integer</td>
<td>Client node ID</td>
</tr>
<tr>
<td><code>client_block_ref</code></td>
<td>integer</td>
<td>Client block reference</td>
</tr>
</tbody>
</table>

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`. It is obtained from the `INFORMATION_SCHEMA` table `NDB_TRANSID_MYSQL_CONNECTION_MAP`.

The `block_instance` refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the `threadblocks` table.

The transaction ID (`transid`) is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `state` column can have any one of the values `CS_ABORTING, CS_COMMITTING, CS_COMMIT_SENT, CS_COMPLETE_SENT, CS_COMPLETING, CS_CONNECTED, CS_DISCONNECTED, CS_FAIL_ABORTED, CS_FAIL_ABORTING, CS_FAIL_COMMITTED, CS_FAIL_COMMITTING, CS_FAIL_COMPLETED, CS_FAIL_PREPARED, CS_PREPARE_TO_COMMIT, CS_RECEIVING, CS_REC_COMMITTING, CS_RESTART, CS_SEND_FIRE_TRIG_REQ, CS_STARTED, CS_START_COMMITTING, CS_START_SCAN, CS_WAIT_ABORT_CONF, CS_WAIT_COMMIT_CONF, CS_WAIT_COMPLETE_CONF, CS_WAIT_FIRE_TRIG_REQ`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dbtc_apiconnect_state` table, which is normally hidden.)

In `client_node_id` and `client_block_ref`, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The `block_instance` column provides the DBTC kernel block instance number. You can use this to obtain information about specific threads from the `threadblocks` table.

This table was added in NDB 7.2.2.
### 18.5.10.17 The ndbinfo threadblocks Table

The `threadblocks` table associates data nodes, threads, and instances of NDB kernel blocks.

The following table provides information about the columns in the `threadblocks` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

**Table 18.277 Columns of the threadblocks table**

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>Node ID</td>
</tr>
<tr>
<td>thr_no</td>
<td>integer</td>
<td>Thread ID</td>
</tr>
<tr>
<td>block_name</td>
<td>string</td>
<td>Block name</td>
</tr>
<tr>
<td>block_instance</td>
<td>integer</td>
<td>Block instance number</td>
</tr>
</tbody>
</table>

The value of the `block_name` in this table is one of the values found in the `block_name` column when selecting from the `ndbinfo.blocks` table. Although the list of possible values is static for a given NDB Cluster release, the list may vary between releases.

The `block_instance` column provides the kernel block instance number.

This table was added in NDB 7.2.2.

### 18.5.10.18 The ndbinfo threadstat Table

The `threadstat` table provides a rough snapshot of statistics for threads running in the NDB kernel.

The following table provides information about the columns in the `threadstat` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

**Table 18.278 Columns of the threadstat table**

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>Node ID</td>
</tr>
<tr>
<td>thr_no</td>
<td>integer</td>
<td>Thread ID</td>
</tr>
<tr>
<td>thr_nm</td>
<td>string</td>
<td>Thread name</td>
</tr>
<tr>
<td>c_loop</td>
<td>string</td>
<td>Number of loops in main loop</td>
</tr>
<tr>
<td>c_exec</td>
<td>string</td>
<td>Number of signals executed</td>
</tr>
<tr>
<td>c_wait</td>
<td>string</td>
<td>Number of times waiting for additional input</td>
</tr>
<tr>
<td>c_l_sent_prioa</td>
<td>integer</td>
<td>Number of priority A signals sent to own node</td>
</tr>
<tr>
<td>c_l_sent_priob</td>
<td>integer</td>
<td>Number of priority B signals sent to own node</td>
</tr>
<tr>
<td>c_r_sent_prioa</td>
<td>integer</td>
<td>Number of priority A signals sent to remote node</td>
</tr>
<tr>
<td>c_r_sent_priob</td>
<td>integer</td>
<td>Number of priority B signals sent to remote node</td>
</tr>
<tr>
<td>os_tid</td>
<td>integer</td>
<td>OS thread ID</td>
</tr>
</tbody>
</table>
### ndbinfo: The NDB Cluster Information Database

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>os_now</td>
<td>integer</td>
<td>OS time (ms)</td>
</tr>
<tr>
<td>os_ru_utime</td>
<td>integer</td>
<td>OS user CPU time (µs)</td>
</tr>
<tr>
<td>os_ru_stime</td>
<td>integer</td>
<td>OS system CPU time (µs)</td>
</tr>
<tr>
<td>os_ru_minflt</td>
<td>integer</td>
<td>OS page reclaims (soft page faults)</td>
</tr>
<tr>
<td>os_ru_majflt</td>
<td>integer</td>
<td>OS page faults (hard page faults)</td>
</tr>
<tr>
<td>os_ru_nvcsw</td>
<td>integer</td>
<td>OS voluntary context switches</td>
</tr>
<tr>
<td>os_ru_nivcsw</td>
<td>integer</td>
<td>OS involuntary context switches</td>
</tr>
</tbody>
</table>

**os_time** uses the system gettimeofday() call.

The values of the os_ru_utime, os_ru_stime, os_ru_minflt, os_ru_majflt, os_ru_nvcsw, and os_ru_nivcsw columns are obtained using the system getrusage() call, or the equivalent.

Since this table contains counts taken at a given point in time, for best results it is necessary to query this table periodically and store the results in an intermediate table or tables. The MySQL Server's Event Scheduler can be employed to automate such monitoring. For more information, see Section 20.4, “Using the Event Scheduler”.

This table was added in NDB 7.2.2.

#### 18.5.10.19 The ndbinfo transporters Table

This table contains information about NDB transporters.

The following table provides information about the columns in the transporters table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

**Table 18.279 Columns of the transporters table**

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>node_id</td>
<td>integer</td>
<td>This data node's unique node ID in the cluster</td>
</tr>
<tr>
<td>remote_node_id</td>
<td>integer</td>
<td>The remote data node's node ID</td>
</tr>
<tr>
<td>status</td>
<td>string</td>
<td>Status of the connection</td>
</tr>
<tr>
<td>remote_address</td>
<td>string</td>
<td>Name or IP address of the remote host</td>
</tr>
<tr>
<td>bytes_sent</td>
<td>integer</td>
<td>Number of bytes sent using this connection</td>
</tr>
<tr>
<td>bytes_received</td>
<td>integer</td>
<td>Number of bytes received using this connection</td>
</tr>
<tr>
<td>connect_count</td>
<td>integer</td>
<td>Number of times connection established on this transporter</td>
</tr>
<tr>
<td>overloaded</td>
<td>boolean (0 or 1)</td>
<td>1 if this transporter is currently overloaded, otherwise 0</td>
</tr>
<tr>
<td>overload_count</td>
<td>integer</td>
<td>Number of times this transporter has entered overload state since connecting</td>
</tr>
<tr>
<td>slowdown</td>
<td>boolean (0 or 1)</td>
<td>1 if this transporter is in slowdown state, otherwise 0</td>
</tr>
</tbody>
</table>
For each running data node in the cluster, the **transporters** table displays a row showing the status of each of that node’s connections with all nodes in the cluster, including itself. This information is shown in the table’s **status** column, which can have any one of the following values: **CONNECTING**, **CONNECTED**, **DISCONNECTING**, or **DISCONNECTED**.

Connections to API and management nodes which are configured but not currently connected to the cluster are shown with status **DISCONNECTED**. Rows where the **node_id** is that of a data node which is not currently connected are not shown in this table. (This is similar omission of disconnected nodes in the **ndbinfo.nodes** table.

The **remote_address**, **bytes_sent**, and **bytes_received** columns were added in NDB 7.2.9. The **remote_address** is the host name or address for the node whose ID is shown in the **remote_node_id** column. The **bytes_sent** from this node and **bytes_received** by this node are the numbers, respectively, of bytes sent and received by the node using this connection since it was established. For nodes whose status is **CONNECTING** or **DISCONNECTED**, these columns always display 0.

Assume you have a 5-node cluster consisting of 2 data nodes, 2 SQL nodes, and 1 management node, as shown in the output of the **SHOW** command in the **ndb_mgm** client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
  [ndbd(NDB)]  2 node(s)
    id=1    @10.100.10.1  (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
    id=2    @10.100.10.2  (5.5.65-ndb-7.2.39, Nodegroup: 0)
  [ndb_mgmd(MGM)]  1 node(s)
    id=10   @10.100.10.10  (5.5.65-ndb-7.2.39)
  [mysqld(API)]  2 node(s)
    id=20   @10.100.10.20  (5.5.65-ndb-7.2.39)
    id=21   @10.100.10.21  (5.5.65-ndb-7.2.39)
```

There are 10 rows in the **transporters** table—5 for the first data node, and 5 for the second—assuming that all data nodes are running, as shown here:

```
mysql> SELECT node_id, remote_node_id, status
    -> FROM ndbinfo.transporters;
+---------+----------------+---------------+
| node_id | remote_node_id | status        |
+---------+----------------+---------------+
|       1 |              1 | DISCONNECTED  |
|       1 |              2 | CONNECTED     |
|       1 |             10 | CONNECTED     |
|       1 |             20 | CONNECTED     |
|       1 |             21 | CONNECTED     |
|       2 |              1 | CONNECTED     |
|       2 |              2 | CONNECTED     |
|       2 |             10 | CONNECTED     |
|       2 |             20 | CONNECTED     |
|       2 |             21 | CONNECTED     |
+---------+----------------+---------------+
10 rows in set (0.04 sec)
```

If you shut down one of the data nodes in this cluster using the command **2 STOP** in the **ndb_mgm** client, then repeat the previous query (again using the **mysql** client), this table now shows only 5 rows—1 row for
NDB Cluster Security Issues

each connection from the remaining management node to another node, including both itself and the data
node that is currently offline—and displays CONNECTING for the status of each remaining connection to the
data node that is currently offline, as shown here:

```sql
mysql> SELECT node_id, remote_node_id, status
    -> FROM ndbinfo.transporters;
+---------+----------------+---------------+
<table>
<thead>
<tr>
<th>node_id</th>
<th>remote_node_id</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>DISCONNECTED</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>CONNECTING</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>CONNECTED</td>
</tr>
</tbody>
</table>
+---------+----------------+---------------+
5 rows in set (0.02 sec)
```

The `connect_count`, `overloaded`, `overload_count`, `slowdown`, and `slowdown_count` columns
were added in NDB 7.2.10. These counters are reset on connection, and retain their values after the
remote node disconnects. Also beginning with NDB 7.2.10, the `bytes_send` and `bytes_received`
counters are reset on connection as well, and so retain their values following disconnection. (Previously,
the values in these columns were reset on disconnection.) (Bug #15935206)

The `overload` state referred to by the `overloaded` and `overload_count` columns occurs
when this transporter's send buffer contains more than `OverloadLimit` bytes (default is 80% of
`SendBufferMemory`, that is, $0.8 \times 2097152 = 1677721$ bytes). When a given transporter is in a state
of overload, any new transaction that tries to use this transporter fails with Error 1218 (`Send Buffers
overloaded in NDB kernel`). This affects both scans and primary key operations.

The `slowdown` state referenced by the `slowdown` and `slowdown_count` columns of this table occurs
when the transporter's send buffer contains more than 60% of the overload limit (equal to $0.6 \times 2097152 =
1258291$ bytes by default). In this state, any new scan using this transporter has its batch size reduced to
minimize the load on the transporter.

Common causes of send buffer slowdown or overloading include the following:

- Data size, in particular the quantity of data stored in `TEXT` columns or `BLOB` columns (or both types of
columns)
- Having a data node (ndbd or ndbmtd) on the same host as an SQL node that is engaged in binary
logging
- Large number of rows per transaction or transaction batch
- Configuration issues such as insufficient `SendBufferMemory`
- Hardware issues such as insufficient RAM or poor network connectivity

See also Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

18.5.11 NDB Cluster Security Issues

This section discusses security considerations to take into account when setting up and running NDB
Cluster.

Topics covered in this section include the following:

- NDB Cluster and network security issues
- Configuration issues relating to running NDB Cluster securely
18.5.11.1 NDB Cluster Security and Networking Issues

In this section, we discuss basic network security issues as they relate to NDB Cluster. It is extremely important to remember that NDB Cluster “out of the box” is not secure; you or your network administrator must take the proper steps to ensure that your cluster cannot be compromised over the network.

Cluster communication protocols are inherently insecure, and no encryption or similar security measures are used in communications between nodes in the cluster. Because network speed and latency have a direct impact on the cluster’s efficiency, it is also not advisable to employ SSL or other encryption to network connections between nodes, as such schemes will effectively slow communications.

It is also true that no authentication is used for controlling API node access to an NDB Cluster. As with encryption, the overhead of imposing authentication requirements would have an adverse impact on Cluster performance.

In addition, there is no checking of the source IP address for either of the following when accessing the cluster:

• SQL or API nodes using “free slots” created by empty [mysqld] or [api] sections in the config.ini file

This means that, if there are any empty [mysqld] or [api] sections in the config.ini file, then any API nodes (including SQL nodes) that know the management server’s host name (or IP address) and port can connect to the cluster and access its data without restriction. (See Section 18.5.11.2, “NDB Cluster and MySQL Privileges”, for more information about this and related issues.)

Note

You can exercise some control over SQL and API node access to the cluster by specifying a HostName parameter for all [mysqld] and [api] sections in the config.ini file. However, this also means that, should you wish to connect an API node to the cluster from a previously unused host, you need to add an [api] section containing its host name to the config.ini file.

More information is available elsewhere in this chapter about the HostName parameter. Also see Section 18.3.1, “Quick Test Setup of NDB Cluster”, for configuration examples using HostName with API nodes.

• Any ndb_mgm client

This means that any cluster management client that is given the management server’s host name (or IP address) and port (if not the standard port) can connect to the cluster and execute any management client command. This includes commands such as ALL STOP and SHUTDOWN.

For these reasons, it is necessary to protect the cluster on the network level. The safest network configuration for Cluster is one which isolates connections between Cluster nodes from any other network communications. This can be accomplished by any of the following methods:

1. Keeping Cluster nodes on a network that is physically separate from any public networks. This option is the most dependable; however, it is the most expensive to implement.

We show an example of an NDB Cluster setup using such a physically segregated network here:
This setup has two networks, one private (solid box) for the Cluster management servers and data nodes, and one public (dotted box) where the SQL nodes reside. (We show the management and data nodes connected using a gigabit switch since this provides the best performance.) Both networks are protected from the outside by a hardware firewall, sometimes also known as a network-based firewall.

This network setup is safest because no packets can reach the cluster's management or data nodes from outside the network—and none of the cluster's internal communications can reach the outside—without going through the SQL nodes, as long as the SQL nodes do not permit any packets to be forwarded. This means, of course, that all SQL nodes must be secured against hacking attempts.

Important

With regard to potential security vulnerabilities, an SQL node is no different from any other MySQL server. See Section 6.1.3, “Making MySQL Secure Against Attackers”, for a description of techniques you can use to secure MySQL servers.

2. Using one or more software firewalls (also known as host-based firewalls) to control which packets pass through to the cluster from portions of the network that do not require access to it. In this type
of setup, a software firewall must be installed on every host in the cluster which might otherwise be accessible from outside the local network.

The host-based option is the least expensive to implement, but relies purely on software to provide protection and so is the most difficult to keep secure.

This type of network setup for NDB Cluster is illustrated here:

**Figure 18.8 NDB Cluster with Software Firewalls**

Using this type of network setup means that there are two zones of NDB Cluster hosts. Each cluster host must be able to communicate with all of the other machines in the cluster, but only those hosting SQL nodes (dotted box) can be permitted to have any contact with the outside, while those in the zone containing the data nodes and management nodes (solid box) must be isolated from any machines that are not part of the cluster. Applications using the cluster and user of those applications must *not* be permitted to have direct access to the management and data node hosts.

To accomplish this, you must set up software firewalls that limit the traffic to the type or types shown in the following table, according to the type of node that is running on each cluster host computer:

**Table 18.8 Node types in a host-based firewall cluster configuration**

<table>
<thead>
<tr>
<th>Node Type</th>
<th>Permitted Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL or API node</td>
<td>• It originates from the IP address of a management or data node (using any TCP or UDP port).</td>
</tr>
<tr>
<td></td>
<td>• It originates from within the network in which the cluster resides and is on the port that your application is using.</td>
</tr>
<tr>
<td>Data node or Management node</td>
<td>• It originates from the IP address of a management or data node (using any TCP or UDP port).</td>
</tr>
</tbody>
</table>
### NDB Cluster Security Issues

<table>
<thead>
<tr>
<th>Node Type</th>
<th>Permitted Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• It originates from the IP address of an SQL or API node.</td>
</tr>
</tbody>
</table>

Any traffic other than that shown in the table for a given node type should be denied.

The specifics of configuring a firewall vary from firewall application to firewall application, and are beyond the scope of this Manual. `iptables` is a very common and reliable firewall application, which is often used with `APF` as a front end to make configuration easier. You can (and should) consult the documentation for the software firewall that you employ, should you choose to implement an NDB Cluster network setup of this type, or of a “mixed” type as discussed under the next item.

3. It is also possible to employ a combination of the first two methods, using both hardware and software to secure the cluster—that is, using both network-based and host-based firewalls. This is between the first two schemes in terms of both security level and cost. This type of network setup keeps the cluster behind the hardware firewall, but permits incoming packets to travel beyond the router connecting all cluster hosts to reach the SQL nodes.

   One possible network deployment of an NDB Cluster using hardware and software firewalls in combination is shown here:

   **Figure 18.9 NDB Cluster with a Combination of Hardware and Software Firewalls**

   ![Diagram showing NDB Cluster with a combination of hardware and software firewalls](image)

   In this case, you can set the rules in the hardware firewall to deny any external traffic except to SQL nodes and API nodes, and then permit traffic to them only on the ports required by your application.

   Whatever network configuration you use, remember that your objective from the viewpoint of keeping the cluster secure remains the same—to prevent any unessential traffic from reaching the cluster while ensuring the most efficient communication between the nodes in the cluster.

   Because NDB Cluster requires large numbers of ports to be open for communications between nodes, the recommended option is to use a segregated network. This represents the simplest way to prevent unwanted traffic from reaching the cluster.
If you wish to administer an NDB Cluster remotely (that is, from outside the local network), the recommended way to do this is to use `ssh` or another secure login shell to access an SQL node host. From this host, you can then run the management client to access the management server safely, from within the Cluster's own local network.

Even though it is possible to do so in theory, it is **not** recommended to use `ndb_mgm` to manage a Cluster directly from outside the local network on which the Cluster is running. Since neither authentication nor encryption takes place between the management client and the management server, this represents an extremely insecure means of managing the cluster, and is almost certain to be compromised sooner or later.

### 18.5.11.2 NDB Cluster and MySQL Privileges

In this section, we discuss how the MySQL privilege system works in relation to NDB Cluster and the implications of this for keeping an NDB Cluster secure.

Standard MySQL privileges apply to NDB Cluster tables. This includes all MySQL privilege types (`SELECT` privilege, `UPDATE` privilege, `DELETE` privilege, and so on) granted on the database, table, and column level. As with any other MySQL Server, user and privilege information is stored in the `mysql` system database. The SQL statements used to grant and revoke privileges on NDB tables, databases containing such tables, and columns within such tables are identical in all respects with the `GRANT` and `REVOKE` statements used in connection with database objects involving any (other) MySQL storage engine. The same thing is true with respect to the `CREATE USER` and `DROP USER` statements.

It is important to keep in mind that, by default, the MySQL grant tables use the `MyISAM` storage engine. Because of this, those tables are not normally duplicated or shared among MySQL servers acting as SQL nodes in an NDB Cluster. In other words, changes in users and their privileges do not automatically propagate between SQL nodes by default. In NDB Cluster 7.2 (and later), you can enable automatic distribution of MySQL users and privileges across NDB Cluster SQL nodes; see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”, for details.

Conversely, because there is no way in MySQL to deny privileges (privileges can either be revoked or not granted in the first place, but not denied as such), there is no special protection for NDB tables on one SQL node from users that have privileges on another SQL node; (This is true even if you are not using automatic distribution of user privileges. The definitive example of this is the MySQL root account, which can perform any action on any database object. In combination with empty `[mysqld]` or `[api]` sections of the `config.ini` file, this account can be especially dangerous. To understand why, consider the following scenario:

- The `config.ini` file contains at least one empty `[mysqld]` or `[api]` section. This means that the NDB Cluster management server performs no checking of the host from which a MySQL Server (or other API node) accesses the NDB Cluster.
- There is no firewall, or the firewall fails to protect against access to the NDB Cluster from hosts external to the network.
- The host name or IP address of the NDB Cluster management server is known or can be determined from outside the network.

If these conditions are true, then anyone, anywhere can start a MySQL Server with `--ndbcluster --ndb-connectstring=management_host` and access this NDB Cluster. Using the MySQL root account, this person can then perform the following actions:
NDB Cluster Security Issues

- Execute metadata statements such as `SHOW DATABASES` statement (to obtain a list of all NDB databases on the server) or `SHOW TABLES FROM some_ndb_database` statement to obtain a list of all NDB tables in a given database

- Run any legal MySQL statements on any of the discovered tables, such as:
  - `SELECT * FROM some_table` to read all the data from any table
  - `DELETE FROM some_table` to delete all the data from a table
  - `DESCRIBE some_table` or `SHOW CREATE TABLE some_table` to determine the table schema
  - `UPDATE some_table SET column1 = some_value` to fill a table column with “garbage” data; this could actually cause much greater damage than simply deleting all the data

  More insidious variations might include statements like these:

  ```
  UPDATE some_table SET an_int_column = an_int_column + 1
  ```

  or

  ```
  UPDATE some_table SET a_varchar_column = REVERSE(a_varchar_column)
  ```

  Such malicious statements are limited only by the imagination of the attacker.

  The only tables that would be safe from this sort of mayhem would be those tables that were created using storage engines other than NDB, and so not visible to a “rogue” SQL node.

  A user who can log in as `root` can also access the `INFORMATION_SCHEMA` database and its tables, and so obtain information about databases, tables, stored routines, scheduled events, and any other database objects for which metadata is stored in `INFORMATION_SCHEMA`.

  It is also a very good idea to use different passwords for the `root` accounts on different NDB Cluster SQL nodes unless you are using distributed privileges.

  In sum, you cannot have a safe NDB Cluster if it is directly accessible from outside your local network.

  **Important**

  Never leave the MySQL `root` account password empty. This is just as true when running MySQL as an NDB Cluster SQL node as it is when running it as a standalone (non-Cluster) MySQL Server, and should be done as part of the MySQL installation process before configuring the MySQL Server as an SQL node in an NDB Cluster.

  Prior to NDB Cluster 7.2, you should never convert the system tables in the `mysql` database to use the NDB storage engine. There are a number of reasons why you should not do this, but the most important reason is this: Many of the SQL statements that affect `mysql` tables storing information about user privileges, stored routines, scheduled events, and other database objects cease to function if these tables are changed to use any storage engine other than MyISAM. This is a consequence of various MySQL Server internals. Beginning with NDB Cluster 7.2, you can use a stored procedure provided for this purpose (see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”), but you are strongly advised not to attempt convert the system tables manually.

  Otherwise, if you need to synchronize `mysql` system tables between SQL nodes, you can use standard MySQL replication to do so, or employ a script to copy table entries between the MySQL servers.
NDB Cluster Security Issues

Summary. The most important points to remember regarding the MySQL privilege system with regard to NDB Cluster are listed here:

1. Users and privileges established on one SQL node do not automatically exist or take effect on other SQL nodes in the cluster. Conversely, removing a user or privilege on one SQL node in the cluster does not remove the user or privilege from any other SQL nodes.

2. You can distribute MySQL users and privileges among SQL nodes using the SQL script, and the stored procedures it contains, that are supplied for this purpose in the NDB Cluster distribution.

3. Once a MySQL user is granted privileges on an NDB table from one SQL node in an NDB Cluster, that user can “see” any data in that table regardless of the SQL node from which the data originated, even if you are not using privilege distribution.

18.5.11.3 NDB Cluster and MySQL Security Procedures

In this section, we discuss MySQL standard security procedures as they apply to running NDB Cluster.

In general, any standard procedure for running MySQL securely also applies to running a MySQL Server as part of an NDB Cluster. First and foremost, you should always run a MySQL Server as the mysql operating system user; this is no different from running MySQL in a standard (non-Cluster) environment. The mysql system account should be uniquely and clearly defined. Fortunately, this is the default behavior for a new MySQL installation. You can verify that the mysqld process is running as the mysql operating system user by using the system command such as the one shown here:

```
shell> ps aux | grep mysql
```

If the mysqld process is running as any other user than mysql, you should immediately shut it down and restart it as the mysql user. If this user does not exist on the system, the mysql user account should be created, and this user should be part of the mysql user group; in this case, you should also make sure that the MySQL data directory on this system (as set using the --datadir option for mysqld) is owned by the mysql user, and that the SQL node's my.cnf file includes user=mysql in the [mysqld] section. Alternatively, you can start the MySQL server process with --user=mysql on the command line, but it is preferable to use the my.cnf option, since you might forget to use the command-line option and so have mysqld running as another user unintentionally. The mysqld_safe startup script forces MySQL to run as the mysql user.

Important

Never run mysqld as the system root user. Doing so means that potentially any file on the system can be read by MySQL, and thus—should MySQL be compromised—by an attacker.

As mentioned in the previous section (see Section 18.5.11.2, “NDB Cluster and MySQL Privileges”), you should always set a root password for the MySQL Server as soon as you have it running. You should also delete the anonymous user account that is installed by default. You can accomplish these tasks using the following statements:

```
shell> mysql -u root
mysql> UPDATE mysql.user
```
NDB Cluster Disk Data Tables

-> SET Password=PASSWORD('secure_password')
-> WHERE User='root';

mysql> DELETE FROM mysql.user
-> WHERE User='';

mysql> FLUSH PRIVILEGES;

Be very careful when executing the DELETE statement not to omit the WHERE clause, or you risk deleting all MySQL users. Be sure to run the FLUSH PRIVILEGES statement as soon as you have modified the mysql.user table, so that the changes take immediate effect. Without FLUSH PRIVILEGES, the changes do not take effect until the next time that the server is restarted.

Note

Many of the NDB Cluster utilities such as ndb_show_tables, ndb_desc, and ndb_select_all also work without authentication and can reveal table names, schemas, and data. By default these are installed on Unix-style systems with the permissions wxr-xr-x (755), which means they can be executed by any user that can access the mysql/bin directory.

See Section 18.4, “NDB Cluster Programs”, for more information about these utilities.

18.5.12 NDB Cluster Disk Data Tables

It is possible to store the nonindexed columns of NDB tables on disk, rather than in RAM.

As part of implementing NDB Cluster Disk Data work, a number of improvements were made in NDB Cluster for the efficient handling of very large amounts (terabytes) of data during node recovery and restart. These include a “no-steal” algorithm for synchronizing a starting node with very large data sets. For more information, see the paper Recovery Principles of NDB Cluster 5.1, by NDB Cluster developers Mikael Ronström and Jonas Oreland.

NDB Cluster Disk Data performance can be influenced by a number of configuration parameters. For information about these parameters and their effects, see NDB Cluster Disk Data configuration parameters and NDB Cluster Disk Data storage and GCP Stop errors

The performance of an NDB Cluster that uses Disk Data storage can also be greatly improved by separating data node file systems from undo log files and tablespace data files, which can be done using symbolic links. For more information, see Section 18.5.12.2, “Using Symbolic Links with Disk Data Objects”.

18.5.12.1 NDB Cluster Disk Data Objects

NDB Cluster Disk Data storage is implemented using a number of Disk Data objects. These include the following:

- **Tablespaces** act as containers for other Disk Data objects.
- **Undo log files** undo information required for rolling back transactions.
- One or more undo log files are assigned to a **log file group**, which is then assigned to a tablespace.
- **Data files** store Disk Data table data. A data file is assigned directly to a tablespace.

Undo log files and data files are actual files in the file system of each data node; by default they are placed in ndb_node_id_fs in the DataDir specified in the NDB Cluster config.ini file, and where node_id
is the data node's node ID. It is possible to place these elsewhere by specifying either an absolute or relative path as part of the filename when creating the undo log or data file. Statements that create these files are shown later in this section.

NDB Cluster tablespaces and log file groups are not implemented as files.

Important
Although not all Disk Data objects are implemented as files, they all share the same namespace. This means that each Disk Data object must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group both named dd1.

Assuming that you have already set up an NDB Cluster with all nodes (including management and SQL nodes), the basic steps for creating an NDB Cluster table on disk are as follows:

1. Create a log file group, and assign one or more undo log files to it (an undo log file is also sometimes referred to as an undofile).

Note
Undo log files are necessary only for Disk Data tables; they are not used for NDBCLUSTER tables that are stored only in memory.

2. Create a tablespace; assign the log file group, as well as one or more data files, to the tablespace.

3. Create a Disk Data table that uses this tablespace for data storage.

Each of these tasks can be accomplished using SQL statements in the mysql client or other MySQL client application, as shown in the example that follows.

1. We create a log file group named `lg_1` using CREATE LOGFILE GROUP. This log file group is to be made up of two undo log files, which we name `undo_1.log` and `undo_2.log`, whose initial sizes are 16 MB and 12 MB, respectively. (The default initial size for an undo log file is 128 MB.) Optionally, you can also specify a size for the log file group's undo buffer, or permit it to assume the default value of 8 MB. In this example, we set the UNDO buffer's size at 2 MB. A log file group must be created with an undo log file; so we add `undo_1.log` to `lg_1` in this CREATE LOGFILE GROUP statement:

   CREATE LOGFILE GROUP lg_1
   ADD UNDOFILE 'undo_1.log'
   INITIAL_SIZE 16M
   UNDO_BUFFER_SIZE 2M
   ENGINE NDBCLUSTER;

   To add `undo_2.log` to the log file group, use the following ALTER LOGFILE GROUP statement:

   ALTER LOGFILE GROUP lg_1
   ADD UNDOFILE 'undo_2.log'
   INITIAL_SIZE 12M
   ENGINE NDBCLUSTER;

Some items of note:

• The .log file extension used here is not required. We use it merely to make the log files easily recognisable.

• Every CREATE LOGFILE GROUP and ALTER LOGFILE GROUP statement must include an ENGINE option. The only permitted values for this option are NDBCLUSTER and NDB.
Important
There can exist at most one log file group in the same NDB Cluster at any given time.

• When you add an undo log file to a log file group using ADD UNDOFILE 'filename', a file with the name filename is created in the ndb_node_id_fs directory within the DataDir of each data node in the cluster, where node_id is the node ID of the data node. Each undo log file is of the size specified in the SQL statement. For example, if an NDB Cluster has 4 data nodes, then the ALTER LOGFILE GROUP statement just shown creates 4 undo log files, 1 each in the data directory of each of the 4 data nodes; each of these files is named undo_2.log and each file is 12 MB in size.

• UNDO_BUFFER_SIZE is limited by the amount of system memory available.

• For more information about the CREATE LOGFILE GROUP statement, see Section 13.1.14, “CREATE LOGFILE GROUP Statement”. For more information about ALTER LOGFILE GROUP, see Section 13.1.4, “ALTER LOGFILE GROUP Statement”.

2. Now we can create a tablespace, which contains files to be used by NDB Cluster Disk Data tables for storing their data. A tablespace is also associated with a particular log file group. When creating a new tablespace, you must specify the log file group which it is to use for undo logging; you must also specify a data file. You can add more data files to the tablespace after the tablespace is created; it is also possible to drop data files from a tablespace (an example of dropping data files is provided later in this section).

Assume that we wish to create a tablespace named ts_1 which uses lg_1 as its log file group. This tablespace is to contain two data files named data_1.dat and data_2.dat, whose initial sizes are 32 MB and 48 MB, respectively. (The default value for INITIAL_SIZE is 128 MB.) We can do this using two SQL statements, as shown here:

```sql
CREATE TABLESPACE ts_1
  ADD DATAFILE 'data_1.dat'
  USE LOGFILE GROUP lg_1
  INITIAL_SIZE 32M
  ENGINE NDBCLUSTER;

ALTER TABLESPACE ts_1
  ADD DATAFILE 'data_2.dat'
  INITIAL_SIZE 48M
  ENGINE NDBCLUSTER;
```

The CREATE TABLESPACE statement creates a tablespace ts_1 with the data file data_1.dat, and associates ts_1 with log file group lg_1. The ALTER TABLESPACE adds the second data file (data_2.dat).

Some items of note:

• As is the case with the .log file extension used in this example for undo log files, there is no special significance for the .dat file extension; it is used merely for easy recognition of data files.

• When you add a data file to a tablespace using ADD DATAFILE 'filename', a file with the name filename is created in the ndb_node_id_fs directory within the DataDir of each data node in the cluster, where node_id is the node ID of the data node. Each data file is of the size specified in the SQL statement. For example, if an NDB Cluster has 4 data nodes, then the ALTER TABLESPACE statement just shown creates 4 data files, 1 each in the data directory of each of the 4 data nodes; each of these files is named data_2.dat and each file is 48 MB in size.
• All `CREATE TABLESPACE` and `ALTER TABLESPACE` statements must contain an `ENGINE` clause; only tables using the same storage engine as the tablespace can be created in the tablespace. In MySQL NDB Cluster 7.2, the only permitted values for this clause are `NDBCLUSTER` and `NDB`.

• For more information about the `CREATE TABLESPACE` and `ALTER TABLESPACE` statements, see Section 13.1.18, “CREATE TABLESPACE Statement”, and Section 13.1.8, “ALTER TABLESPACE Statement”.

3. Now it is possible to create a table whose nonindexed columns are stored on disk in the tablespace `ts_1`:

```sql
CREATE TABLE dt_1 (
    member_id INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    last_name VARCHAR(50) NOT NULL,
    first_name VARCHAR(50) NOT NULL,
    dob DATE NOT NULL,
    joined DATE NOT NULL,
    INDEX(last_name, first_name)
) TABLESPACE ts_1 STORAGE DISK
ENGINE NDBCLUSTER;
```

The `TABLESPACE ... STORAGE DISK` option tells the `NDBCLUSTER` storage engine to use tablespace `ts_1` for disk data storage.

Once table `ts_1` has been created as shown, you can perform `INSERT`, `SELECT`, `UPDATE`, and `DELETE` statements on it just as you would with any other MySQL table.

It is also possible to specify whether an individual column is stored on disk or in memory by using a `STORAGE` clause as part of the column’s definition in a `CREATE TABLE` or `ALTER TABLE` statement. `STORAGE DISK` causes the column to be stored on disk, and `STORAGE MEMORY` causes in-memory storage to be used. See Section 13.1.17, “CREATE TABLE Statement”, for more information.

**Indexing of columns implicitly stored on disk.** For table `dt_1` as defined in the example just shown, only the `dob` and `joined` columns are stored on disk. This is because there are indexes on the `id`, `last_name`, and `first_name` columns, and so data belonging to these columns is stored in RAM. Only nonindexed columns can be held on disk; indexes and indexed column data continue to be stored in memory. This tradeoff between the use of indexes and conservation of RAM is something you must keep in mind as you design Disk Data tables.

You cannot add an index to a column that has been explicitly declared `STORAGE DISK`, without first changing its storage type to `MEMORY`; any attempt to do so fails with an error. A column which *implicitly* uses disk storage can be indexed; when this is done, the column’s storage type is changed to `MEMORY` automatically. By “implicitly”, we mean a column whose storage type is not declared, but which is which inherited from the parent table. In the following `CREATE TABLE` statement (using the tablespace `ts_1` defined previously), columns `c2` and `c3` use disk storage implicitly:

```sql
mysql> CREATE TABLE ti (
    -> c1 INT PRIMARY KEY,
    ~> c2 INT,
    ~> c3 INT,
    ~> c4 INT
    -> )
    ~> STORAGE DISK
    ~> TABLESPACE ts_1
    ~> ENGINE NDBCLUSTER;
Query OK, 0 rows affected (1.31 sec)
```
Because $c_2$, $c_3$, and $c_4$ are themselves not declared with \texttt{STORAGE DISK}, it is possible to index them. Here, we add indexes to $c_2$ and $c_3$, using, respectively, \texttt{CREATE INDEX} and \texttt{ALTER TABLE}:

```
mysql> CREATE INDEX i1 ON ti(c2);
Query OK, 0 rows affected (2.72 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

```
mysql> ALTER TABLE ti ADD INDEX i2(c3);
Query OK, 0 rows affected (0.92 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

\texttt{SHOW CREATE TABLE} confirms that the indexes were added.

```
mysql> SHOW CREATE TABLE ti\G
*************************** 1. row ***************************
Table: ti
Create Table: CREATE TABLE `ti` (
  `c1` int(11) NOT NULL,
  `c2` int(11) DEFAULT NULL,
  `c3` int(11) DEFAULT NULL,
  `c4` int(11) DEFAULT NULL,
  PRIMARY KEY (`c1`),
  KEY `i1` (`c2`),
  KEY `i2` (`c3`) ) /*!50100 TABLESPACE `ts_1` STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

You can see using \texttt{ndb_desc} that the indexed columns (emphasized text) now use in-memory rather than on-disk storage:

```
shell> ./ndb_desc -d test ti
-- ti --
Version: 33554433
Fragment type: HashMapPartition
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 317
Max Rows: 0
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
PartitionCount: 4
FragmentCount: 4
PartitionBalance: FGR_RP_BY_LDM
ExtraRowGciBits: 0
ExtraRowAuthorBits: 0
TableStatus: Retrieved
Table options:
  HashMap: DEFAULT-HASHMAP-3840-4
-- Attributes --
  c1 Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY
  c2 Int NULL AT=FIXED ST=MEMORY
  c3 Int NULL AT=FIXED ST=MEMORY
  c4 Int NULL AT=FIXED ST=DISK
-- Indexes --
  PRIMARY KEY(c1) - UniqueHashIndex
  i2(c3) - OrderedIndex
  PRIMARY(c1) - OrderedIndex
  i1(c2) - OrderedIndex
NDBT_ProgramExit: 0 - OK
```

2521
**Performance note.** The performance of a cluster using Disk Data storage is greatly improved if Disk Data files are kept on a separate physical disk from the data node file system. This must be done for each data node in the cluster to derive any noticeable benefit.

You may use absolute and relative file system paths with `ADD UNDOFILE` and `ADD DATAFILE`. Relative paths are calculated relative to the data node’s data directory. You may also use symbolic links; see Section 18.5.12.2, “Using Symbolic Links with Disk Data Objects”, for more information and examples.

A log file group, a tablespace, and any Disk Data tables using these must be created in a particular order. The same is true for dropping any of these objects:

- A log file group cannot be dropped as long as any tablespaces are using it.
- A tablespace cannot be dropped as long as it contains any data files.
- You cannot drop any data files from a tablespace as long as there remain any tables which are using the tablespace.
- It is not possible to drop files created in association with a different tablespace than the one with which the files were created. (Bug #20053)

For example, to drop all the objects created so far in this section, you would use the following statements:

```
mysql> DROP TABLE dt_1;
mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_2.dat'
    -> ENGINE NDBCLUSTER;
mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_1.dat'
    -> ENGINE NDBCLUSTER;
mysql> DROP TABLESPACE ts_1
    -> ENGINE NDBCLUSTER;
mysql> DROP LOGFILE GROUP lg_1
    -> ENGINE NDBCLUSTER;
```

These statements must be performed in the order shown, except that the two `ALTER TABLESPACE ... DROP DATAFILE` statements may be executed in either order.

You can obtain information about data files used by Disk Data tables by querying the `FILES` table in the `INFORMATION_SCHEMA` database. An extra “NULL row” provides additional information about undo log files. For more information and examples, see Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.

### 18.5.12.2 Using Symbolic Links with Disk Data Objects

The performance of an NDB Cluster that uses Disk Data storage can be greatly improved by separating data node file systems from undo log files and tablespace data files and placing these on different disks. In early versions of NDB Cluster, there was no direct support for this in NDB Cluster, but it was possible to achieve this separation using symbolic links as described in this section. NDB Cluster 7.2 supports the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles`, which make the use of symbolic links for this purpose unnecessary. For more information about these parameters, see Disk Data file system parameters.

Each data node in the cluster creates a file system in the directory named `ndb_node_id_fs` under the data node’s `DataDir` as defined in the `config.ini` file. In this example, we assume that each data node host has 3 disks, aliased as `/data0`, `/data1`, and `/data2`, and that the cluster’s `config.ini` includes the following:
Our objective is to place all Disk Data log files in /data1, and all Disk Data data files in /data2, on each data node host.

Note
In this example, we assume that the cluster's data node hosts are all using Linux operating systems. For other platforms, you may need to substitute your operating system's commands for those shown here.

To accomplish this, perform the following steps:

- Under the data node file system create symbolic links pointing to the other drives:
  
  ```
  shell> cd /data0/ndb_2_fs
  shell> ls
  D1  D10  D11  D2  D8  D9  LCP
  shell> ln -s /data0 dnlogs
  shell> ln -s /data1 dndata
  ```

  You should now have two symbolic links:
  
  ```
  shell> ls -l --hide=D*
  lrwxrwxrwx 1 user group   30 2007-03-19 13:58 dndata -> /data1
  lrwxrwxrwx 1 user group   30 2007-03-19 13:59 dnlogs -> /data2
  ```

  We show this only for the data node with node ID 2; however, you must do this for each data node.

- Now, in the `mysql` client, create a log file group and tablespace using the symbolic links, as shown here:
  
  ```
  mysql> CREATE LOGFILE GROUP lg1
       -> ADD UNDOFILE 'dnlogs/undo1.log'
       -> INITIAL_SIZE 150M
       -> UNDO_BUFFER_SIZE = 1M
       -> ENGINE=NDBCLUSTER;
  mysql> CREATE TABLESPACE ts1
       -> ADD DATAFILE 'dndata/data1.log'
       -> USE LOGFILE GROUP lg1
       -> INITIAL_SIZE 1G
       -> ENGINE=NDBCLUSTER;
  ```

  Verify that the files were created and placed correctly as shown here:
  
  ```
  shell> cd /data1
  shell> ls -l
  total 2099304
  -rw-rw-r--  1 user group 157286400 2007-03-19 14:02 undo1.dat
  shell> cd /data2
  shell> ls -l
  total 2099304
  -rw-rw-r--  1 user group 1073741824 2007-03-19 14:02 data1.dat
  ```

- If you are running multiple data nodes on one host, you must take care to avoid having them try to use the same space for Disk Data files. You can make this easier by creating a symbolic link in each data node file system. Suppose you are using /data0 for both data node file systems, but you wish to have the Disk Data files for both nodes on /data1. In this case, you can do something similar to what is shown here:
  
  ```
  shell> cd /data0
  ```
NDB Cluster Disk Data Tables

- Now you can create a logfile group and tablespace using the symbolic link, like this:

  mysql> CREATE LOGFILE GROUP lg1
        -> ADD UNDOFILE 'dd/undo1.log'
        -> INITIAL_SIZE 150M
        -> UNDO_BUFFER_SIZE = 1M
        -> ENGINE=NDDBCLUSTER;

  mysql> CREATE TABLESPACE ts1
        -> ADD DATAFILE 'dd/data1.log'
        -> USE LOGFILE GROUP lg1
        -> INITIAL_SIZE 1G
        -> ENGINE=NDDBCLUSTER;

Verify that the files were created and placed correctly as shown here:

- In a Disk Data table, the first 256 bytes of a TEXT or BLOB column are stored in memory; only the remainder is stored on disk.

- Each row in a Disk Data table uses 8 bytes in memory to point to the data stored on disk. This means that, in some cases, converting an in-memory column to the disk-based format can actually result in greater memory usage. For example, converting a CHAR(4) column from memory-based to disk-based format increases the amount of DataMemory used per row from 4 to 8 bytes.

Important

Starting the cluster with the --initial option does not remove Disk Data files. You must remove these manually prior to performing an initial restart of the cluster.

18.5.12.3 NDB Cluster Disk Data Storage Requirements

The following items apply to Disk Data storage requirements:

- Variable-length columns of Disk Data tables take up a fixed amount of space. For each row, this is equal to the space required to store the largest possible value for that column.

For general information about calculating these values, see Section 11.6, “Data Type Storage Requirements”.

You can obtain an estimate the amount of space available in data files and undo log files by querying the INFORMATION_SCHEMA.FILES table. For more information and examples, see Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.

Note

The OPTIMIZE TABLE statement does not have any effect on Disk Data tables.

- Variable-length columns of Disk Data tables take up a fixed amount of space. For each row, this is equal to the space required to store the largest possible value for that column.

For general information about calculating these values, see Section 11.6, “Data Type Storage Requirements”.

You can obtain an estimate the amount of space available in data files and undo log files by querying the INFORMATION_SCHEMA.FILES table. For more information and examples, see Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”.

Note

The OPTIMIZE TABLE statement does not have any effect on Disk Data tables.

- In a Disk Data table, the first 256 bytes of a TEXT or BLOB column are stored in memory; only the remainder is stored on disk.

- Each row in a Disk Data table uses 8 bytes in memory to point to the data stored on disk. This means that, in some cases, converting an in-memory column to the disk-based format can actually result in greater memory usage. For example, converting a CHAR(4) column from memory-based to disk-based format increases the amount of DataMemory used per row from 4 to 8 bytes.

Important

Starting the cluster with the --initial option does not remove Disk Data files. You must remove these manually prior to performing an initial restart of the cluster.
Performance of Disk Data tables can be improved by minimizing the number of disk seeks by making sure that `DiskPageBufferMemory` is of sufficient size. You can query the `diskpagebuffer` table to help determine whether the value for this parameter needs to be increased.

### 18.5.13 Online Operations with ALTER TABLE in NDB Cluster

Operations that add and drop indexes on variable-width columns of `NDBCLUSTER` tables occur online. Online operations are noncopying; that is, they do not require that indexes be re-created. They do not lock the table being altered from access by other API nodes in an NDB Cluster (but see Limitations later in this section). Such operations do not require single user mode for `NDBCLUSTER` table alterations made in a cluster with multiple API nodes; transactions can continue uninterrupted during online DDL operations.

The `ONLINE` keyword can be used to perform online `ADD COLUMN`, `ADD INDEX` (including `CREATE INDEX` statements), and `DROP INDEX` operations on `NDBCLUSTER` tables. Online renaming of `NDBCLUSTER` tables is also supported.

The `ONLINE` and `OFFLINE` keywords are supported only in NDB Cluster. For standard MySQL Server 5.5 releases:

- The server determines automatically whether an `ADD INDEX` or `DROP INDEX` operation can be (and is) performed online or offline; if the column is of a variable-width data type, the operation is performed online. It is not possible to override the server behavior in this regard.

- Attempting to use the `ONLINE` or `OFFLINE` keyword in an `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX` statement results in an error.

Currently you cannot add disk-based columns to `NDBCLUSTER` tables online. This means that, if you wish to add an in-memory column to an `NDBCLUSTER` table that uses a table-level `STORAGE DISK` option, you must declare the new column as using memory-based storage explicitly. For example—assuming that you have already created tablespace `ts1`—suppose that you create table `t1` as follows:

```
mysql> CREATE TABLE t1 (  
>   c1 INT NOT NULL PRIMARY KEY,  
>   c2 VARCHAR(30)  
> )  
> TABLESPACE ts1 STORAGE DISK  
> ENGINE NDBCLUSTER;
Query OK, 0 rows affected (1.73 sec)  
Records: 0  Duplicates: 0  Warnings: 0
```

You can add a new in-memory column to this table online as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC STORAGE MEMORY;
Query OK, 0 rows affected (1.25 sec)  
Records: 0  Duplicates: 0  Warnings: 0
```

This statement fails if the `STORAGE MEMORY` option is omitted:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC;
ERROR 1235 (42000): This version of MySQL doesn't yet support 'ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC'
```

If you omit the `COLUMN_FORMAT DYNAMIC` option, the dynamic column format is employed automatically, but a warning is issued, as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT STORAGE MEMORY;
Query OK, 0 rows affected, 1 warning (1.17 sec)  
Records: 0  Duplicates: 0  Warnings: 0
```
Online Operations with ALTER TABLE in NDB Cluster

```sql
mysql> SHOW WARNINGS;
+---------+------+---------------------------------------------------------------+
| Level   | Code | Message                                                       |
|---------+------+---------------------------------------------------------------+
| Warning | 1478 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+---------------------------------------------------------------+
1 row in set (0.00 sec)

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
Table: t1
Create Table: CREATE TABLE `t1` (
    `c1` int(11) NOT NULL,
    `c2` varchar(30) DEFAULT NULL,
    `c3` int(11) /*!50120 STORAGE MEMORY */ /*!50120 COLUMN_FORMAT DYNAMIC */ DEFAULT NULL,
    `t4` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL,
    PRIMARY KEY (`c1`) ) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.03 sec)
```

Note

The `STORAGE` and `COLUMN_FORMAT` keywords are supported only in NDB Cluster; in any other version of MySQL, attempting to use either of these keywords in a `CREATE TABLE` or `ALTER TABLE` statement results in an error.

It is also possible to use the statement `ALTER ONLINE TABLE ... REORGANIZE PARTITION` with no `partition_names INTO (partition_definitions)` option on NDB tables. This can be used to redistribute NDB Cluster data among new data nodes that have been added to the cluster online. This does not perform any defragmentation, which requires an `OPTIMIZE TABLE` or null `ALTER TABLE` statement. For more information, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

Limitations of NDB online operations

Online `DROP COLUMN` operations are not supported.

Online `ALTER TABLE, CREATE INDEX, or DROP INDEX` statements that add columns or add or drop indexes are subject to the following limitations:

- A given online `ALTER TABLE` can use only one of `ADD COLUMN, ADD INDEX, or DROP INDEX`. One or more columns can be added online in a single statement; only one index may be created or dropped online in a single statement.

- An `ALTER TABLE` statement that performs a rename while using the `ONLINE` or `OFFLINE` keyword cannot perform any other operations, including but not limited to `ADD COLUMN, ADD INDEX, or DROP INDEX`. Beginning with MySQL NDB Cluster 7.2.11, such statements are specifically disallowed, and fail with `ER_NOT_SUPPORTED_YET` (Bug #16021021).

- The table being altered is not locked with respect to API nodes other than the one on which an online `ALTER TABLE ADD COLUMN, ADD INDEX, or DROP INDEX` operation (or `CREATE INDEX` or `DROP INDEX` statement) is run. However, the table is locked against any other operations originating on the same API node while the online operation is being executed.

- The table to be altered must have an explicit primary key; the hidden primary key created by the NDB storage engine is not sufficient for this purpose.

- The storage engine used by the table cannot be changed online.

- When used with NDB Cluster Disk Data tables, it is not possible to change the storage type (`DISK` or `MEMORY`) of a column online. This means, that when you add or drop an index in such a way that the
operation would be performed online, and you want the storage type of the column or columns to be changed, you must use the OFFLINE keyword in the statement that adds or drops the index.

Columns to be added online cannot use the BLOB or TEXT type, and must meet the following criteria:

- The columns must be dynamic; that is, it must be possible to create them using COLUMN_FORMAT DYNAMIC. If you omit the COLUMN_FORMAT DYNAMIC option, the dynamic column format is employed automatically.

- The columns must permit NULL values and not have any explicit default value other than NULL. Columns added online are automatically created as DEFAULT NULL, as can be seen here:

```sql
mysql> CREATE TABLE t1 (  
    > c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY  
    > ) ENGINE=NDB;
Query OK, 0 rows affected (1.44 sec)
mysql> ALTER ONLINE TABLE t1  
    > ADD COLUMN c2 INT,  
    > ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)
```

- The columns must be added following any existing columns. If you attempt to add a column online before any existing columns or using the FIRST keyword, the statement fails with an error.

- Existing table columns cannot be reordered online.

For online ALTER TABLE operations on NDB tables, fixed-format columns are converted to dynamic when they are added online, or when indexes are created or dropped online, as shown here:

```sql
mysql> CREATE TABLE t1 (  
    > c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY  
    > ) ENGINE=NDB;
Query OK, 0 rows affected (1.44 sec)
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c2 INT, ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)
Records: 0  Duplicates: 0  Warnings: 0
mysql> SHOW WARNINGS;
+---------+------+---------------------------------------------------------------+  
| Level   | Code | Message                                                       |
+---------+------+---------------------------------------------------------------+  
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+---------------------------------------------------------------+  
2 rows in set (0.00 sec)
```

Note

Existing columns, including the table’s primary key, need not be dynamic; only the column or columns to be added online must be dynamic.
Adding NDB Cluster Data Nodes Online

```
mysql> CREATE TABLE t2 (  
>   c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY COLUMN_FORMAT FIXED  
> ) ENGINE=NDB;
Query OK, 0 rows affected (2.10 sec)

mysql> ALTER ONLINE TABLE t2 ADD COLUMN c2 INT;
Query OK, 0 rows affected, 1 warning (0.78 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+---------------------------------------------------------------+
<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>1475</td>
<td>Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN</td>
</tr>
</tbody>
</table>
+---------+------+---------------------------------------------------------------+
1 row in set (0.00 sec)
```

Columns are not converted from FIXED to DYNAMIC column format by renaming operations. For more information about COLUMN_FORMAT, see Section 13.1.17, "CREATE TABLE Statement".

The KEY, CONSTRAINT, and IGNORE keywords are supported in ALTER TABLE statements using the ONLINE keyword.

18.5.14 Adding NDB Cluster Data Nodes Online

This section describes how to add NDB Cluster data nodes “online”—that is, without needing to shut down the cluster completely and restart it as part of the process.

**Important**
Currently, you must add new data nodes to an NDB Cluster as part of a new node group. In addition, it is not possible to change the number of replicas (or the number of nodes per node group) online.

18.5.14.1 Adding NDB Cluster Data Nodes Online: General Issues

This section provides general information about the behavior of and current limitations in adding NDB Cluster nodes online.

**Redistribution of Data.** The ability to add new nodes online includes a means to reorganize NDBCLUSTER table data and indexes so that they are distributed across all data nodes, including the new ones, by means of the ALTER ONLINE TABLE ... REORGANIZE PARTITION statement. Table reorganization of both in-memory and Disk Data tables is supported. This redistribution does not currently include unique indexes (only ordered indexes are redistributed). Prior to NDB 7.2.14, BLOB table data is also not redistributed using this method (Bug #13714148).

The redistribution for NDBCLUSTER tables already existing before the new data nodes were added is not automatic, but can be accomplished using simple SQL statements in mysql or another MySQL client application. However, all data and indexes added to tables created after a new node group has been added are distributed automatically among all cluster data nodes, including those added as part of the new node group.

**Partial starts.** It is possible to add a new node group without all of the new data nodes being started. It is also possible to add a new node group to a degraded cluster—that is, a cluster that is only partially started, or where one or more data nodes are not running. In the latter case, the cluster must have enough nodes running to be viable before the new node group can be added.

**Effects on ongoing operations.** Normal DML operations using NDB Cluster data are not prevented by the creation or addition of a new node group, or by table reorganization. However, it is not possible
to perform DDL concurrently with table reorganization—that is, no other DDL statements can be issued while an `ALTER TABLE ... REORGANIZE PARTITION` statement is executing. In addition, during the execution of `ALTER TABLE ... REORGANIZE PARTITION` (or the execution of any other DDL statement), it is not possible to restart cluster data nodes.

**Failure handling.** Failures of data nodes during node group creation and table reorganization are handled as shown in the following table:

### Table 18.281 Data node failure handling during node group creation and table reorganization

<table>
<thead>
<tr>
<th>Failure during</th>
<th>Failure in “Old” data node</th>
<th>Failure in “New” data node</th>
<th>System Failure</th>
</tr>
</thead>
</table>
| **Node group creation** | • If a node other than the master fails: The creation of the node group is always rolled forward.  
  • If the master fails:  
    • If the internal commit point has been reached: The creation of the node group is rolled forward.  
    • If the internal commit point has not yet been reached: The creation of the node group is rolled back.  | • If a node other than the master fails: The creation of the node group is always rolled forward.  
  • If the master fails:  
    • If the internal commit point has been reached: The creation of the node group is rolled forward.  
    • If the internal commit point has not yet been reached: The creation of the node group is rolled back.  | • If the execution of `CREATE NODEGROUP` has reached the internal commit point: When restarted, the cluster includes the new node group. Otherwise it without.  
  • If the execution of `CREATE NODEGROUP` has not yet reached the internal commit point: When restarted, the cluster does not include the new node group. |
| **Table reorganization** | • If a node other than the master fails: The table reorganization is always rolled forward.  
  • If the master fails:  
    • If the internal commit point has been reached: The table reorganization is rolled forward.  
    • If the internal commit point has not yet been reached: The table reorganization is rolled back.  | • If a node other than the master fails: The table reorganization is always rolled forward.  
  • If the master fails:  
    • If the internal commit point has been reached: The table reorganization is rolled forward.  
    • If the internal commit point has not yet been reached: The table reorganization is rolled back.  | • If the execution of an `ALTER TABLE ... REORGANIZE PARTITION` statement has reached the internal commit point: When the cluster is restarted, the data and indexes belonging to `table` are distributed using the “new” data nodes.  
  • If the execution of an `ALTER TABLE ... REORGANIZE PARTITION` statement has not yet reached the internal commit point: When the cluster is restarted,
Adding NDB Cluster Data Nodes Online

<table>
<thead>
<tr>
<th>Failure during</th>
<th>Failure in “Old” data node</th>
<th>Failure in “New” data node</th>
<th>System Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>the data and indexes belonging to table are distributed using only the “old” data nodes.</td>
</tr>
</tbody>
</table>

**Dropping node groups.** The ndb_mgm client supports a DROP NODEGROUP command, but it is possible to drop a node group only when no data nodes in the node group contain any data. Since there is currently no way to “empty” a specific data node or node group, this command works only the following two cases:

1. After issuing CREATE NODEGROUP in the ndb_mgm client, but before issuing any ALTER ONLINE TABLE ... REORGANIZE PARTITION statements in the mysql client.
2. After dropping all NDBCLUSTER tables using DROP TABLE.

**TRUNCATE TABLE** does not work for this purpose because the data nodes continue to store the table definitions.

### 18.5.14.2 Adding NDB Cluster Data Nodes Online: Basic procedure

In this section, we list the basic steps required to add new data nodes to an NDB Cluster. This procedure applies whether you are using ndbd or ndbmtd binaries for the data node processes. For a more detailed example, see Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”.

Assuming that you already have a running NDB Cluster, adding data nodes online requires the following steps:

1. Edit the cluster configuration config.ini file, adding new [ndbd] sections corresponding to the nodes to be added. In the case where the cluster uses multiple management servers, these changes need to be made to all config.ini files used by the management servers.

   You must be careful that node IDs for any new data nodes added in the config.ini file do not overlap node IDs used by existing nodes. In the event that you have API nodes using dynamically allocated node IDs and these IDs match node IDs that you want to use for new data nodes, it is possible to force any such API nodes to “migrate”, as described later in this procedure.

2. Perform a rolling restart of all NDB Cluster management servers.

   **Important**
   All management servers must be restarted with the --reload or --initial option to force the reading of the new configuration.

3. Perform a rolling restart of all existing NDB Cluster data nodes. It is not necessary (or usually even desirable) to use --initial when restarting the existing data nodes.

   If you are using API nodes with dynamically allocated IDs matching any node IDs that you wish to assign to new data nodes, you must restart all API nodes (including SQL nodes) before restarting any of the data nodes processes in this step. This causes any API nodes with node IDs that were previously not explicitly assigned to relinquish those node IDs and acquire new ones.

4. Perform a rolling restart of any SQL or API nodes connected to the NDB Cluster.

5. Start the new data nodes.
Adding NDB Cluster Data Nodes Online

The new data nodes may be started in any order. They can also be started concurrently, as long as they are started after the rolling restarts of all existing data nodes have been completed, and before proceeding to the next step.

6. Execute one or more `CREATE NODEGROUP` commands in the NDB Cluster management client to create the new node group or node groups to which the new data nodes will belong.

7. Redistribute the cluster’s data among all data nodes, including the new ones. Normally this is done by issuing an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement in the `mysql` client for each `NDBCLUSTER` table.

   *Exception*: For tables created using the `MAX_ROWS` option, this statement does not work; instead, use `ALTER ONLINE TABLE ... MAX_ROWS=...` to reorganize such tables.

   **Note**

   This needs to be done only for tables already existing at the time the new node group is added. Data in tables created after the new node group is added is distributed automatically; however, data added to any given table `tbl` that existed before the new nodes were added is not distributed using the new nodes until that table has been reorganized.

8. `ALTER ONLINE TABLE ... REORGANIZE PARTITION` reorganizes partitions but does not reclaim the space freed on the “old” nodes. You can do this by issuing, for each `NDBCLUSTER` table, an `OPTIMIZE TABLE` statement in the `mysql` client.

   This works for space used by variable-width columns of in-memory `NDB` tables. `OPTIMIZE TABLE` is not supported for fixed-width columns of in-memory tables; it is also not supported for Disk Data tables.

   You can add all the nodes desired, then issue several `CREATE NODEGROUP` commands in succession to add the new node groups to the cluster.

### 18.5.14.3 Adding NDB Cluster Data Nodes Online: Detailed Example

In this section we provide a detailed example illustrating how to add new NDB Cluster data nodes online, starting with an NDB Cluster having 2 data nodes in a single node group and concluding with a cluster having 4 data nodes in 2 node groups.

**Starting configuration.** For purposes of illustration, we assume a minimal configuration, and that the cluster uses a `config.ini` file containing only the following information:

```ini
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[mgm]
HostName = 198.51.100.10
Id = 10
```
Adding NDB Cluster Data Nodes Online

Note
We have left a gap in the sequence between data node IDs and other nodes. This make it easier later to assign node IDs that are not already in use to data nodes which are newly added.

We also assume that you have already started the cluster using the appropriate command line or my.cnf options, and that running SHOW in the management client produces output similar to what is shown here:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @198.51.100.1  (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=2    @198.51.100.2  (5.5.65-ndb-7.2.39, Nodegroup: 0)
[ndb_mgmd(MGM)] 1 node(s)
id=10   @198.51.100.10  (5.5.65-ndb-7.2.39)
[mysqld(API)]   2 node(s)
id=20   @198.51.100.20  (5.5.65-ndb-7.2.39)
id=21   @198.51.100.21  (5.5.65-ndb-7.2.39)
```

Finally, we assume that the cluster contains a single NDBCLUSTER table created as shown here:

```
USE n;
CREATE TABLE ips (  
id BIGINT NOT NULL AUTO_INCREMENT PRIMARY KEY,  
country_code CHAR(2) NOT NULL,  
type CHAR(4) NOT NULL,  
ip_address VARCHAR(15) NOT NULL,  
addresses BIGINT UNSIGNED DEFAULT NULL,  
date BIGINT UNSIGNED DEFAULT NULL)   ENGINE NDBCLUSTER;
```

The memory usage and related information shown later in this section was generated after inserting approximately 50000 rows into this table.

Note
In this example, we show the single-threaded ndbd being used for the data node processes. However—beginning with NDB 7.0.4—you can also apply this example, if you are using the multithreaded ndbmtd by substituting ndbmtd for ndbd wherever it appears in the steps that follow. (Bug #43108)

Step 1: Update configuration file. Open the cluster global configuration file in a text editor and add [ndbd] sections corresponding to the 2 new data nodes. (We give these data nodes IDs 3 and 4, and assume that they are to be run on host machines at addresses 198.51.100.3 and 198.51.100.4, respectively.) After you have added the new sections, the contents of the config.ini file should look like what is shown here, where the additions to the file are shown in bold type:

```
[ndbd default]  
```
Adding NDB Cluster Data Nodes Online

DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[ndbd]
Id = 3
HostName = 198.51.100.3

[ndbd]
Id = 4
HostName = 198.51.100.4

[mgm]
HostName = 198.51.100.10
Id = 10

[api]
Id=20
HostName = 198.51.100.20

[api]
Id=21
HostName = 198.51.100.21

Once you have made the necessary changes, save the file.

**Step 2: Restart the management server.** Restarting the cluster management server requires that you issue separate commands to stop the management server and then to start it again, as follows:

1. **Stop the management server using the management client** `STOP` **command, as shown here:**

    ```
    ndb_mgm> 10 STOP
    Node 10 has shut down.
    Disconnecting to allow Management Server to shutdown
    shell>
    ```

2. **Because shutting down the management server causes the management client to terminate,** you must start the management server from the system shell. For simplicity, we assume that `config.ini` is in the same directory as the management server binary, but in practice, you must supply the correct path to the configuration file. You must also supply the `--reload` or `--initial` option so that the management server reads the new configuration from the file rather than its configuration cache. If your shell's current directory is also the same as the directory where the management server binary is located, then you can invoke the management server as shown here:

    ```
    shell> ndb_mgm -f config.ini --reload
    2008-12-08 17:29:23 [MgmSrvr] INFO -- NDB Cluster Management Server. 5.5.65-ndb-7.2.39
    2008-12-08 17:29:23 [MgmSrvr] INFO -- Reading cluster configuration from 'config.ini'
    ```

If you check the output of `SHOW` in the management client after restarting the `ndb_mgm` process, you should now see something like this:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
```
Adding NDB Cluster Data Nodes Online

---

[nbdb(NDB)] 2 node(s)
id=1 198.51.100.1 (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=2 198.51.100.2 (5.5.65-ndb-7.2.39, Nodegroup: 0)
id=3 (not connected, accepting connect from 198.51.100.3)
id=4 (not connected, accepting connect from 198.51.100.4)

[ndb_mgmd(MGM)] 1 node(s)
id=10 198.51.100.10 (5.5.65-ndb-7.2.39)

[mysqld(API)] 2 node(s)
id=20 198.51.100.20 (5.5.65-ndb-7.2.39)
id=21 198.51.100.21 (5.5.65-ndb-7.2.39)

**Step 3: Perform a rolling restart of the existing data nodes.** This step can be accomplished entirely within the cluster management client using the **RESTART** command, as shown here:

```
ndb_mgm> 1 RESTART
Node 1: Node shutdown initiated
Node 1: Node shutdown completed, restarting, no start.
Node 1 is being restarted

ndb_mgm> Node 1: Start initiated (version 7.2.39)
Node 1: Started (version 7.2.39)
```

```
ndb_mgm> 2 RESTART
Node 2: Node shutdown initiated
Node 2: Node shutdown completed, restarting, no start.
Node 2 is being restarted

ndb_mgm> Node 2: Start initiated (version 7.2.39)
ndb_mgm> Node 2: Started (version 7.2.39)
```

**Important**

After issuing each X **RESTART** command, wait until the management client reports Node X: Started (version ...) before proceeding any further.

You can verify that all existing data nodes were restarted using the updated configuration by checking the **ndbinfo.nodes** table in the **mysql** client.

**Step 4: Perform a rolling restart of all cluster API nodes.** Shut down and restart each MySQL server acting as an SQL node in the cluster using **mysqladmin shutdown** followed by **mysqld_safe** (or another startup script). This should be similar to what is shown here, where **password** is the MySQL root password for a given MySQL server instance:

```
shell> mysqladmin -u root -p password shutdown
081208 20:19:56 mysqld_safe mysqld from pid file /
/usr/local/mysql/var/tonfisk.pid ended
shell> mysqld_safe --ndbcluster --ndb-connectstring=198.51.100.10 &
081208 20:20:06 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
081208 20:20:06 mysqld_safe Starting mysqld daemon with databases
from /usr/local/mysql/var
```

Of course, the exact input and output depend on how and where MySQL is installed on the system, as well as which options you choose to start it (and whether or not some or all of these options are specified in a **my.cnf** file).

**Step 5: Perform an initial start of the new data nodes.** From a system shell on each of the hosts for the new data nodes, start the data nodes as shown here, using the **--initial** option:

```
shell> ndbd -c 198.51.100.10 --initial
```
Adding NDB Cluster Data Nodes Online

Note
Unlike the case with restarting the existing data nodes, you can start the new data nodes concurrently; you do not need to wait for one to finish starting before starting the other.

Wait until both of the new data nodes have started before proceeding with the next step. Once the new data nodes have started, you can see in the output of the management client SHOW command that they do not yet belong to any node group (as indicated with bold type here):

```
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)] 2 node(s)
id=1 @198.51.100.1 (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=2 @198.51.100.2 (5.5.65-ndb-7.2.39, Nodegroup: 0)
id=3 @198.51.100.3 (5.5.65-ndb-7.2.39, no nodegroup)
id=4 @198.51.100.4 (5.5.65-ndb-7.2.39, no nodegroup)

[ndb_mgmd(MGM)] 1 node(s)
id=10 @198.51.100.10 (5.5.65-ndb-7.2.39)

[mysqld(API)] 2 node(s)
id=20 @198.51.100.20 (5.5.65-ndb-7.2.39)
id=21 @198.51.100.21 (5.5.65-ndb-7.2.39)
```

Step 6: Create a new node group. You can do this by issuing a CREATE NODEGROUP command in the cluster management client. This command takes as its argument a comma-separated list of the node IDs of the data nodes to be included in the new node group, as shown here:

```
ndb_mgm> CREATE NODEGROUP 3,4
Nodegroup 1 created
```

By issuing SHOW again, you can verify that data nodes 3 and 4 have joined the new node group (again indicated in bold type):

```
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)] 2 node(s)
id=1 @198.51.100.1 (5.5.65-ndb-7.2.39, Nodegroup: 0, *)
id=2 @198.51.100.2 (5.5.65-ndb-7.2.39, Nodegroup: 0)
id=3 @198.51.100.3 (5.5.65-ndb-7.2.39, Nodegroup: 1)
id=4 @198.51.100.4 (5.5.65-ndb-7.2.39, Nodegroup: 1)

[ndb_mgmd(MGM)] 1 node(s)
id=10 @198.51.100.10 (5.5.65-ndb-7.2.39)

[mysqld(API)] 2 node(s)
id=20 @198.51.100.20 (5.5.65-ndb-7.2.39)
id=21 @198.51.100.21 (5.5.65-ndb-7.2.39)
```

Step 7: Redistribute cluster data. When a node group is created, existing data and indexes are not automatically distributed to the new node group’s data nodes, as you can see by issuing the appropriate REPORT command in the management client:

```
ndb_mgm> ALL REPORT MEMORY
Node 1: Data usage is 5% (177 32K pages of total 3200)
Node 1: Index usage is 0% (108 8K pages of total 12832)
Node 2: Data usage is 5% (177 32K pages of total 3200)
```
Adding NDB Cluster Data Nodes Online

Node 2: Index usage is 0%(108 8K pages of total 12832)
Node 3: Data usage is 0%(0 32K pages of total 3200)
Node 4: Data usage is 0%(0 32K pages of total 3200)
Node 4: Index usage is 0%(0 8K pages of total 12832)

By using `ndb_desc` with the `-p` option, which causes the output to include partitioning information, you can see that the table still uses only 2 partitions (in the Per partition info section of the output, shown here in bold text):

```
shell> ndb_desc -c 198.51.100.10 -d n ips -p
-- ips --
Version: 1
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 340
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
  id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
  country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
  type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
  ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
  addresses Bigunsigned NULL AT=FIXED ST=MEMORY
  date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
  PRIMARY KEY(id) - UniqueHashIndex
  PRIMARY(id) - OrderedIndex

-- Per partition info --
<table>
<thead>
<tr>
<th>Partition</th>
<th>Row count</th>
<th>Commit count</th>
<th>Frag fixed memory</th>
<th>Frag varsized memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>26086</td>
<td>26086</td>
<td>1572864</td>
<td>557056</td>
</tr>
<tr>
<td>1</td>
<td>26329</td>
<td>26329</td>
<td>1605632</td>
<td>557056</td>
</tr>
</tbody>
</table>

NDBT_ProgramExit: 0 - OK
```

You can cause the data to be redistributed among all of the data nodes by performing, for each NDB table, an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement in the `mysql` client.

**Important**

`ALTER ONLINE TABLE ... REORGANIZE PARTITION` does not work on tables that were created with the `MAX_ROWS` option. Instead, use `ALTER ONLINE TABLE ... MAX_ROWS=...` to reorganize such tables.

After issuing the statement `ALTER ONLINE TABLE ips REORGANIZE PARTITION`, you can see using `ndb_desc` that the data for this table is now stored using 4 partitions, as shown here (with the relevant portions of the output in bold type):

```
shell> ndb_desc -c 198.51.100.10 -d n ips -p
-- ips --
Version: 16777217
Fragment type: 9
K Value: 6
```
Adding NDB Cluster Data Nodes Online

Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 341
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
TableStatus: Retrieved

-- Attributes --
  id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
  country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
  type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
  ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
  addresses Bigunsigned NULL AT=FIXED ST=MEMORY
  date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
  PRIMARY KEY(id) - UniqueHashIndex
  PRIMARY(id) - OrderedIndex

-- Per partition info --

<table>
<thead>
<tr>
<th>Partition</th>
<th>Row count</th>
<th>Commit count</th>
<th>Frag fixed memory</th>
<th>Frag varsized memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12981</td>
<td>52296</td>
<td>1572864</td>
<td>557056</td>
</tr>
<tr>
<td>1</td>
<td>13236</td>
<td>52515</td>
<td>1605632</td>
<td>557056</td>
</tr>
<tr>
<td>2</td>
<td>13105</td>
<td>13105</td>
<td>819200</td>
<td>294912</td>
</tr>
<tr>
<td>3</td>
<td>13093</td>
<td>13093</td>
<td>819200</td>
<td>294912</td>
</tr>
</tbody>
</table>

NDBT_ProgramExit: 0 - OK

Note

Normally, `ALTER [ONLINE] TABLE table_name REORGANIZE PARTITION` is used with a list of partition identifiers and a set of partition definitions to create a new partitioning scheme for a table that has already been explicitly partitioned. Its use here to redistribute data onto a new NDB Cluster node group is an exception in this regard; when used in this way, only the name of the table is used following the `TABLE` keyword, and no other keywords or identifiers follow `REORGANIZE PARTITION`.

For more information, see Section 13.1.7, “ALTER TABLE Statement”.

In addition, for each table, the `ALTER ONLINE TABLE` statement should be followed by an `OPTIMIZE TABLE` to reclaim wasted space. You can obtain a list of all NDBCLUSTER tables using the following query against the `INFORMATION_SCHEMA.TABLES` table:

```sql
SELECT TABLE_SCHEMA, TABLE_NAME
FROM INFORMATION_SCHEMA.TABLES
WHERE ENGINE = 'NDBCLUSTER';
```

Note

The `INFORMATION_SCHEMA.TABLES.ENGINE` value for an NDB Cluster table is always `NDBCLUSTER`, regardless of whether the `CREATE TABLE` statement used to create the table (or `ALTER TABLE` statement used to convert an existing table from a different storage engine) used `NDB` or `NDBCLUSTER` in its `ENGINE` option.

You can see after performing these statements in the output of `ALL REPORT MEMORY` that the data and indexes are now redistributed between all cluster data nodes, as shown here:
Adding NDB Cluster Data Nodes Online

```
ndb_mgm> ALL REPORT MEMORY

Node 1: Data usage is 5%(176 32K pages of total 3200)
Node 1: Index usage is 0%(76 8K pages of total 12832)
Node 2: Data usage is 5%(176 32K pages of total 3200)
Node 2: Index usage is 0%(76 8K pages of total 12832)
Node 3: Data usage is 2%(80 32K pages of total 3200)
Node 3: Index usage is 0%(51 8K pages of total 12832)
Node 4: Data usage is 2%(80 32K pages of total 3200)
Node 4: Index usage is 0%(50 8K pages of total 12832)
```

**Note**

Since only one DDL operation on NDBCLUSTER tables can be executed at a time, you must wait for each `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement to finish before issuing the next one.

It is not necessary to issue `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements for NDBCLUSTER tables created after the new data nodes have been added; data added to such tables is distributed among all data nodes automatically. However, in NDBCLUSTER tables that existed prior to the addition of the new nodes, neither existing nor new data is distributed using the new nodes until these tables have been reorganized using `ALTER ONLINE TABLE ... REORGANIZE PARTITION`.

**Alternative procedure, without rolling restart.** It is possible to avoid the need for a rolling restart by configuring the extra data nodes, but not starting them, when first starting the cluster. We assume, as before, that you wish to start with two data nodes—nodes 1 and 2—in one node group and later to expand the cluster to four data nodes, by adding a second node group consisting of nodes 3 and 4:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[ndbd]
Id = 3
HostName = 198.51.100.3
Nodegroup = 65536

[ndbd]
Id = 4
HostName = 198.51.100.4
Nodegroup = 65536

[mgm]
HostName = 198.51.100.10
Id = 10

[api]
Id=20
HostName = 198.51.100.20

[api]
Id=21
HostName = 198.51.100.21
```
Note
In NDB Cluster 7.2, it is no longer necessary to perform the initial start of the cluster using --nowait-nodes option with ndbd or ndbmtd as it was in some earlier versions of NDB Cluster.

The data nodes to be brought online at a later time (nodes 3 and 4) can be configured with NodeGroup = 65536, in which case nodes 1 and 2 can each be started as shown here:

shell> ndbd -c 198.51.100.10 --initial

The data nodes configured with NodeGroup = 65536 are treated by the management server as though you had started nodes 1 and 2 using --nowait-nodes=3,4 after waiting for a period of time determined by the setting for the StartNoNodeGroupTimeout data node configuration parameter. By default, this is 15 seconds (15000 milliseconds).

Note
StartNoNodeGroupTimeout must be the same for all data nodes in the cluster; for this reason, you should always set it in the [ndbd default] section of the config.ini file, rather than for individual data nodes.

When you are ready to add the second node group, you need only perform the following additional steps:

1. Start data nodes 3 and 4, invoking the data node process once for each new node:

shell> ndbd -c 198.51.100.10 --initial

2. Issue the appropriate CREATE NODEGROUP command in the management client:

ndb_mgm> CREATE NODEGROUP 3,4

3. In the mysql client, issue ALTER ONLINE TABLE ... REORGANIZE PARTITION and OPTIMIZE TABLE statements for each existing NDBCLUSTER table. (As noted elsewhere in this section, existing NDB Cluster tables cannot use the new nodes for data distribution until this has been done.)

18.5.15 Distributed Privileges Using Shared Grant Tables

NDB Cluster 7.2 introduces support for distributing MySQL users and privileges across all SQL nodes in an NDB Cluster. This support is not enabled by default; you should follow the procedure outlined in this section in order to do so.

Normally, each MySQL server's user privilege tables in the mysql database must use the MyISAM storage engine, which means that a user account and its associated privileges created on one SQL node are not available on the cluster's other SQL nodes. In NDB Cluster 7.2 and later, an SQL file ndb_dist_priv.sql is provided with the NDB Cluster distribution. This file can be found in the share directory in the MySQL installation directory.

The first step in enabling distributed privileges is to load this script into a MySQL Server that functions as an SQL node (which we refer to after this as the target SQL node or MySQL Server). You can do this by executing the following command from the system shell on the target SQL node after changing to its MySQL installation directory (where options stands for any additional options needed to connect to this SQL node):

shell> mysql options -uroot < share/ndb_dist_priv.sql

Importing ndb_dist_priv.sql creates a number of stored routines (six stored procedures and one stored function) in the mysql database on the target SQL node. After connecting to the SQL node in the mysql client (as the MySQL root user), you can verify that these were created as shown here:
Distributed Privileges Using Shared Grant Tables

```
mysql> SELECT ROUTINE_NAME, ROUTINE_SCHEMA, ROUTINE_TYPE -> FROM INFORMATION_SCHEMA.ROUTINES -> WHERE ROUTINE_NAME LIKE 'mysql_cluster%' -> ORDER BY ROUTINE_TYPE;
+---------------------------------------------+----------------+--------------+
| ROUTINE_NAME                                | ROUTINE_SCHEMA | ROUTINE_TYPE |
+---------------------------------------------+----------------+--------------+
| mysql_cluster_privileges_are_distributed    | mysql          | FUNCTION     |
| mysql_cluster_backup_privileges             | mysql          | PROCEDURE    |
| mysql_cluster_move_grant_tables             | mysql          | PROCEDURE    |
| mysql_cluster_move_privileges               | mysql          | PROCEDURE    |
| mysql_cluster_restore_local_privileges      | mysql          | PROCEDURE    |
| mysql_cluster_restore_privileges            | mysql          | PROCEDURE    |
| mysql_cluster_restore_privileges_from_local | mysql          | PROCEDURE    |
+---------------------------------------------+----------------+--------------+
7 rows in set (0.01 sec)
```

The stored procedure named `mysql_cluster_move_privileges` creates backup copies of the existing privilege tables, then converts them to NDB.

`mysql_cluster_move_privileges` performs the backup and conversion in two steps. The first step is to call `mysql_cluster_backup_privileges`, which creates two sets of copies in the `mysql` database:

- A set of local copies that use the MyISAM storage engine. Their names are generated by adding the suffix `_backup` to the original privilege table names.
- A set of distributed copies that use the NDBCLUSTER storage engine. These tables are named by prefixing `ndb_` and appending `_backup` to the names of the original tables.

After the copies are created, `mysql_cluster_move_privileges` invokes `mysql_cluster_move_grant_tables`, which contains the `ALTER TABLE ... ENGINE = NDB` statements that convert the `mysql` system tables to NDB.

Normally, you should not invoke either `mysql_cluster_backup_privileges` or `mysql_cluster_move_grant_tables` manually; these stored procedures are intended only for use by `mysql_cluster_move_privileges`.

Although the original privilege tables are backed up automatically, it is always a good idea to create backups manually of the existing privilege tables on all affected SQL nodes before proceeding. You can do this using `mysqldump` in a manner similar to what is shown here:

```
shell> mysqldump options -uroot 
   mysql host user db tables_priv columns_priv procs_priv proxies_priv > backup_file
```

To perform the conversion, you must be connected to the target SQL node using the `mysql` client (again, as the MySQL root user). Invoke the stored procedure like this:

```
mysql> CALL mysql.mysql_cluster_move_privileges();
Query OK, 0 rows affected (22.32 sec)
```

Depending on the number of rows in the privilege tables, this procedure may take some time to execute. If some of the privilege tables are empty, you may see one or more No data - zero rows fetched, selected, or processed warnings when `mysql_cluster_move_privileges` returns. In such cases, the warnings may be safely ignored. To verify that the conversion was successful, you can use the stored function `mysql_cluster_privileges_are_distributed` as shown here:

```
mysql> SELECT CONCAT(
```
Distributed Privileges Using Shared Grant Tables

mysql_cluster_privileges_are_distributed checks for the existence of the distributed privilege tables and returns 1 if all of the privilege tables are distributed; otherwise, it returns 0.

You can verify that the backups have been created using a query such as this one:

```sql
mysql> SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'mysql' AND TABLE_NAME LIKE '%backup'
ORDER BY ENGINE;
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>ENGINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>columns_priv_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>user_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>tables_priv_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>proxies_priv_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>procs_priv_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>host_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>db_backup</td>
<td>MyISAM</td>
</tr>
<tr>
<td>ndb_user_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_tables_priv_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_proxies_priv_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_procs_priv_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_host_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_db_backup</td>
<td>ndbcluster</td>
</tr>
<tr>
<td>ndb_columns_priv_backup</td>
<td>ndbcluster</td>
</tr>
</tbody>
</table>
+-------------------------+------------+
14 rows in set (0.02 sec)

Once the conversion to distributed privileges has been made, any time a MySQL user account is created, dropped, or has its privileges updated on any SQL node, the changes take effect immediately on all other MySQL servers attached to the cluster. Once privileges are distributed, any new MySQL Servers that connect to the cluster automatically participate in the distribution.

**Note**

For clients connected to SQL nodes at the time that `mysql_cluster_move_privileges` is executed, you may need to execute `FLUSH PRIVILEGES` on those SQL nodes, or to disconnect and then reconnect the clients, in order for those clients to be able to see the changes in privileges.

All MySQL user privileges are distributed across all connected MySQL Servers. This includes any privileges associated with views and stored routines, even though distribution of views and stored routines themselves is not currently supported.

In the event that an SQL node becomes disconnected from the cluster while `mysql_cluster_move_privileges` is running, you must drop its privilege tables after reconnecting to the cluster, using a statement such as `DROP TABLE IF EXISTS mysql.user mysql.db mysql.tables_priv mysql.columns_priv mysql.procs_priv`. This causes the SQL node to use the shared privilege tables rather than its own local versions of them. This is not needed when connecting a new SQL node to the cluster for the first time.
In the event of an initial restart of the entire cluster (all data nodes shut down, then started again with `--initial`), the shared privilege tables are lost. If this happens, you can restore them using the original target SQL node either from the backups made by `mysql_cluster_move_privileges` or from a dump file created with `mysqldump`. If you need to use a new MySQL Server to perform the restoration, you should start it with `--skip-grant-tables` when connecting to the cluster for the first time; after this, you can restore the privilege tables locally, then distribute them again using `mysql_cluster_move_privileges`. After restoring and distributing the tables, you should restart this MySQL Server without the `--skip-grant-tables` option.

You can also restore the distributed tables using `ndb_restore --restore-privilege-tables` from a backup made using `START BACKUP` in the `ndb_mgm` client. (The MyISAM tables created by `mysql_cluster_move_privileges` are not backed up by the `START BACKUP` command.) `ndb_restore` does not restore the privilege tables by default; the `--restore-privilege-tables` option causes it to do so.

You can restore the SQL node's local privileges using either of two procedures. `mysql_cluster_restore_privileges` works as follows:

1. If copies of the `mysql.ndb_*_backup` tables are available, attempt to restore the system tables from these.
2. Otherwise, attempt to restore the system tables from the local backups named `*_backup` (without the `ndb_` prefix).

The other procedure, named `mysql_cluster_restore_local_privileges`, restores the system tables from the local backups only, without checking the `ndb_*` backups.

The system tables re-created by `mysql_cluster_restore_privileges` or `mysql_cluster_restore_local_privileges` use the MySQL server default storage engine; they are not shared or distributed in any way, and do not use NDB Cluster's NDB storage engine.

The additional stored procedure `mysql_cluster_restore_privileges_from_local` is intended for the use of `mysql_cluster_restore_privileges` and `mysql_cluster_restore_local_privileges`. It should not be invoked directly.

---

### Important

Applications that access NDB Cluster data directly, including NDB API and ClusterJ applications, are not subject to the MySQL privilege system. This means that, once you have distributed the grant tables, they can be freely accessed by such applications, just as they can any other NDB tables. In particular, you should keep in mind that NDB API and ClusterJ applications can read and write user names, host names, password hashes, and any other contents of the distributed grant tables without any restrictions.

---

### 18.5.16 NDB API Statistics Counters and Variables

A number of types of statistical counters relating to actions performed by or affecting Ndb objects are available. Such actions include starting and closing (or aborting) transactions; primary key and unique key operations; table, range, and pruned scans; threads blocked while waiting for the completion of various operations; and data and events sent and received by `NDBCLUSTER`. The counters are incremented inside the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes. `mysqld` exposes these counters as system status variables; their values can be read in the output of `SHOW STATUS`, or by querying the `INFORMATION_SCHEMA.SESSION_STATUS` or `INFORMATION_SCHEMA.GLOBAL_STATUS` table. By comparing the values before and after statements
NDB API Statistics Counters and Variables

operating on NDB tables, you can observe the corresponding actions taken on the API level, and thus the cost of performing the statement.

You can list all of these status variables using the following `SHOW STATUS` statement:

```sql
mysql> SHOW STATUS LIKE 'ndb_api%';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_api_wait_exec_complete_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_scan_result_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_meta_request_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_nanos_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_bytes_sent_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_bytes_received_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_start_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_commit_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_abort_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_close_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pk_op_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_uk_op_count_session</td>
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</tr>
<tr>
<td>Ndb_api_table_scan_count_session</td>
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</tr>
<tr>
<td>Ndb_api_range_scan_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pruned_scan_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_scan_batch_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_read_row_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_local_read_row_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_event_data_count_injector</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_event_nondata_count_injector</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_event_bytes_count_injector</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_exec_complete_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_scan_result_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_meta_request_count_slave</td>
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<tr>
<td>Ndb_api_wait_nanos_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_bytes_sent_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_bytes_received_count_slave</td>
<td>0</td>
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<tr>
<td>Ndb_api_trans_start_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_commit_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_abort_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_close_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pk_op_count_slave</td>
<td>0</td>
</tr>
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<td>Ndb_api_uk_op_count_slave</td>
<td>0</td>
</tr>
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<td>Ndb_api_table_scan_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_range_scan_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pruned_scan_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_scan_batch_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_read_row_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_local_read_row_count_slave</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_exec_complete_count</td>
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</tr>
<tr>
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<tr>
<td>Ndb_api_wait_meta_request_count</td>
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<tr>
<td>Ndb_api_trans_commit_count</td>
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<tr>
<td>Ndb_api_trans_abort_count</td>
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</tr>
<tr>
<td>Ndb_api_trans_close_count</td>
<td>2</td>
</tr>
<tr>
<td>Ndb_api_pk_op_count</td>
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</tr>
<tr>
<td>Ndb_api_uk_op_count</td>
<td>0</td>
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<tr>
<td>Ndb_api_table_scan_count</td>
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</tr>
<tr>
<td>Ndb_api_range_scan_count</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pruned_scan_count</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_scan_batch_count</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_read_row_count</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_trans_local_read_row_count</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_event_data_count</td>
<td>0</td>
</tr>
</tbody>
</table>
NDB API Statistics Counters and Variables

<table>
<thead>
<tr>
<th>Ndb_api_event_nondata_count</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_api_event_bytes_count</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>---</td>
</tr>
</tbody>
</table>

60 rows in set (0.02 sec)

These status variables are also available from the `SESSION_STATUS` and `GLOBAL_STATUS` tables of the `INFORMATION_SCHEMA` database, as shown here:

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS
    -> WHERE VARIABLE_NAME LIKE 'ndb_api%';
+--------------------------------------------+----------------+
| VARIABLE_NAME                              | VARIABLE_VALUE |
+--------------------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION   | 2              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION     | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SESSION    | 1              |
| NDB_API_WAIT_NANOS_COUNT_SESSION           | 8144375        |
| NDB_API_BYTES_SENT_COUNT_SESSION           | 68             |
| NDB_API_BYTES_RECEIVED_COUNT_SESSION       | 84             |
| NDB_API_TRANS_START_COUNT_SESSION          | 1              |
| NDB_API_TRANS_COMMIT_COUNT_SESSION         | 1              |
| NDB_API_TRANS_ABORT_COUNT_SESSION          | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SESSION          | 1              |
| NDB_API_PK_OP_COUNT_SESSION                | 1              |
| NDB_API_UK_OP_COUNT_SESSION                | 0              |
| NDB_API_TABLE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_RANGE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SESSION          | 0              |
| NDB_API_SCAN_BATCH_COUNT_SESSION           | 0              |
| NDB_API_READ_ROW_COUNT_SESSION             | 1              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION | 1              |
| NDB_API_EVENT_DATA_COUNT_INJECTOR          | 0              |
| NDB_API_EVENT_NONDATA_COUNT_INJECTOR       | 0              |
| NDB_API_EVENT_BYTES_COUNT_INJECTOR         | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE     | 0              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE       | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE      | 0              |
| NDB_API_WAIT_NANOS_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_SENT_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE         | 0              |
| NDB_API_TRANS_START_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_COMMIT_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE            | 0              |
| NDB_API_PK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_UK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_SCAN_BATCH_COUNT_SLAVE             | 0              |
| NDB_API_READ_ROW_COUNT_SLAVE               | 0              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SLAVE   | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE     | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE       | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE      | 28             |
| NDB_API_WAIT_NANOS_COUNT_SLAVE             | 53756398       |
| NDB_API_BYTES_SENT_COUNT_SLAVE             | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE         | 9724           |
| NDB_API_TRANS_START_COUNT_SLAVE            | 3              |
| NDB_API_TRANS_COMMITCOUNT_SLAVE            | 2              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE            | 3              |
| NDB_API_PK_OP_COUNT_SLAVE                  | 2              |
| NDB_API_UK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE             | 1              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE            | 0              |
```

2544
### NDB API Statistics Counters and Variables

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDB_API_SCAN_BATCH_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_READ_ROW_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_TRANS_LOCAL_READ_ROW_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_EVENT_DATA_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_EVENT_NONDATA_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_EVENT_BYTES_COUNT</td>
<td>0</td>
</tr>
</tbody>
</table>

60 rows in set (0.00 sec)

```sql
SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS
WHERE VARIABLE_NAME LIKE 'ndb_api%';
```

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_WAIT_META_REQUEST_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_WAIT_NANOS_COUNT_SESSION</td>
<td>8144175</td>
</tr>
<tr>
<td>NDB_API_BYTES_SENT_COUNT_SESSION</td>
<td>68</td>
</tr>
<tr>
<td>NDB_API_BYTES_RECEIVED_COUNT_SESSION</td>
<td>84</td>
</tr>
<tr>
<td>NDB_API_TRANS_START_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_TRANS_COMMIT_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_TRANS_ABORT_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_CLOSE_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_PK_OP_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_UK_OP_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TABLE_SCAN_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_RANGE_SCAN_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_PRUNED_SCAN_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_SCAN_BATCH_COUNT_SESSION</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_READ_ROW_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_WAIT_META_REQUEST_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_WAIT_NANOS_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_BYTES_SENT_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_BYTES_RECEIVED_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_START_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_COMMIT_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_ABORT_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_CLOSE_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TABLE_SCAN_COUNT_SLAVE</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_RANGE_SCAN_COUNT_SLAVE</td>
<td>0</td>
</tr>
</tbody>
</table>
Each `Ndb` object has its own counters. NDB API applications can read the values of the counters for use in optimization or monitoring. For multithreaded clients which use more than one `Ndb` object concurrently, it is also possible to obtain a summed view of counters from all `Ndb` objects belonging to a given `Ndb_cluster_connection`.

Four sets of these counters are exposed. One set applies to the current session only; the other 3 are global. This is in spite of the fact that their values can be obtained as either session or global status variables in the `mysql` client. This means that specifying the `SESSION` or `GLOBAL` keyword with `SHOW STATUS` has no effect on the values reported for NDB API statistics status variables, and the value for each of these variables is the same whether the value is obtained from the equivalent column of the `SESSION_STATUS` or the `GLOBAL_STATUS` table.

- **Session counters (session specific)**

  Session counters relate to the `Ndb` objects in use by (only) the current session. Use of such objects by other MySQL clients does not influence these counts.

  In order to minimize confusion with standard MySQL session variables, we refer to the variables that correspond to these NDB API session counters as "_session variables", with a leading underscore.

- **Slave counters (global)**

  This set of counters relates to the `Ndb` objects used by the replication slave SQL thread, if any. If this `mysqld` does not act as a replication slave, or does not use `NDB` tables, then all of these counts are 0.

  We refer to the related status variables as "_slave variables" (with a leading underscore).

- **Injector counters (global)**

  Injector counters relate to the `Ndb` object used to listen to cluster events by the binary log injector thread. Even when not writing a binary log, `mysqld` processes attached to an NDB Cluster continue to listen for some events, such as schema changes.

  We refer to the status variables that correspond to NDB API injector counters as "_injector variables" (with a leading underscore).

- **Server (Global) counters (global)**

  This set of counters relates to all `Ndb` objects currently used by this `mysqld`. This includes all MySQL client applications, the slave SQL thread (if any), the binlog injector, and the `NDB` utility thread.

  We refer to the status variables that correspond to these counters as "global variables" or "mysqld-level variables".

You can obtain values for a particular set of variables by additionally filtering for the substring `session`, `slave`, or `injector` in the variable name (along with the common prefix `Ndb_api`). For _session variables, this can be done as shown here:

```
mysql> SHOW STATUS LIKE 'ndb_api%session';
2546
```
NDB API Statistics Counters and Variables

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_api_wait_exec_complete_count_session</td>
<td>2</td>
</tr>
<tr>
<td>Ndb_api_wait_scan_result_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_wait_meta_request_count_session</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_wait_nanos_count_session</td>
<td>8144375</td>
</tr>
<tr>
<td>Ndb_api_bytes_sent_count_session</td>
<td>68</td>
</tr>
<tr>
<td>Ndb_api_bytes_received_count_session</td>
<td>84</td>
</tr>
<tr>
<td>Ndb_api_trans_start_count_session</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_trans_commit_count_session</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_trans_abort_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_trans_close_count_session</td>
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<tr>
<td>Ndb_api_pk_op_count_session</td>
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<tr>
<td>Ndb_api_uk_op_count_session</td>
<td>0</td>
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<tr>
<td>Ndb_api_table_scan_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_range_scan_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_pruned_scan_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_scan_batch_count_session</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_read_row_count_session</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_api_trans_local_read_row_count_session</td>
<td>1</td>
</tr>
</tbody>
</table>

18 rows in set (0.50 sec)

To obtain a listing of the NDB API mysqld-level status variables, filter for variable names beginning with ndb_api and ending in _count, like this:

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS 
    -> WHERE VARIABLE_NAME LIKE 'ndb_api%count';
```

<table>
<thead>
<tr>
<th>VARIABLE_NAME</th>
<th>VARIABLE_VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDB_API_WAIT_EXEC_COMPLETE_COUNT</td>
<td>4</td>
</tr>
<tr>
<td>NDB_API_WAIT_SCAN_RESULT_COUNT</td>
<td>3</td>
</tr>
<tr>
<td>NDB_API_WAIT_META_REQUEST_COUNT</td>
<td>28</td>
</tr>
<tr>
<td>NDB_API_WAIT_NANOS_COUNT</td>
<td>53756398</td>
</tr>
<tr>
<td>NDB_API_BYTES_SENT_COUNT</td>
<td>1060</td>
</tr>
<tr>
<td>NDB_API_BYTES_RECEIVED_COUNT</td>
<td>9724</td>
</tr>
<tr>
<td>NDB_API_TRANS_START_COUNT</td>
<td>3</td>
</tr>
<tr>
<td>NDB_API_TRANS_COMMIT_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_TRANS_ABORT_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TRANS_CLOSE_COUNT</td>
<td>3</td>
</tr>
<tr>
<td>NDB_API_PK_OP_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_UK_OP_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_TABLE_SCAN_COUNT</td>
<td>1</td>
</tr>
<tr>
<td>NDB_API_RANGE_SCAN_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_PRUNED_SCAN_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_SCAN_BATCH_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_READ_ROW_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_TRANS_LOCAL_READ_ROW_COUNT</td>
<td>2</td>
</tr>
<tr>
<td>NDB_API_EVENT_DATA_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_EVENT_NONDATA_COUNT</td>
<td>0</td>
</tr>
<tr>
<td>NDB_API_EVENT_BYTES_COUNT</td>
<td>0</td>
</tr>
</tbody>
</table>

21 rows in set (0.09 sec)

Not all counters are reflected in all 4 sets of status variables. For the event counters DataEventsRecvdCount, NondataEventsRecvdCount, and EventBytesRecvdCount, only _injector and mysqld-level NDB API status variables are available:

```sql
mysql> SHOW STATUS LIKE 'ndb_api%event%';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_api_event_data_count_injector</td>
<td>0</td>
</tr>
<tr>
<td>Ndb_api_event_nondata_count_injector</td>
<td>0</td>
</tr>
</tbody>
</table>

2547
NDB API Statistics Counters and Variables

<table>
<thead>
<tr>
<th>Counter Name</th>
<th>Description</th>
<th>Status Variables (by statistic type):</th>
</tr>
</thead>
<tbody>
<tr>
<td>WaitExecCompleteCount</td>
<td>Number of times thread has been blocked while waiting for execution of an operation to complete. Includes all execute() calls as well as implicit executes for blob operations and auto-increment not visible to clients.</td>
<td>• Ndb_api_wait_exec_complete_count_session</td>
</tr>
<tr>
<td>WaitScanResultCount</td>
<td>Number of times thread has been blocked while waiting for a scan-based signal, such waiting for additional results, or for a scan to close.</td>
<td>• Ndb_api_wait_scan_result_count_session</td>
</tr>
<tr>
<td>WaitMetaRequestCount</td>
<td>Number of times thread has been blocked waiting for a metadata-based signal; this can occur when waiting for a DDL operation or for an epoch to be started (or ended).</td>
<td>• Ndb_api_wait_meta_request_count_session</td>
</tr>
<tr>
<td>WaitNanosCount</td>
<td>Total time (in nanoseconds) spent waiting for some type of signal from the data nodes.</td>
<td>• Ndb_api_wait_nanos_count_session</td>
</tr>
<tr>
<td>Counter Name</td>
<td>Description</td>
<td>Status Variables (by statistic type):</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Injector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Server</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_wait_nanos_count</td>
</tr>
<tr>
<td>BytesSentCount</td>
<td>Amount of data (in bytes) sent to the data nodes</td>
<td>• Ndb_api_bytes_sent_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_bytes_sent_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_bytes_sent_count</td>
</tr>
<tr>
<td>BytesRecvdCount</td>
<td>Amount of data (in bytes) received from the data nodes</td>
<td>• Ndb_api_bytes_received_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_bytes_received_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_bytes_received_count</td>
</tr>
<tr>
<td>TransStartCount</td>
<td>Number of transactions started.</td>
<td>• Ndb_api_trans_start_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_start_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_start_count</td>
</tr>
<tr>
<td>TransCommitCount</td>
<td>Number of transactions committed.</td>
<td>• Ndb_api_trans_commit_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_commit_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_commit_count</td>
</tr>
<tr>
<td>TransAbortCount</td>
<td>Number of transactions aborted.</td>
<td>• Ndb_api_trans_abort_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_abort_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_abort_count</td>
</tr>
<tr>
<td>TransCloseCount</td>
<td>Number of transactions aborted. (This value may be greater than the sum of</td>
<td>• Ndb_api_trans_close_count_session</td>
</tr>
<tr>
<td></td>
<td>TransCommitCount and TransAbortCount.)</td>
<td>• Ndb_api_trans_close_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_trans_close_count</td>
</tr>
<tr>
<td>Counter Name</td>
<td>Description</td>
<td>Status Variables (by statistic type):</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PkOpCount</td>
<td>Number of operations based on or using primary keys. This count includes</td>
<td>• Ndb_api_pk_op_count_session</td>
</tr>
<tr>
<td></td>
<td>blob-part table operations, implicit unlocking operations, and auto-increment</td>
<td>• Ndb_api_pk_op_count_slave</td>
</tr>
<tr>
<td></td>
<td>operations, as well as primary key operations normally visible to MySQL</td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td>clients.</td>
<td>• Ndb_api_pk_op_count</td>
</tr>
<tr>
<td>UkOpCount</td>
<td>Number of operations based on or using unique keys.</td>
<td>• Ndb_api_uk_op_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_uk_op_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_uk_op_count</td>
</tr>
<tr>
<td>TableScanCount</td>
<td>Number of table scans that have been started. This includes scans of</td>
<td>• Ndb_api_table_scan_count_session</td>
</tr>
<tr>
<td></td>
<td>internal tables.</td>
<td>• Ndb_api_table_scan_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_table_scan_count</td>
</tr>
<tr>
<td>RangeScanCount</td>
<td>Number of range scans that have been started.</td>
<td>• Ndb_api_range_scan_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_range_scan_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_range_scan_count</td>
</tr>
<tr>
<td>PrunedScanCount</td>
<td>Number of scans that have been pruned to a single partition.</td>
<td>• Ndb_api_pruned_scan_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_pruned_scan_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_pruned_scan_count</td>
</tr>
<tr>
<td>ScanBatchCount</td>
<td>Number of batches of rows received. *(A batch in this context is a set of</td>
<td>• Ndb_api_scan_batch_count_session</td>
</tr>
<tr>
<td></td>
<td>scan results from a single fragment.)*</td>
<td>• Ndb_api_scan_batch_count_slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• [none]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_scan_batch_count</td>
</tr>
<tr>
<td>ReadRowCount</td>
<td>Total number of rows that have been read. Includes rows read using</td>
<td>• Ndb_api_read_row_count_session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ndb_api_read_row_count_slave</td>
</tr>
</tbody>
</table>
### Counter Name | Description | Status Variables (by statistic type):
--- | --- | ---
 | primary key, unique key, and scan operations. | - [none]
 | Ndb_api_read_row_count |

| Ndb_api_trans_local_read_row_count_session
| Ndb_api_trans_local_read_row_count_slave
| Ndb_api_trans_local_read_row_count

- **TransLocalReadRowCount**: Number of rows read from the data same node on which the transaction was being run.
  - Ndb_api_trans_local_read_row_count_session
  - Ndb_api_trans_local_read_row_count_slave
  - Ndb_api_trans_local_read_row_count

- **DataEventsRecvdCount**: Number of row change events received.
  - Ndb_api_event_data_count_injector
  - Ndb_api_event_data_count

- **NondataEventsRecvdCount**: Number of events received, other than row change events.
  - Ndb_api_event_nondata_count_injector
  - Ndb_api_event_nondata_count

- **EventBytesRecvdCount**: Number of bytes of events received.
  - Ndb_api_event_bytes_count_injector
  - Ndb_api_event_bytes_count

---

To see all counts of committed transactions—that is, all TransCommitCount counter status variables—you can filter the results of `SHOW STATUS` for the substring `trans_commit_count`, like this:

```
mysql> SHOW STATUS LIKE '%trans_commit_count%';
+------------------------------------+-------+
| Variable_name                      | Value |
+------------------------------------+-------+
| Ndb_api_trans_commit_count_session | 1     |
| Ndb_api_trans_commit_count_slave   | 0     |
| Ndb_api_trans_commit_count         | 2     |
+------------------------------------+-------+
3 rows in set (0.00 sec)
```

From this you can determine that 1 transaction has been committed in the current `mysql` client session, and 2 transactions have been committed on this `mysqlld` since it was last restarted.
You can see how various NDB API counters are incremented by a given SQL statement by comparing the values of the corresponding _session status variables immediately before and after performing the statement. In this example, after getting the initial values from `SHOW STATUS`, we create in the test database an NDB table, named t, that has a single column:

```sql
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+--------------------------------------------+--------+
| Variable_name                              | Value  |
+--------------------------------------------+--------+
| Ndb_api_wait_exec_complete_count_session   | 2      |
| Ndb_api_wait_scan_result_count_session     | 0      |
| Ndb_api_wait_meta_request_count_session    | 3      |
| Ndb_api_wait_nanos_count_session           | 820705 |
| Ndb_api_bytes_sent_count_session           | 132    |
| Ndb_api_bytes_received_count_session       | 372    |
| Ndb_api_trans_start_count_session          | 1      |
| Ndb_api_trans_commit_count_session         | 1      |
| Ndb_api_trans_abort_count_session          | 0      |
| Ndb_api_trans_close_count_session          | 1      |
| Ndb_api_pk_op_count_session                | 1      |
| Ndb_api_uk_op_count_session                | 0      |
| Ndb_api_table_scan_count_session           | 0      |
| Ndb_api_range_scan_count_session           | 0      |
| Ndb_api_pruned_scan_count_session          | 0      |
| Ndb_api_scan_batch_count_session           | 0      |
| Ndb_api_read_row_count_session             | 1      |
| Ndb_api_trans_local_read_row_count_session | 1      |
+--------------------------------------------+--------+
18 rows in set (0.00 sec)
```

Now you can execute a new `SHOW STATUS` statement and observe the changes, as shown here (with the changed rows highlighted in the output):

```sql
mysql> USE test;
Database changed
mysql> CREATE TABLE t (c INT) ENGINE NDBCLUSTER;
Query OK, 0 rows affected (0.85 sec)
```

Similarly, you can see the changes in the NDB API statistics counters caused by inserting a row into t:

```sql
mysql> INSERT INTO t VALUES (1);
Query OK, 0 rows affected (0.00 sec)
```

```sql
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+--------------------------------------------+-----------+
| Variable_name                              | Value     |
+--------------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session   | 8         |
| Ndb_api_wait_scan_result_count_session     | 0         |
| Ndb_api_wait_meta_request_count_session    | 17        |
| Ndb_api_wait_nanos_count_session           | 706871709 |
| Ndb_api_bytes_sent_count_session           | 2376      |
| Ndb_api_bytes_received_count_session       | 3844      |
| Ndb_api_trans_start_count_session          | 4         |
| Ndb_api_trans_commit_count_session         | 4         |
| Ndb_api_trans_abort_count_session          | 0         |
| Ndb_api_trans_close_count_session          | 4         |
| Ndb_api_pk_op_count_session                | 6         |
| Ndb_api_uk_op_count_session                | 0         |
| Ndb_api_table_scan_count_session           | 0         |
| Ndb_api_range_scan_count_session           | 0         |
| Ndb_api_pruned_scan_count_session          | 0         |
| Ndb_api_scan_batch_count_session           | 0         |
| Ndb_api_read_row_count_session             | 1         |
| Ndb_api_trans_local_read_row_count_session | 1         |
+--------------------------------------------+-----------+
18 rows in set (0.00 sec)
```

Insert the row, then run the same `SHOW STATUS` statement used in the previous example, as shown here:
mysql> INSERT INTO t VALUES (100);
Query OK, 1 row affected (0.00 sec)

mysql> SHOW STATUS LIKE 'ndb_api\%session\%';
+--------------------------------------------+-----------+
| Variable_name                              | Value     |
+--------------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session   | 11        |
| Ndb_api_wait_scan_result_count_session     | 6         |
| Ndb_api_wait_meta_request_count_session    | 20        |
| Ndb_api_wait_nanos_count_session           | 707370418 |
| Ndb_api_bytes_sent_count_session           | 2724      |
| Ndb_api_bytes_received_count_session       | 4116      |
| Ndb_api_trans_start_count_session          | 7         |
| Ndb_api_trans_commit_count_session         | 6         |
| Ndb_api_trans_abort_count_session          | 0         |
| Ndb_api_trans_close_count_session          | 7         |
| Ndb_api_pk_op_count_session                | 8         |
| Ndb_api_uk_op_count_session                | 0         |
| Ndb_api_table_scan_count_session           | 1         |
| Ndb_api_range_scan_count_session           | 0         |
| Ndb_api_pruned_scan_count_session          | 0         |
| Ndb_api_scan_batch_count_session           | 0         |
| Ndb_api_read_row_count_session             | 3         |
| Ndb_api_trans_local_read_row_count_session | 2         |
+--------------------------------------------+-----------+
18 rows in set (0.00 sec)

We can make a number of observations from these results:

• Although we created \textit{t} with no explicit primary key, 5 primary key operations were performed in doing so (the difference in the “before” and “after” values of \texttt{Ndb_api_pk_op_count_session}, or 6 minus 1). This reflects the creation of the hidden primary key that is a feature of all tables using the NDB storage engine.

• By comparing successive values for \texttt{Ndb_api_wait_nanos_count_session}, we can see that the NDB API operations implementing the \texttt{CREATE TABLE} statement waited much longer (706871709 - 820705 = 706051004 nanoseconds, or approximately 0.7 second) for responses from the data nodes than those executed by the \texttt{INSERT} (707370418 - 706871709 = 498709 ns or roughly .0005 second). The execution times reported for these statements in the mysql client correlate roughly with these figures.

On platforms without sufficient (nanosecond) time resolution, small changes in the value of the \texttt{WaitNanosCount} NDB API counter due to SQL statements that execute very quickly may not always be visible in the values of \texttt{Ndb_api_wait_nanos_count_session}, \texttt{Ndb_api_wait_nanos_count_slave}, or \texttt{Ndb_api_wait_nanos_count}.

• The \texttt{INSERT} statement incremented both the \texttt{ReadRowCount} and \texttt{TransLocalReadRowCount} NDB API statistics counters, as reflected by the increased values of \texttt{Ndb_api_read_row_count_session} and \texttt{Ndb_api_trans_local_read_row_count_session}.

18.6 NDB Cluster Replication

NDB Cluster supports \textit{asynchronous replication}, more usually referred to simply as “replication”. This section explains how to set up and manage a configuration in which one group of computers operating as an NDB Cluster replicates to a second computer or group of computers. We assume some familiarity on the part of the reader with standard MySQL replication as discussed elsewhere in this Manual. (See Chapter 17, \textit{Replication}).
NDB Cluster Replication

Note

Semisynchronous replication is not supported by the NDB storage engine.

Normal (non-clustered) replication involves a “master” server and a “slave” server, the master being the source of the operations and data to be replicated and the slave being the recipient of these. In NDB Cluster, replication is conceptually very similar but can be more complex in practice, as it may be extended to cover a number of different configurations including replicating between two complete clusters. Although an NDB Cluster itself depends on the NDB storage engine for clustering functionality, it is not necessary to use NDB as the storage engine for the slave’s copies of the replicated tables (see Replication from NDB to other storage engines). However, for maximum availability, it is possible (and preferable) to replicate from one NDB Cluster to another, and it is this scenario that we discuss, as shown in the following figure:

Figure 18.10 NDB Cluster-to-Cluster Replication Layout

In this scenario, the replication process is one in which successive states of a master cluster are logged and saved to a slave cluster. This process is accomplished by a special thread known as the NDB binary log injector thread, which runs on each MySQL server and produces a binary log (binlog). This thread ensures that all changes in the cluster producing the binary log—and not just those changes that are effected through the MySQL Server—are inserted into the binary log with the correct serialization order. We refer to the MySQL replication master and replication slave servers as replication servers or replication nodes, and the data flow or line of communication between them as a replication channel.

For information about performing point-in-time recovery with NDB Cluster and NDB Cluster Replication, see Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”.

NDB API_slave status variables. NDB API counters can provide enhanced monitoring capabilities on NDB Cluster replication slaves. These are implemented as NDB statistics_slave status variables, as seen in the output of SHOW STATUS, or in the results of queries against the SESSION_STATUS or GLOBAL_STATUS table in a mysql client session connected to a MySQL Server that is acting as a slave in NDB Cluster Replication. By comparing the values of these status variables before and after the execution of statements affecting replicated NDB tables, you can observe the corresponding actions taken on the NDB API level by the slave, which can be useful when monitoring or troubleshooting NDB Cluster Replication. Section 18.5.16, “NDB API Statistics Counters and Variables”, provides additional information.

Replication from NDB to non-NDB tables. It is possible to replicate NDB tables from an NDB Cluster acting as the master to tables using other MySQL storage engines such as InnoDB or MyISAM on a slave
This is subject to a number of conditions; see Replication from NDB to other storage engines, and Replication from NDB to a nontransactional storage engine, for more information.

18.6.1 NDB Cluster Replication: Abbreviations and Symbols

Throughout this section, we use the following abbreviations or symbols for referring to the master and slave clusters, and to processes and commands run on the clusters or cluster nodes:

<table>
<thead>
<tr>
<th>Symbol or Abbreviation</th>
<th>Description (Refers to...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>The cluster serving as the (primary) replication master</td>
</tr>
<tr>
<td>S</td>
<td>The cluster acting as the (primary) replication slave</td>
</tr>
<tr>
<td>shellM&gt;</td>
<td>Shell command to be issued on the master cluster</td>
</tr>
<tr>
<td>mysqlM&gt;</td>
<td>MySQL client command issued on a single MySQL server running as an SQL node on the master cluster</td>
</tr>
<tr>
<td>mysqlM*&gt;</td>
<td>MySQL client command to be issued on all SQL nodes participating in the replication master cluster</td>
</tr>
<tr>
<td>shellS&gt;</td>
<td>Shell command to be issued on the slave cluster</td>
</tr>
<tr>
<td>mysqlS&gt;</td>
<td>MySQL client command issued on a single MySQL server running as an SQL node on the slave cluster</td>
</tr>
<tr>
<td>mysqlS*&gt;</td>
<td>MySQL client command to be issued on all SQL nodes participating in the replication slave cluster</td>
</tr>
<tr>
<td>C</td>
<td>Primary replication channel</td>
</tr>
<tr>
<td>C'</td>
<td>Secondary replication channel</td>
</tr>
<tr>
<td>M'</td>
<td>Secondary replication master</td>
</tr>
<tr>
<td>S'</td>
<td>Secondary replication slave</td>
</tr>
</tbody>
</table>

18.6.2 General Requirements for NDB Cluster Replication

A replication channel requires two MySQL servers acting as replication servers (one each for the master and slave). For example, this means that in the case of a replication setup with two replication channels (to provide an extra channel for redundancy), there will be a total of four replication nodes, two per cluster.

Replication of an NDB Cluster as described in this section and those following is dependent on row-based replication. This means that the replication master MySQL server must be running with `--binlog-format=ROW` or `--binlog-format=MIXED`, as described in Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”. For general information about row-based replication, see Section 17.1.2, “Replication Formats”.

Important

If you attempt to use NDB Cluster Replication with `--binlog-format=STATEMENT`, replication fails to work properly because the `ndb_binlog_index` table on the master and the epoch column of the `ndb_apply_status` table on the slave are not updated (see Section 18.6.4, “NDB Cluster Replication Schema and Tables”). Instead, only updates on the MySQL server acting as the replication master propagate to the slave, and no updates from any other SQL nodes on the master cluster are replicated.
Beginning with NDB 7.2.13, the default value for the `--binlog-format` option is `MIXED`. (Bug #16417224)

In NDB 7.2.12 and earlier NDB Cluster 7.2 releases, the default for `--binlog-format` was `STATEMENT`; this meant that you were required to change the binary logging format to `ROW` (or `MIXED`) manually on all MySQL Servers on the master NDB Cluster, prior to starting NDB Cluster replication. If necessary, you can do this on startup using the `--binlog-format` option, or at runtime by setting the global `binlog_format` system variable. Using the startup option is preferred in such cases.

Each MySQL server used for replication in either cluster must be uniquely identified among all the MySQL replication servers participating in either cluster (you cannot have replication servers on both the master and slave clusters sharing the same ID). This can be done by starting each SQL node using the `--server-id=id` option, where `id` is a unique integer. Although it is not strictly necessary, we will assume for purposes of this discussion that all NDB Cluster binaries are of the same release version.

It is generally true in MySQL Replication that both MySQL servers (`mysqld` processes) involved must be compatible with one another with respect to both the version of the replication protocol used and the SQL feature sets which they support (see Section 17.4.2, “Replication Compatibility Between MySQL Versions”). It is due to such differences between the binaries in the NDB Cluster and MySQL Server 5.5 distributions that NDB Cluster Replication has the additional requirement that both `mysqld` binaries come from an NDB Cluster distribution. The simplest and easiest way to assure that the `mysqld` servers are compatible is to use the same NDB Cluster distribution for all master and slave `mysqld` binaries.

We assume that the slave server or cluster is dedicated to replication of the master, and that no other data is being stored on it.

All NDB tables being replicated must be created using a MySQL server and client. Tables and other database objects created using the NDB API (with, for example, `Dictionary::createTable()`) are not visible to a MySQL server and so are not replicated. Updates by NDB API applications to existing tables that were created using a MySQL server can be replicated.

Note

It is possible to replicate an NDB Cluster using statement-based replication. However, in this case, the following restrictions apply:

- All updates to data rows on the cluster acting as the master must be directed to a single MySQL server.
- It is not possible to replicate a cluster using multiple simultaneous MySQL replication processes.
- Only changes made at the SQL level are replicated.

These are in addition to the other limitations of statement-based replication as opposed to row-based replication; see Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”, for more specific information concerning the differences between the two replication formats.

18.6.3 Known Issues in NDB Cluster Replication

This section discusses known problems or issues when using replication with NDB Cluster 7.2.
Loss of master-slave connection. A loss of connection can occur either between the replication master SQL node and the replication slave SQL node, or between the replication master SQL node and the data nodes in the master cluster. In the latter case, this can occur not only as a result of loss of physical connection (for example, a broken network cable), but due to the overflow of data node event buffers; if the SQL node is too slow to respond, it may be dropped by the cluster (this is controllable to some degree by adjusting the `MaxBufferedEpochs` and `TimeBetweenEpochs` configuration parameters). If this occurs, it is entirely possible for new data to be inserted into the master cluster without being recorded in the replication master's binary log. For this reason, to guarantee high availability, it is extremely important to maintain a backup replication channel, to monitor the primary channel, and to fail over to the secondary replication channel when necessary to keep the slave cluster synchronized with the master. NDB Cluster is not designed to perform such monitoring on its own; for this, an external application is required.

The replication master issues a “gap” event when connecting or reconnecting to the master cluster. (A gap event is a type of “incident event,” which indicates an incident that occurs that affects the contents of the database but that cannot easily be represented as a set of changes. Examples of incidents are server crashes, database resynchronization, (some) software updates, and (some) hardware changes.) When the slave encounters a gap in the replication log, it stops with an error message. This message is available in the output of `SHOW SLAVE STATUS`, and indicates that the SQL thread has stopped due to an incident registered in the replication stream, and that manual intervention is required. See Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for more information about what to do in such circumstances.

Important

Because NDB Cluster is not designed on its own to monitor replication status or provide failover, if high availability is a requirement for the slave server or cluster, then you must set up multiple replication lines, monitor the master `mysqld` on the primary replication line, and be prepared fail over to a secondary line if and as necessary. This must be done manually, or possibly by means of a third-party application. For information about implementing this type of setup, see Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”, and Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

However, if you are replicating from a standalone MySQL server to an NDB Cluster, one channel is usually sufficient.

Circular replication. NDB Cluster Replication supports circular replication, as shown in the next example. The replication setup involves three NDB Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1, thus completing the circle. Each NDB Cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same.
- All SQL nodes acting as replication masters and slaves are started with the `log_slave_updates` system variable enabled.

This type of circular replication setup is shown in the following diagram:
In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the curved arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It should also be possible to set up circular replication in which not all master SQL nodes are also slaves, as shown here:
In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must not start any of the SQL nodes with the `log_slave_updates` system variable enabled. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the curved arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

### Note

The NDB storage engine uses *idempotent execution mode*, which suppresses duplicate-key and other errors that otherwise break circular replication of NDB Cluster. This is equivalent to setting the global `slave_exec_mode` system variable to `IDEMPOTENT`, although this is not necessary in NDB Cluster replication, since NDB Cluster sets this variable automatically and ignores any attempts to set it explicitly.

**NDB Cluster replication and primary keys.** In the event of a node failure, errors in replication of NDB tables without primary keys can still occur, due to the possibility of duplicate rows being inserted in such cases. For this reason, it is highly recommended that all NDB tables being replicated have primary keys.

**NDB Cluster Replication and Unique Keys.** In older versions of NDB Cluster, operations that updated values of unique key columns of NDB tables could result in duplicate-key errors when replicated.
This issue is solved for replication between NDB tables by deferring unique key checks until after all table row updates have been performed.

Deferring constraints in this way is currently supported only by NDB. Thus, updates of unique keys when replicating from NDB to a different storage engine such as MyISAM or InnoDB are still not supported.

The problem encountered when replicating without deferred checking of unique key updates can be illustrated using NDB table such as `t`, is created and populated on the master (and replicated to a slave that does not support deferred unique key updates) as shown here:

```sql
CREATE TABLE t (
    p INT PRIMARY KEY,
    c INT,
    UNIQUE KEY u (c)
) ENGINE NDB;

INSERT INTO t
VALUES (1,1), (2,2), (3,3), (4,4), (5,5);
```

The following `UPDATE` statement on `t` succeeded on the master, since the rows affected are processed in the order determined by the `ORDER BY` option, performed over the entire table:

```sql
UPDATE t SET c = c - 1 ORDER BY p;
```

However, the same statement failed with a duplicate key error or other constraint violation on the slave, because the ordering of the row updates was done for one partition at a time, rather than for the table as a whole.

---

**Note**

Every NDB table is implicitly partitioned by key when it is created. See Section 19.2.5, “KEY Partitioning”, for more information.

---

**Restarting with --initial.** Repeating the cluster with the `--initial` option causes the sequence of GCI and epoch numbers to start over from 0. (This is generally true of NDB Cluster and not limited to replication scenarios using NDB.) The MySQL servers involved in replication should in this case be restarted. After this, you should use the `RESET MASTER` and `RESET SLAVE` statements to clear the invalid `ndb_binlog_index` and `ndb_apply_status` tables, respectively.

**Replication from NDB to other storage engines.** It is possible to replicate an NDB table on the master to a table using a different storage engine on the slave, taking into account the restrictions listed here:

- Multi-master and circular replication are not supported (tables on both the master and the slave must use the NDB storage engine for this to work).

- Using a storage engine which does not perform binary logging for slave tables requires special handling.

- Use of a nontransactional storage engine for slave tables also requires special handling.

- The master `mysqld` must be started with `--ndb-log-update-as-write=0` or `--ndb-log-update-as-write=OFF`.

The next few paragraphs provide additional information about each of the issues just described.

**Multiple masters not supported when replicating NDB to other storage engines.** For replication from NDB to a different storage engine, the relationship between the two databases must be a simple master-slave one. This means that circular or master-master replication is not supported between NDB Cluster and other storage engines.

In addition, it is not possible to configure more than one replication channel when replicating between NDB and a different storage engine. (However, an NDB Cluster database can simultaneously replicate to
multiple slave NDB Cluster databases.) If the master uses NDB tables, it is still possible to have more than one MySQL Server maintain a binary log of all changes; however, for the slave to change masters (fail over), the new master-slave relationship must be explicitly defined on the slave.

**Replicating NDB to a slave storage engine that does not perform binary logging.** If you attempt to replicate from an NDB Cluster to a slave that uses a storage engine that does not handle its own binary logging, the replication process aborts with the error **Statement cannot be written atomically since more than one engine involved and at least one engine is self-logging (Error 1595).** It is possible to work around this issue in one of the following ways:

- **Turn off binary logging on the slave.** This can be accomplished by setting `sql_log_bin = 0`.
- **Change the storage engine used for the mysql.ndb_apply_status table.** Causing this table to use an engine that does not handle its own binary logging can also eliminate the conflict. This can be done by issuing a statement such as `ALTER TABLE mysql.ndb_apply_status ENGINE=MyISAM` on the slave. It is safe to do this when using a non-NDB storage engine on the slave, since you do not then need to worry about keeping multiple slave SQL nodes synchronized.
- **Filter out changes to the mysql.ndb_apply_status table on the slave.** This can be done by starting the slave SQL node with `--replicate-ignore-table=mysql.ndb_apply_status`. If you need for other tables to be ignored by replication, you might wish to use an appropriate `--replicate-wild-ignore-table` option instead.

**Important**

You should *not* disable replication or binary logging of `mysql.ndb_apply_status` or change the storage engine used for this table when replicating from one NDB Cluster to another. See Replication and binary log filtering rules with replication between NDB Clusters, for details.

**Replication from NDB to a nontransactional storage engine.** When replicating from NDB to a nontransactional storage engine such as MyISAM, you may encounter unnecessary duplicate key errors when replicating `INSERT ... ON DUPLICATE KEY UPDATE` statements. You can suppress these by using `--ndb-log-update-as-write=0`, which forces updates to be logged as writes (rather than as updates).

In addition, when replicating from NDB to a storage engine that does not implement transactions, if the slave fails to apply any row changes from a given transaction, it does not roll back the rest of the transaction. (This is true when replicating tables using any transactional storage engine—not only NDB—to a nontransactional storage engine.) Because of this, it cannot be guaranteed that transactional consistency will be maintained on the slave in such cases.

**Replication and binary log filtering rules with replication between NDB Clusters.** If you are using any of the options `--replicate-do-*, --replicate-ignore-*, --binlog-do-db`, or `--binlog-ignore-db` to filter databases or tables being replicated, care must be taken not to block replication or binary logging of the `mysql.ndb_apply_status`, which is required for replication between NDB Clusters to operate properly. In particular, you must keep in mind the following:

1. Using `--replicate-do-db=db_name` (and no other `--replicate-do-` or `--replicate-ignore-` options) means that only tables in database `db_name` are replicated. In this case, you should also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

Using `--binlog-do-db=db_name` (and no other `--binlog-do-db` options) means that changes only to tables in database `db_name` are written to the binary log. In this case, you should
also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

2. Using `--replicate-ignore-db=mysql` means that no tables in the `mysql` database are replicated. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated.

Using `--binlog-ignore-db=mysql` means that no changes to tables in the `mysql` database are written to the binary log. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is replicated.

You should also remember that each replication rule requires the following:

1. Its own `--replicate-do-*` or `--replicate-ignore-*` option, and that multiple rules cannot be expressed in a single replication filtering option. For information about these rules, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

2. Its own `--binlog-do-db` or `--binlog-ignore-db` option, and that multiple rules cannot be expressed in a single binary log filtering option. For information about these rules, see Section 5.4.4, “The Binary Log”.

If you are replicating an NDB Cluster to a slave that uses a storage engine other than NDB, the considerations just given previously may not apply, as discussed elsewhere in this section.

**NDB Cluster Replication and IPv6.** Currently, the NDB API and MGM API do not support IPv6. However, MySQL Servers—including those acting as SQL nodes in an NDB Cluster—can use IPv6 to contact other MySQL Servers. This means that you can replicate between NDB Clusters using IPv6 to connect the master and slave SQL nodes as shown by the dotted arrow in the following diagram:

![Figure 18.13 Replication Between SQL Nodes Connected Using IPv6](image)

However, all connections originating within the NDB Cluster—represented in the preceding diagram by solid arrows—must use IPv4. In other words, all NDB Cluster data nodes, management servers, and
management clients must be accessible from one another using IPv4. In addition, SQL nodes must use IPv4 to communicate with the cluster.

Since there is currently no support in the NDB and MGM APIs for IPv6, any applications written using these APIs must also make all connections using IPv4.

**Attribute promotion and demotion.** NDB Cluster Replication includes support for attribute promotion and demotion. The implementation of the latter distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

For more information about attribute promotion and demotion in NDB Cluster, see [Row-based replication: attribute promotion and demotion](#).

## 18.6.4 NDB Cluster Replication Schema and Tables

Replication in NDB Cluster makes use of a number of dedicated tables in the `mysql` database on each MySQL Server instance acting as an SQL node in both the cluster being replicated and the replication slave (whether the slave is a single server or a cluster). These tables are created during the MySQL installation process by the `mysql_install_db` script, and include a table for storing the binary log’s indexing data. Since the `ndb_binlog_index` table is local to each MySQL server and does not participate in clustering, it uses the *MyISAM* storage engine. This means that it must be created separately on each `mysqld` participating in the master cluster. (However, the binary log itself contains updates from all MySQL servers in the cluster to be replicated.) This table is defined as follows:

```sql
CREATE TABLE `ndb_binlog_index` (  
`Position` BIGINT(20) UNSIGNED NOT NULL,  
`File` VARCHAR(255) NOT NULL,  
`epoch` BIGINT(20) UNSIGNED NOT NULL,  
`inserts` INT(10) UNSIGNED NOT NULL,  
`updates` INT(10) UNSIGNED NOT NULL,  
`deletes` INT(10) UNSIGNED NOT NULL,  
`schemaops` INT(10) UNSIGNED NOT NULL,  
`orig_server_id` INT(10) UNSIGNED NOT NULL,  
`orig_epoch` BIGINT(20) UNSIGNED NOT NULL,  
`gci` INT(10) UNSIGNED NOT NULL,  
`next_position` bigint(20) unsigned NOT NULL,  
`next_file` varchar(255) NOT NULL,  
PRIMARY KEY (`epoch`,`orig_server_id`,`orig_epoch`)  
) ENGINE=MyISAM DEFAULT CHARSET=latin1;
```

The size of this table is dependent on the number of epochs per binary log file and the number of binary log files. The number of epochs per binary log file normally depends on the amount of binary log generated per epoch and the size of the binary log file, with smaller epochs resulting in more epochs per file. You should be aware that empty epochs produce inserts to the `ndb_binlog_index` table, even when the `--ndb-log-empty-epochs` option is OFF, meaning that the number of entries per file depends on the length of time that the file is in use; that is,

```
[number of epochs per file] = [time spent per file] / TimeBetweenEpochs
```

A busy NDB Cluster writes to the binary log regularly and presumably rotates binary log files more quickly than a quiet one. This means that a “quiet” NDB Cluster with `--ndb-log-empty-epochs=ON` can actually have a much higher number of `ndb_binlog_index` rows per file than one with a great deal of activity.

When `mysqld` is started with the `--ndb-log-orig` option, the `orig_server_id` and `orig_epoch` columns store, respectively, the ID of the server on which the event originated and the epoch in which the event took place on the originating server, which is useful in NDB Cluster replication setups employing multiple masters. The `SELECT` statement used to find the closest binary log position to the highest
applied epoch on the slave in a multi-master setup (see Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”) employs these two columns, which are not indexed. This can lead to performance issues when trying to fail over, since the query must perform a table scan, especially when the master has been running with `--ndb-log-empty-epochs=ON`. You can improve multi-master failover times by adding an index to these columns, as shown here:

```sql
ALTER TABLE mysql.ndb_binlog_index
    ADD INDEX orig_lookup USING BTREE (orig_server_id, orig_epoch);
```

Adding this index provides no benefit when replicating from a single master to a single slave, since the query used to get the binary log position in such cases makes no use of `orig_server_id` or `orig_epoch`.

The `next_position` and `next_file` columns were added in NDB 7.2.6; see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for more information about using these columns.

The following figure shows the relationship of the NDB Cluster replication master server, its binary log injector thread, and the `mysql.ndb_binlog_index` table.

**Figure 18.14 The Replication Master Cluster**

MySQL Replication Between Clusters, Injecting into Binlog

An additional table, named `ndb_apply_status`, is used to keep a record of the operations that have been replicated from the master to the slave. Unlike the case with `ndb_binlog_index`, the data in this table is not specific to any one SQL node in the (slave) cluster, and so `ndb_apply_status` can use the NDBCLUSTER storage engine, as shown here:

```sql
CREATE TABLE `ndb_apply_status` (
  `server_id` INT(10) UNSIGNED NOT NULL,
  `epoch` BIGINT(20) UNSIGNED NOT NULL,
  `log_name` VARCHAR(255) CHARACTER SET latin1 COLLATE latin1_bin NOT NULL,
  `start_pos` BIGINT(20) UNSIGNED NOT NULL,
  `end_pos` BIGINT(20) UNSIGNED NOT NULL,
  PRIMARY KEY (`server_id`) USING HASH
) ENGINE=NDBCLUSTER;
```
Preparing the NDB Cluster for Replication

The `ndb_apply_status` table is populated only on slaves, which means that, on the master, this table never contains any rows; thus, there is no need to allow for `DataMemory` or `IndexMemory` to be allotted to `ndb_apply_status` there.

Because this table is populated from data originating on the master, it should be allowed to replicate; any replication filtering or binary log filtering rules that inadvertently prevent the slave from updating `ndb_apply_status` or the master from writing into the binary log may prevent replication between clusters from operating properly. For more information about potential problems arising from such filtering rules, see Replication and binary log filtering rules with replication between NDB Clusters.

The `ndb_binlog_index` and `ndb_apply_status` tables are created in the `mysql` database because they should not be explicitly replicated by the user. User intervention is normally not required to create or maintain either of these tables, since both `ndb_binlog_index` and the `ndb_apply_status` are maintained by the NDB binary log (binlog) injector thread. This keeps the master `mysqld` process updated to changes performed by the NDB storage engine. The NDB binlog injector thread receives events directly from the NDB storage engine. The NDB injector is responsible for capturing all the data events within the cluster, and ensures that all events which change, insert, or delete data are recorded in the `ndb_binlog_index` table. The slave I/O thread transfers the events from the master's binary log to the slave's relay log.

However, it is advisable to check for the existence and integrity of these tables as an initial step in preparing an NDB Cluster for replication. It is possible to view event data recorded in the binary log by querying the `mysql.ndb_binlog_index` table directly on the master. This can also be accomplished using the `SHOW BINLOG EVENTS` statement on either the replication master or slave MySQL servers. (See Section 13.7.5.3, “SHOW BINLOG EVENTS Statement”.)

You can also obtain useful information from the output of `SHOW ENGINE NDB STATUS`.

Note

When performing schema changes on NDB tables, applications should wait until the `ALTER TABLE` statement has returned in the MySQL client connection that issued the statement before attempting to use the updated definition of the table.

If the `ndb_apply_status` table does not exist on the slave, `ndb_restore` re-creates it.

Conflict resolution for NDB Cluster Replication requires the presence of an additional `mysql.ndb_replication` table. Currently, this table must be created manually. For information about how to do this, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

18.6.5 Preparing the NDB Cluster for Replication

Preparing the NDB Cluster for replication consists of the following steps:

1. Check all MySQL servers for version compatibility (see Section 18.6.2, “General Requirements for NDB Cluster Replication”).

2. Create a slave account on the master Cluster with the appropriate privileges:

   ```
   mysql> GRANT REPLICATION SLAVE
   -> ON *.* TO 'slave_user'@'slave_host'
   -> IDENTIFIED BY 'slave_password';
   ```

   In the previous statement, `slave_user` is the slave account user name, `slave_host` is the host name or IP address of the replication slave, and `slave_password` is the password to assign to this account.
Preparing the NDB Cluster for Replication

For example, to create a slave user account with the name `myslave`, logging in from the host named `rep-slave`, and using the password `53cr37`, use the following `GRANT` statement:

```
mysql> GRANT REPLICATION SLAVE
    -> ON `*`.* TO 'myslave'@'rep-slave'
    -> IDENTIFIED BY '53cr37';
```

For security reasons, it is preferable to use a unique user account—not employed for any other purpose—for the replication slave account.

3. Configure the slave to use the master. Using the MySQL Monitor, this can be accomplished with the `CHANGE MASTER TO` statement:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_host',
    -> MASTER_PORT=master_port,
    -> MASTER_USER='slave_user',
    -> MASTER_PASSWORD='slave_password';
```

In the previous statement, `master_host` is the host name or IP address of the replication master, `master_port` is the port for the slave to use for connecting to the master, `slave_user` is the user name set up for the slave on the master, and `slave_password` is the password set for that user account in the previous step.

For example, to tell the slave to replicate from the MySQL server whose host name is `rep-master`, using the replication slave account created in the previous step, use the following statement:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='rep-master',
    -> MASTER_PORT=3306,
    -> MASTER_USER='myslave',
    -> MASTER_PASSWORD='53cr37';
```

For a complete list of options that can be used with this statement, see Section 13.4.2.1, "CHANGE MASTER TO Statement".

To provide replication backup capability, you also need to add an `--ndb-connectstring` option to the slave’s `my.cnf` file prior to starting the replication process. See Section 18.6.9, "NDB Cluster Backups With NDB Cluster Replication", for details.

For additional options that can be set in `my.cnf` for replication slaves, see Section 17.1.3, "Replication and Binary Logging Options and Variables".

4. If the master cluster is already in use, you can create a backup of the master and load this onto the slave to cut down on the amount of time required for the slave to synchronize itself with the master. If the slave is also running NDB Cluster, this can be accomplished using the backup and restore procedure described in Section 18.6.9, "NDB Cluster Backups With NDB Cluster Replication".

```
ndb-connectstring=management_host[:port]
```

In the event that you are not using NDB Cluster on the replication slave, you can create a backup with this command on the replication master:

```
shell> mysql dump --master-data=1
```

Then import the resulting data dump onto the slave by copying the dump file over to the slave. After this, you can use the `mysql` client to import the data from the dump file into the slave database as shown here, where `dump_file` is the name of the file that was generated using `mysqldump` on the master, and `db_name` is the name of the database to be replicated:
Starting NDB Cluster Replication (Single Replication Channel)

shell> mysql -u root -p db_name < dump_file

For a complete list of options to use with mysqldump, see Section 4.5.4, "mysqldump — A Database Backup Program".

Note

If you copy the data to the slave in this fashion, you should make sure that the slave is started with the --skip-slave-start option on the command line, or else include skip-slave-start in the slave's my.cnf file to keep it from trying to connect to the master to begin replicating before all the data has been loaded. Once the data loading has completed, follow the additional steps outlined in the next two sections.

5. Ensure that each MySQL server acting as a replication master is configured with a unique server ID, and with binary logging enabled, using the row format. (See Section 17.1.2, “Replication Formats”.) These options can be set either in the master server’s my.cnf file, or on the command line when starting the master mysqld process. See Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”, for information regarding the latter option.

18.6.6 Starting NDB Cluster Replication (Single Replication Channel)

This section outlines the procedure for starting NDB Cluster replication using a single replication channel.

1. Start the MySQL replication master server by issuing this command:

shell> mysqld --ndbcluster --server-id=id --log-bin &

If the master is running NDB 7.2.12 or earlier, it must also be started with --binlog-format=ROW (or MIXED). (Bug #16417224)

In the previous statement, id is this server's unique ID (see Section 18.6.2, “General Requirements for NDB Cluster Replication”). This starts the server's mysqld process with binary logging enabled using the proper logging format.

Note

You can also start the master with --binlog-format=MIXED, in which case row-based replication is used automatically when replicating between clusters. STATEMENT based binary logging is not supported for NDB Cluster Replication (see Section 18.6.2, “General Requirements for NDB Cluster Replication”).

2. Start the MySQL replication slave server as shown here:

shell> mysqld --ndbcluster --server-id=id &

In the command just shown, id is the slave server's unique ID. It is not necessary to enable logging on the replication slave.

Note

You should use the --skip-slave-start option with this command or else you should include skip-slave-start in the slave server's my.cnf file, unless you want replication to begin immediately. With the use of this option, the start of replication is delayed until the appropriate START SLAVE statement has been issued, as explained in Step 4 below.
3. It is necessary to synchronize the slave server with the master server’s replication binary log. If binary logging has not previously been running on the master, run the following statement on the slave:

```sql
mysql> CHANGE MASTER TO
    -> MASTER_LOG_FILE='',
    -> MASTER_LOG_POS=4;
```

This instructs the slave to begin reading the master’s binary log from the log’s starting point. Otherwise—that is, if you are loading data from the master using a backup—see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for information on how to obtain the correct values to use for `MASTER_LOG_FILE` and `MASTER_LOG_POS` in such cases.

4. Finally, you must instruct the slave to begin applying replication by issuing this command from the `mysql` client on the replication slave:

```sql
mysql> START SLAVE;
```

This also initiates the transmission of replication data from the master to the slave.

It is also possible to use two replication channels, in a manner similar to the procedure described in the next section; the differences between this and using a single replication channel are covered in Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”.

It is also possible to improve cluster replication performance by enabling batched updates. This can be accomplished by setting the `slave_allow_batching` system variable on the slave `mysqld` processes. Normally, updates are applied as soon as they are received. However, the use of batching causes updates to be applied in 32 KB batches, which can result in higher throughput and less CPU usage, particularly where individual updates are relatively small.

**Note**

Slave batching works on a per-epoch basis; updates belonging to more than one transaction can be sent as part of the same batch.

All outstanding updates are applied when the end of an epoch is reached, even if the updates total less than 32 KB.

Batching can be turned on and off at runtime. To activate it at runtime, you can use either of these two statements:

```sql
SET GLOBAL slave_allow_batching = 1;
SET GLOBAL slave_allow_batching = ON;
```

If a particular batch causes problems (such as a statement whose effects do not appear to be replicated correctly), slave batching can be deactivated using either of the following statements:

```sql
SET GLOBAL slave_allow_batching = 0;
SET GLOBAL slave_allow_batching = OFF;
```

You can check whether slave batching is currently being used by means of an appropriate `SHOW VARIABLES` statement, like this one:

```sql
mysql> SHOW VARIABLES LIKE 'slave%';
+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| slave_allow_batching      | ON    |
| slave_compressed_protocol | OFF   |
| slave_load_tmpdir         | /tmp  |
```
Using Two Replication Channels for NDB Cluster Replication

18.6.7 Using Two Replication Channels for NDB Cluster Replication

In a more complete example scenario, we envision two replication channels to provide redundancy and thereby guard against possible failure of a single replication channel. This requires a total of four replication servers, two masters for the master cluster and two slave servers for the slave cluster. For purposes of the discussion that follows, we assume that unique identifiers are assigned as shown here:

Table 18.284 NDB Cluster replication servers described in the text

<table>
<thead>
<tr>
<th>Server ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Master - primary replication channel (M)</td>
</tr>
<tr>
<td>2</td>
<td>Master - secondary replication channel (M')</td>
</tr>
<tr>
<td>3</td>
<td>Slave - primary replication channel (S)</td>
</tr>
<tr>
<td>4</td>
<td>Slave - secondary replication channel (S')</td>
</tr>
</tbody>
</table>

Setting up replication with two channels is not radically different from setting up a single replication channel. First, the `mysqld` processes for the primary and secondary replication masters must be started, followed by those for the primary and secondary slaves. Then the replication processes may be initiated by issuing the `START SLAVE` statement on each of the slaves. The commands and the order in which they need to be issued are shown here:

1. Start the primary replication master:

```
shell> mysqld --ndbcluster --server-id=1 \
       --log-bin &
```

For NDB 7.2.12 and earlier, you should use the following (Bug #16417224):

```
shell> mysqld --ndbcluster --server-id=1 \
       --log-bin --binlog-format=ROW &
```

2. Start the secondary replication master:

```
shell> mysqld --ndbcluster --server-id=2 \
       --log-bin &
```

For NDB 7.2.12 and earlier, you should use this instead (Bug #16417224):

```
shell> mysqld --ndbcluster --server-id=2 \
       --log-bin --binlog-format=ROW &
```

3. Start the primary replication slave server:

```
shell> mysqld --ndbcluster --server-id=3 \
       --skip-slave-start &
```

4. Start the secondary replication slave:

```
shell> mysqld --ndbcluster --server-id=4 \
       --skip-slave-start &
```

5. Finally, initiate replication on the primary channel by executing the `START SLAVE` statement on the primary slave as shown here:

```
2569
```
Implementing Failover with NDB Cluster Replication

Warning

Only the primary channel is to be started at this point. The secondary replication channel is to be started only in the event that the primary replication channel fails, as described in Section 18.6.8, “Implementing Failover with NDB Cluster Replication”. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.

As mentioned previously, it is not necessary to enable binary logging on replication slaves.

18.6.8 Implementing Failover with NDB Cluster Replication

In the event that the primary Cluster replication process fails, it is possible to switch over to the secondary replication channel. The following procedure describes the steps required to accomplish this.

1. Obtain the time of the most recent global checkpoint (GCP). That is, you need to determine the most recent epoch from the \texttt{ndb_apply_status} table on the slave cluster, which can be found using the following query:

   \begin{verbatim}
   mysql>
   SELECT @latest:=MAX(epoch) FROM mysql.ndb_apply_status;
   \end{verbatim}

   In a circular replication topology, with a master and a slave running on each host, when you are using \texttt{ndb_log_apply_status=1}, NDB Cluster epochs are written in the slave binary logs. This means that the \texttt{ndb_apply_status} table contains information for the slave on this host as well as for any other host which acts as a slave of the master running on this host.

   In this case, you need to determine the latest epoch on this slave to the exclusion of any epochs from any other slaves in this slave’s binary log that were not listed in the \texttt{IGNORE_SERVER_IDS} options of the \texttt{CHANGE MASTER TO} statement used to set up this slave. The reason for excluding such epochs is that rows in the \texttt{mysql.ndb_apply_status} table whose server IDs have a match in the \texttt{IGNORE_SERVER_IDS} list used with the \texttt{CHANGE MASTER TO} statement used to prepare this slave’s master are also considered to be from local servers, in addition to those having the slave’s own server ID. You can retrieve this list as \texttt{Replicate Ignore Server Ids} from the output of \texttt{SHOW SLAVE STATUS}. We assume that you have obtained this list and are substituting it for \texttt{ignore_server_ids} in the query shown here, which like the previous version of the query, selects the greatest epoch into a variable named \texttt{@latest}:

   \begin{verbatim}
   mysql>
   SELECT @latest:=MAX(epoch)
   FROM mysql.ndb_apply_status
   WHERE server_id NOT IN (ignore_server_ids);
   \end{verbatim}

   In some cases, it may be simpler or more efficient (or both) to use a list of the server IDs to be included and \texttt{server_id IN server_id_list} in the \texttt{WHERE} condition of the preceding query.

2. Using the information obtained from the query shown in Step 1, obtain the corresponding records from the \texttt{ndb_binlog_index} table on the master cluster.

Prior to NDB 7.2.6, you should use the following query to accomplish this task:

   \begin{verbatim}
   mysql>
   SELECT
   @file:=SUBSTRING_INDEX(File, '/', -1),
   @pos:=Position
   FROM mysql.ndb_binlog_index
   WHERE epoch > @latest
   ORDER BY epoch ASC LIMIT 1;
   \end{verbatim}
Implementing Failover with NDB Cluster Replication

Beginning with NDB 7.2.6, you can take advantage of the improved binary logging of DDL statements implemented in those and later versions by using the following query to obtain the needed records from the master's `ndb_binlog_index` table:

```
mysql> SELECT
      -> @file:=SUBSTRING_INDEX(next_file, '/', -1),
      -> @pos:=next_position
      -> FROM mysql.ndb_binlog_index
      -> WHERE epoch >= @latest
      -> ORDER BY epoch ASC LIMIT 1;
```

In either case, these are the records saved on the master since the failure of the primary replication channel. We have employed a user variable `@latest` here to represent the value obtained in Step 1. Of course, it is not possible for one `mysqld` instance to access user variables set on another server instance directly. These values must be “plugged in” to the second query manually or in application code.

---

**Important**

If (and only if) you use the second of the two queries just shown against `ndb_binlog_index` (that is, the query that employs the `next_position` and `next_file` columns), you must ensure that the slave `mysqld` is started with `--slave-skip-errors=ddl_exist_errors` before executing `START SLAVE`. Otherwise, replication may stop with duplicate DDL errors.

---

3. Now it is possible to synchronize the secondary channel by running the following query on the secondary slave server:

```
mysqlS>' CHANGE MASTER TO
      -> MASTER_LOG_FILE='@file',
      -> MASTER_LOG_POS=@pos;
```

Again we have employed user variables (in this case `@file` and `@pos`) to represent the values obtained in Step 2 and applied in Step 3; in practice these values must be inserted manually or using application code that can access both of the servers involved.

---

**Note**

`@file` is a string value such as `'@/var/log/mysql/replication-master-bin.00001'`, and so must be quoted when used in SQL or application code. However, the value represented by `@pos` must not be quoted. Although MySQL normally attempts to convert strings to numbers, this case is an exception.

---

4. You can now initiate replication on the secondary channel by issuing the appropriate command on the secondary slave `mysqld`:

```
mysqlS>' START SLAVE;
```

Once the secondary replication channel is active, you can investigate the failure of the primary and effect repairs. The precise actions required to do this will depend upon the reasons for which the primary channel failed.

---

**Warning**

The secondary replication channel is to be started only if and when the primary replication channel has failed. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.
If the failure is limited to a single server, it should (in theory) be possible to replicate from $M$ to $S'$, or from $M'$ to $S$; however, this has not yet been tested.

### 18.6.9 NDB Cluster Backups With NDB Cluster Replication

This section discusses making backups and restoring from them using NDB Cluster replication. We assume that the replication servers have already been configured as covered previously (see Section 18.6.5, “Preparing the NDB Cluster for Replication”, and the sections immediately following). This having been done, the procedure for making a backup and then restoring from it is as follows:

1. There are two different methods by which the backup may be started.

   - **Method A.** This method requires that the cluster backup process was previously enabled on the master server, prior to starting the replication process. This can be done by including the following line in a `[mysql_cluster]` section in the `my.cnf` file, where `management_host` is the IP address or host name of the NDB management server for the master cluster, and `port` is the management server's port number:

     ```
     ndb-connectstring=management_host[:port]
     ```

     **Note**

     The port number needs to be specified only if the default port (1186) is not being used. See Section 18.2.3, “Initial Configuration of NDB Cluster”, for more information about ports and port allocation in NDB Cluster.

     In this case, the backup can be started by executing this statement on the replication master:

     ```sh
     ndb_mgm -e "START BACKUP"
     ```

   - **Method B.** If the `my.cnf` file does not specify where to find the management host, you can start the backup process by passing this information to the NDB management client as part of the `START BACKUP` command. This can be done as shown here, where `management_host` and `port` are the host name and port number of the management server:

     ```sh
     ndb_mgm management_host:port -e "START BACKUP"
     ```

     In our scenario as outlined earlier (see Section 18.6.5, “Preparing the NDB Cluster for Replication”), this would be executed as follows:

     ```sh
     ndb_mgm rep-master:1186 -e "START BACKUP"
     ```

2. Copy the cluster backup files to the slave that is being brought on line. Each system running an `ndbd` process for the master cluster will have cluster backup files located on it, and all of these files must be copied to the slave to ensure a successful restore. The backup files can be copied into any directory on the computer where the slave management host resides, so long as the MySQL and NDB binaries have read permissions in that directory. In this case, we will assume that these files have been copied into the directory `/var/BACKUPS/BACKUP-1`.

   It is not necessary that the slave cluster have the same number of `ndbd` processes (data nodes) as the master; however, it is highly recommended this number be the same. It is necessary that the slave be started with the `--skip-slave-start` option, to prevent premature startup of the replication process.

3. Create any databases on the slave cluster that are present on the master cluster that are to be replicated to the slave.
NDB Cluster Backups With NDB Cluster Replication

**Important**

A `CREATE DATABASE` (or `CREATE SCHEMA`) statement corresponding to each database to be replicated must be executed on each SQL node in the slave cluster.

4. Reset the slave cluster using this statement in the MySQL Monitor:

```
mysql> RESET SLAVE;
```

5. You can now start the cluster restoration process on the replication slave using the `ndb_restore` command for each backup file in turn. For the first of these, it is necessary to include the `-m` option to restore the cluster metadata:

```
shell> ndb_restore -c slave_host:port -n node-id \
   -b backup-id -m -r dir
```

`dir` is the path to the directory where the backup files have been placed on the replication slave. For the `ndb_restore` commands corresponding to the remaining backup files, the `-m` option should *not* be used.

For restoring from a master cluster with four data nodes (as shown in the figure in Section 18.6, “NDB Cluster Replication”) where the backup files have been copied to the directory `/var/BACKUPS/BACKUP-1`, the proper sequence of commands to be executed on the slave might look like this:

```
shell> ndb_restore -c rep-slave:1186 -n 2 -b 1 -m \ 
   -r ./var/BACKUPS/BACKUP-1
shell> ndb_restore -c rep-slave:1186 -n 3 -b 1 \ 
   -r ./var/BACKUPS/BACKUP-1
shell> ndb_restore -c rep-slave:1186 -n 4 -b 1 \ 
   -r ./var/BACKUPS/BACKUP-1
shell> ndb_restore -c rep-slave:1186 -n 5 -b 1 -e \ 
   -r ./var/BACKUPS/BACKUP-1
```

**Important**

The `-e` (or `--restore-epoch`) option in the final invocation of `ndb_restore` in this example is required in order that the epoch is written to the slave `mysql.ndb_apply_status`. Without this information, the slave will not be able to synchronize properly with the master. (See Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”.)

6. Now you need to obtain the most recent epoch from the `ndb_apply_status` table on the slave (as discussed in Section 18.6.8, “Implementing Failover with NDB Cluster Replication”):

```
mysql> SELECT @latest:=MAX(epoch) 
   FROM mysql.ndb_apply_status;
```

7. Using `@latest` as the epoch value obtained in the previous step, you can obtain the correct starting position `@pos` in the correct binary log file `@file` from the master’s `mysql.ndb_binlog_index` table using the query shown here:

```
mysql> SELECT SUBSTRING_INDEX(File, '/', -1), 
   Position 
   FROM mysql.ndb_binlog_index 
   WHERE epoch >= @latest
```
In the event that there is currently no replication traffic, you can get this information by running `SHOW MASTER STATUS` on the master and using the value in the `Position` column for the file whose name has the suffix with the greatest value for all files shown in the `File` column. However, in this case, you must determine this and supply it in the next step manually or by parsing the output with a script.

8. Using the values obtained in the previous step, you can now issue the appropriate `CHANGE MASTER TO` statement in the slave's `mysql` client:

```
mysql> CHANGE MASTER TO
    -> MASTER_LOG_FILE='@file',
    -> MASTER_LOG_POS=@pos;
```

9. Now that the slave “knows” from what point in which binary log file to start reading data from the master, you can cause the slave to begin replicating with this standard MySQL statement:

```
mysql> START SLAVE;
```

To perform a backup and restore on a second replication channel, it is necessary only to repeat these steps, substituting the host names and IDs of the secondary master and slave for those of the primary master and slave replication servers where appropriate, and running the preceding statements on them.

For additional information on performing Cluster backups and restoring Cluster from backups, see Section 18.5.3, “Online Backup of NDB Cluster”.

18.6.9.1 NDB Cluster Replication: Automating Synchronization of the Replication Slave to the Master Binary Log

It is possible to automate much of the process described in the previous section (see Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”). The following Perl script `reset-slave.pl` serves as an example of how you can do this.

```perl
#!/usr/bin/perl -w
# file: reset-slave.pl
# Copyright ©2005-2017 Oracle and/or its affiliates
# This program is free software; you can redistribute it and/or modify
# it under the terms of the GNU General Public License as published by
# the Free Software Foundation; either version 2 of the License, or
# (at your option) any later version.
# This program is distributed in the hope that it will be useful,
# but WITHOUT ANY WARRANTY; without even the implied warranty of
# MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
# GNU General Public License for more details.
# You should have received a copy of the GNU General Public License
# along with this program; if not, write to:
# Free Software Foundation, Inc.
# 59 Temple Place, Suite 330
# Boston, MA 02111-1307 USA
# Version 1.1

# Includes #include DBI;
```
my $m_host = ''; my $m_port = ''; my $m_user = ''; my $m_pass = ''; my $s_host = ''; my $s_port = ''; my $s_user = ''; my $s_pass = ''; my $dbhM = ''; my $dbhS = '';  

Sub Prototypes

sub CollectCommandPromptInfo; sub ConnectToDatabases; sub DisconnectFromDatabases; sub GetSlaveEpoch; sub GetMasterInfo; sub UpdateSlave;

Program Main

CollectCommandPromptInfo; ConnectToDatabases; GetSlaveEpoch; GetMasterInfo; UpdateSlave; DisconnectFromDatabases;

Collect Command Prompt Info

sub CollectCommandPromptInfo
{
### Check that user has supplied correct number of command line args
die "Usage: \nreset-slave >master MySQL host< >master MySQL port< \n>master user< >master pass< >slave MySQL host< \n>slave MySQL port< >slave user< >slave pass< \nAll 8 arguments must be passed. Use BLANK for NULL passwords\n"
unless @ARGV == 8;

$m_host = $ARGV[0]; $m_port = $ARGV[1]; $m_user = $ARGV[2]; $m_pass = $ARGV[3];
$s_host = $ARGV[4]; $s_port = $ARGV[5]; $s_user = $ARGV[6]; $s_pass = $ARGV[7];

if ($m_pass eq "BLANK") { $m_pass = ''; } if ($s_pass eq "BLANK") { $s_pass = ''; }
}

Make connections to both databases

sub ConnectToDatabases
{
### Connect to both master and slave cluster databases

### Connect to master
$dbhM = DBI->connect("dbi:mysql:database=mysql;host=$m_host;port=$m_port", "$m_user", "$m_pass")
or die "Can't connect to Master Cluster MySQL process!";
}
NDB Cluster Backups With NDB Cluster Replication

### Connect to slave
$dbhS = DBI->connect("dbi:mysql:database=mysql;host=$s_host", "$s_user", "$s_pass")
or die "Can't connect to Slave Cluster MySQL process! Error: $DBI::errstr"
;

### Disconnect from both databases

sub DisconnectFromDatabases {
    ### Disconnect from master
    $dbhM->disconnect
    or warn " Disconnection failed: $DBI::errstr"
;
    ### Disconnect from slave
    $dbhS->disconnect
    or warn " Disconnection failed: $DBI::errstr"
;
}

### Find the last good GCI

sub GetSlaveEpoch {
    $sth = $dbhS->prepare("SELECT MAX(epoch) FROM mysql.ndb_apply_status;")
or die "Error while preparing to select epoch from slave: ", $dbhS->errstr;

    $sth->execute
    or die "Selecting epoch from slave error: ", $sth->errstr;

    $sth->bind_col (1, $epoch);
    $sth->fetch;
    print "Slave Epoch = $epoch"
;
    $sth->finish;
}

### Find the position of the last GCI in the binary log

sub GetMasterInfo {
    $sth = $dbhM->prepare("SELECT
        SUBSTRING_INDEX(File, '/', -1), Position
    FROM mysql.ndb_binlog_index
    WHERE epoch > $epoch
    ORDER BY epoch ASC LIMIT 1;")
or die "Prepare to select from master error: ", $dbhM->errstr;

    $sth->execute
    or die "Selecting from master error: ", $sth->errstr;

    $sth->bind_col (1, $binlog);
    $sth->bind_col (2, $binpos);
    $sth->fetch;
    print "Master binary log = $binlog"
;
    print "Master binary log position = $binpos"
;
    $sth->finish;
}

### Set the slave to process from that location

$sth = $dbhS->prepare("SET GLOBAL tidb_enable_desync = 1;")
or die "Prepare to execute to enable desync from slave: ", $dbhS->errstr;

$sth->execute
or die "Executing to enable desync from slave error: ", $sth->errstr;

$sth->bind_col (1, $desync);
$sth->execute;
print "Executing to enable desync from slave success: ", $sth->errstr;

$sth->finish;

2576
sub UpdateSlave
{
    $sth = $dbhS->prepare("CHANGE MASTER TO
        MASTER_LOG_FILE='$binlog',
        MASTER_LOG_POS=$binpos;")
    or die "Prepare to CHANGE MASTER error: ", $dbhS->errstr;
    $sth->execute
    or die "CHANGE MASTER on slave error: ", $sth->errstr;
    $sth->finish;
    print "\t Slave has been updated. You may now start the slave.\n";
}
# end reset-slave.pl

18.6.9.2 Point-In-Time Recovery Using NDB Cluster Replication

Point-in-time recovery—that is, recovery of data changes made since a given point in time—is performed after restoring a full backup that returns the server to its state when the backup was made. Performing point-in-time recovery of NDB Cluster tables with NDB Cluster and NDB Cluster Replication can be accomplished using a native NDB data backup (taken by issuing CREATE BACKUP in the ndb_mgm client) and restoring the ndb_binlog_index table (from a dump made using mysqldump).

To perform point-in-time recovery of NDB Cluster, it is necessary to follow the steps shown here:

1. Back up all NDB databases in the cluster, using the START BACKUP command in the ndb_mgm client (see Section 18.5.3, “Online Backup of NDB Cluster”).

2. At some later point, prior to restoring the cluster, make a backup of the mysql.ndb_binlog_index table. It is probably simplest to use mysqldump for this task. Also back up the binary log files at this time.

    This backup should be updated regularly—perhaps even hourly—depending on your needs.

3. (Catastrophic failure or error occurs.)

4. Locate the last known good backup.

5. Clear the data node file systems (using ndbd --initial or ndbmtd --initial).

   Note

   NDB Cluster Disk Data tablespace and log files are not removed by --initial. You must delete these manually.

6. Use DROP TABLE or TRUNCATE TABLE with the mysql.ndb_binlog_index table.

7. Execute ndb_restore, restoring all data. You must include the --restore-epoch option when you run ndb_restore, so that the ndb_apply_status table is populated correctly. (See Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”, for more information.)

8. Restore the ndb_binlog_index table from the output of mysqldump and restore the binary log files from backup, if necessary.

9. Find the epoch applied most recently—that is, the maximum epoch column value in the ndb_apply_status table—as the user variable @LATEST_EPOCH (emphasized):

    SELECT @LATEST_EPOCH:=MAX(epoch)
    FROM mysql.ndb_apply_status;
10. Find the latest binary log file (@FIRST_FILE) and position (Position column value) within this file that correspond to @LATEST_EPOCH in the ndb_binlog_index table:

```sql
SELECT Position, @FIRST_FILE:=File
FROM mysql.ndb_binlog_index
WHERE epoch > @LATEST_EPOCH ORDER BY epoch ASC LIMIT 1;
```

11. Using `mysqlbinlog`, replay the binary log events from the given file and position up to the point of the failure. (See Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files").

See also Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”, for more information about the binary log, replication, and incremental recovery.

### 18.6.10 NDB Cluster Replication: Multi-Master and Circular Replication

It is possible to use NDB Cluster in multi-master replication, including circular replication between a number of NDB Clusters.

**Circular replication example.** In the next few paragraphs we consider the example of a replication setup involving three NDB Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1. Each cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same.
- All SQL nodes acting as replication masters and slaves are started with the `log_slave_updates` system variable enabled.

This type of circular replication setup is shown in the following diagram:
In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the curved arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It is also possible to set up circular replication in such a way that not all master SQL nodes are also slaves, as shown here:
In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must not start any of the SQL nodes with the `log_slave_updates` system variable enabled. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the curved arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

**Using NDB-native backup and restore to initialize a slave NDB Cluster.** When setting up circular replication, it is possible to initialize the slave cluster by using the management client `BACKUP` command on one NDB Cluster to create a backup and then applying this backup on another NDB Cluster using `ndb_restore`. However, this does not automatically create binary logs on the second NDB Cluster’s SQL node acting as the replication slave. In order to cause the binary logs to be created, you must issue a `SHOW TABLES` statement on that SQL node; this should be done prior to running `START SLAVE`.

This is a known issue which we intend to address in a future release.

**Multi-master failover example.** In this section, we discuss failover in a multi-master NDB Cluster replication setup with three NDB Clusters having server IDs 1, 2, and 3. In this scenario, Cluster 1 replicates to Clusters 2 and 3; Cluster 2 also replicates to Cluster 3. This relationship is shown here:
In other words, data replicates from Cluster 1 to Cluster 3 through 2 different routes: directly, and by way of Cluster 2.

Not all MySQL servers taking part in multi-master replication must act as both master and slave, and a given NDB Cluster might use different SQL nodes for different replication channels. Such a case is shown here:

MySQL servers acting as replication slaves must be run with the `log_slave_updates` system variable enabled. Which `mysqld` processes require this option is also shown in the preceding diagram.

**Note**

Using the `log_slave_updates` system variable has no effect on servers not being run as replication slaves.

The need for failover arises when one of the replicating clusters goes down. In this example, we consider the case where Cluster 1 is lost to service, and so Cluster 3 loses 2 sources of updates from Cluster 1.
Because replication between NDB Clusters is asynchronous, there is no guarantee that Cluster 3’s updates originating directly from Cluster 1 are more recent than those received through Cluster 2. You can handle this by ensuring that Cluster 3 catches up to Cluster 2 with regard to updates from Cluster 1. In terms of MySQL servers, this means that you need to replicate any outstanding updates from MySQL server C to server F.

On server C, perform the following queries:

```
mysqlC> SELECT @latest:=MAX(epoch)
    ->     FROM mysql.ndb_apply_status
    ->     WHERE server_id=1;
```

```
mysqlC> SELECT
    ->     @file:=SUBSTRING_INDEX(File, '/', -1),
    ->     @pos:=Position
    ->     FROM mysql.ndb_binlog_index
    ->     WHERE orig_epoch >= @latest
    ->     AND orig_server_id = 1
    ->     ORDER BY epoch ASC LIMIT 1;
```

**Note**

You can improve the performance of this query, and thus likely speed up failover times significantly, by adding the appropriate index to the `ndb_binlog_index` table. See Section 18.6.4, “NDB Cluster Replication Schema and Tables”, for more information.

Copy over the values for `@file` and `@pos` manually from server C to server F (or have your application perform the equivalent). Then, on server F, execute the following `CHANGE MASTER TO` statement:

```
mysqlF> CHANGE MASTER TO
    ->     MASTER_HOST = 'serverC'
    ->     MASTER_LOG_FILE='@file',
    ->     MASTER_LOG_POS=@pos;
```

Once this has been done, you can issue a `START SLAVE` statement on MySQL server F, and any missing updates originating from server B will be replicated to server F.

The `CHANGE MASTER TO` statement also supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. For more information, see Section 13.4.2.1, “CHANGE MASTER TO Statement”, and Section 13.7.5.35, “SHOW SLAVE STATUS Statement”. For information about how this option interacts with the `ndb_log_apply_status` variable, see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

### 18.6.11 NDB Cluster Replication Conflict Resolution

When using a replication setup involving multiple masters (including circular replication), it is possible that different masters may try to update the same row on the slave with different data. Conflict resolution in NDB Cluster Replication provides a means of resolving such conflicts by permitting a user-defined resolution column to be used to determine whether or not an update on a given master should be applied on the slave.

Some types of conflict resolution supported by NDB Cluster (`NDB$OLD()`, `NDB$MAX()`, `NDB$MAX_DELETE_WIN()`) implement this user-defined column as a “timestamp” column (although its type cannot be `TIMESTAMP`, as explained later in this section). These types of conflict resolution are always applied a row-by-row basis rather than a transactional basis. The epoch-based conflict resolution functions introduced in NDB 7.2.1 (`NDB$EPOCH()` and `NDB$EPOCH_TRANS()`) compare the order in which epochs
are replicated (and thus these functions are transactional). Different methods can be used to compare resolution column values on the slave when conflicts occur, as explained later in this section; the method used can be set on a per-table basis.

You should also keep in mind that it is the application's responsibility to ensure that the resolution column is correctly populated with relevant values, so that the resolution function can make the appropriate choice when determining whether to apply an update.

Requirements. Preparations for conflict resolution must be made on both the master and the slave. These tasks are described in the following list:

• On the master writing the binary logs, you must determine which columns are sent (all columns or only those that have been updated). This is done for the MySQL Server as a whole by applying the `--ndb-log-updated-only` startup option (described later in this section) or on a per-table basis by entries in the `mysql.ndb_replication` table (see The ndb_replication system table).

  **Note**

  If you are replicating tables with very large columns (such as TEXT or BLOB columns), `--ndb-log-updated-only` can also be useful for reducing the size of the master and slave binary logs and avoiding possible replication failures due to exceeding `max_allowed_packet`.

  See Section 17.4.1.19, “Replication and max_allowed_packet”, for more information about this issue.

• On the slave, you must determine which type of conflict resolution to apply (“latest timestamp wins”, “same timestamp wins”, “primary wins”, “primary wins, complete transaction”, or none). This is done using the `mysql.ndb_replication` system table, on a per-table basis (see The ndb_replication system table).

• Prior to NDB 7.2.5, conflict detection and resolution did not always work properly unless set up for NDB tables created on the same server only (Bug #13578660).

When using the functions `NDB$OLD()`, `NDB$MAX()`, and `NDB$MAX_DELETE_WIN()` for timestamp-based conflict resolution, we often refer to the column used for determining updates as a “timestamp” column. However, the data type of this column is never `TIMESTAMP`; instead, its data type should be `INT` (INTEGER) or `BIGINT`. The “timestamp” column should also be `UNSIGNED` and `NOT NULL`.

The `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions discussed later in this section work by comparing the relative order of replication epochs applied on a primary and secondary NDB Cluster, and do not make use of timestamps.

Master column control. We can see update operations in terms of “before” and “after” images—that is, the states of the table before and after the update is applied. Normally, when updating a table with a primary key, the “before” image is not of great interest; however, when we need to determine on a per-update basis whether or not to use the updated values on a replication slave, we need to make sure that both images are written to the master's binary log. This is done with the `--ndb-log-update-as-write` option for `mysqld`, as described later in this section.

**Important**

Whether logging of complete rows or of updated columns only is done is decided when the MySQL server is started, and cannot be changed online; you must either restart `mysqld`, or start a new `mysqld` instance with different logging options.
Logging Full or Partial Rows (--ndb-log-updated-only Option)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-updated-only[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_updated_only</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

For purposes of conflict resolution, there are two basic methods of logging rows, as determined by the setting of the `--ndb-log-updated-only` option for `mysqld`:

- Log complete rows
- Log only column data that has been updated—that is, column data whose value has been set, regardless of whether or not this value was actually changed. This is the default behavior.

It is usually sufficient—and more efficient—to log updated columns only; however, if you need to log full rows, you can do so by setting `--ndb-log-updated-only` to 0 or OFF.

--ndb-log-update-as-write Option: Logging Changed Data as Updates

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--ndb-log-update-as-write[={OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>ndb_log_update_as_write</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Yes</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>ON</td>
</tr>
</tbody>
</table>

The setting of the MySQL Server's `--ndb-log-update-as-write` option determines whether logging is performed with or without the "before" image. Because conflict resolution is done in the MySQL Server's update handler, it is necessary to control logging on the master such that updates are updates and not writes; that is, such that updates are treated as changes in existing rows rather than the writing of new rows (even though these replace existing rows). This option is turned on by default; in other words, updates are treated as writes. (That is, updates are by default written as `write_row` events in the binary log, rather than as `update_row` events.)

To turn off the option, start the master `mysqld` with `--ndb-log-update-as-write=0` or `--ndb-log-update-as-write=OFF`. You must do this when replicating from NDB tables to tables using a different storage engine; see Replication from NDB to other storage engines.

Conflict resolution control. Conflict resolution is usually enabled on the server where conflicts can occur. Like logging method selection, it is enabled by entries in the `mysql.ndb_replication` table.

The ndb_replication system table. To enable conflict resolution, it is necessary to create an `ndb_replication` table in the `mysql` system database on the master, the slave, or both, depending on the conflict resolution type and method to be employed. This table is used to control logging and conflict resolution functions on a per-table basis, and has one row per table involved in replication.
NDB Cluster Replication Conflict Resolution

`ndb_replication` is created and filled with control information on the server where the conflict is to be resolved. In a simple master-slave setup where data can also be changed locally on the slave this will typically be the slave. In a more complex master-master (2-way) replication schema this will usually be all of the masters involved. Each row in `mysql.ndb_replication` corresponds to a table being replicated, and specifies how to log and resolve conflicts (that is, which conflict resolution function, if any, to use) for that table. The definition of the `mysql.ndb_replication` table is shown here:

```sql
CREATE TABLE mysql.ndb_replication  (
  db VARBINARY(63),
  table_name VARBINARY(63),
  server_id INT UNSIGNED,
  binlog_type INT UNSIGNED,
  conflict_fn VARBINARY(128),
  PRIMARY KEY USING HASH (db, table_name, server_id)
) ENGINE=NDB
PARTITION BY KEY(db,table_name);
```

The columns in this table are described in the next few paragraphs.

**db.** The name of the database containing the table to be replicated.

Beginning with NDB 7.2.5, you may employ either or both of the wildcards _ and % as part of the database name. Matching is similar to what is implemented for the `LIKE` operator.

**table_name.** The name of the table to be replicated.

Beginning with NDB 7.2.5, the table name may include either or both of the wildcards _ and %. Matching is similar to what is implemented for the `LIKE` operator.

**server_id.** The unique server ID of the MySQL instance (SQL node) where the table resides.

**binlog_type.** The type of binary logging to be employed. This is determined as shown in the following table:

**Table 18.285 binlog_type values, with internal values and descriptions**

<table>
<thead>
<tr>
<th>Value</th>
<th>Internal Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><code>NBT_DEFAULT</code></td>
<td>Use server default</td>
</tr>
<tr>
<td>1</td>
<td><code>NBT_NO_LOGGING</code></td>
<td>Do not log this table in the binary log</td>
</tr>
<tr>
<td>2</td>
<td><code>NBT_UPDATED_ONLY</code></td>
<td>Only updated attributes are logged</td>
</tr>
<tr>
<td>3</td>
<td><code>NBT_FULL</code></td>
<td>Log full row, even if not updated (MySQL server default behavior)</td>
</tr>
<tr>
<td>4</td>
<td><code>NBT_USE_UPDATE</code></td>
<td>(For generating <code>NBT_UPDATED_ONLY_USE_UPDATE</code> and <code>NBT_FULL_USE_UPDATE</code> values only—not intended for separate use)</td>
</tr>
<tr>
<td>5</td>
<td>[Not used]</td>
<td>---</td>
</tr>
<tr>
<td>6</td>
<td><code>NBT_UPDATED_ONLY</code></td>
<td>Use updated attributes, even if values are unchanged</td>
</tr>
<tr>
<td></td>
<td>(equal to <code>NBT_UPDATED_ONLY</code></td>
<td>(equal to <code>NBT_UPDATED_ONLY</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><code>NBT_FULL_USE_UPDATE</code></td>
<td>Use full row, even if values are unchanged</td>
</tr>
<tr>
<td></td>
<td>(equal to <code>NBT_FULL</code></td>
<td>(equal to <code>NBT_FULL</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
conflict_fn. The conflict resolution function to be applied. This function must be specified as one of those shown in the following list:

- NDB$OLD(column_name)
- NDB$MAX(column_name)
- NDB$MAX_DELETE_WIN()
- NDB$EPOCH() and NDB$EPOCH_TRANS() (NDB 7.2.1 and later)
- NDB$EPOCH_TRANS() (NDB 7.2.1 and later)
- NULL: Indicates that conflict resolution is not to be used for the corresponding table.

These functions are described in the next few paragraphs.

NDB$OLD(column_name). If the value of column_name is the same on both the master and the slave, then the update is applied; otherwise, the update is not applied on the slave and an exception is written to the log. This is illustrated by the following pseudocode:

```plaintext
if (master_old_column_value == slave_current_column_value)
    apply_update();
else
    log_exception();
```

This function can be used for “same value wins” conflict resolution. This type of conflict resolution ensures that updates are not applied on the slave from the wrong master.

Important
The column value from the master’s “before” image is used by this function.

NDB$MAX(column_name). If the “timestamp” column value for a given row coming from the master is higher than that on the slave, it is applied; otherwise it is not applied on the slave. This is illustrated by the following pseudocode:

```plaintext
if (master_new_column_value > slave_current_column_value)
    apply_update();
```

This function can be used for “greatest timestamp wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was most recently updated is the version that persists.

Important
The column value from the master’s “after” image is used by this function.

NDB$MAX_DELETE_WIN(). This is a variation on NDB$MAX(). Due to the fact that no timestamp is available for a delete operation, a delete using NDB$MAX() is in fact processed as NDB$OLD. However, for some use cases, this is not optimal. For NDB$MAX_DELETE_WIN(), if the “timestamp” column value for a given row adding or updating an existing row coming from the master is higher than that on the slave, it is applied. However, delete operations are treated as always having the higher value. This is illustrated in the following pseudocode:

```plaintext
if ( (master_new_column_value > slave_current_column_value)
    ||
```

2586
operation.type == "delete")
apply_update();

This function can be used for “greatest timestamp, delete wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was deleted or (otherwise) most recently updated is the version that persists.

Note
As with NDB$MAX(), the column value from the master’s “after” image is the value used by this function.

NDB$EPOCH() and NDB$EPOCH_TRANS(). The NDB$EPOCH() function, available beginning with NDB 7.2.1, tracks the order in which replicated epochs are applied on a slave NDB Cluster relative to changes originating on the slave. This relative ordering is used to determine whether changes originating on the slave are concurrent with any changes that originate locally, and are therefore potentially in conflict.

Most of what follows in the description of NDB$EPOCH() also applies to NDB$EPOCH_TRANS(). Any exceptions are noted in the text.

NDB$EPOCH() is asymmetric, operating on one NDB Cluster in a two-cluster circular replication configuration (sometimes referred to as “active-active” replication). We refer here to cluster on which it operates as the primary, and the other as the secondary. The slave on the primary is responsible for detecting and handling conflicts, while the slave on the secondary is not involved in any conflict detection or handling.

When the slave on the primary detects conflicts, it injects events into its own binary log to compensate for these; this ensures that the secondary NDB Cluster eventually realigns itself with the primary and so keeps the primary and secondary from diverging. This compensation and realignment mechanism requires that the primary NDB Cluster always wins any conflicts with the secondary—that is, that the primary’s changes are always used rather than those from the secondary in event of a conflict. This “primary always wins” rule has the following implications:

• Operations that change data, once committed on the primary, are fully persistent and will not be undone or rolled back by conflict detection and resolution.

• Data read from the primary is fully consistent. Any changes committed on the Primary (locally or from the slave) will not be reverted later.

• Operations that change data on the secondary may later be reverted if the primary determines that they are in conflict.

• Individual rows read on the secondary are self-consistent at all times, each row always reflecting either a state committed by the secondary, or one committed by the primary.

• Sets of rows read on the secondary may not necessarily be consistent at a given single point in time. For NDB$EPOCH_TRANS(), this is a transient state; for NDB$EPOCH(), it can be a persistent state.

• Assuming a period of sufficient length without any conflicts, all data on the secondary NDB Cluster (eventually) becomes consistent with the primary's data.

NDB$EPOCH() and NDB$EPOCH_TRANS() do not require any user schema modifications, or application changes to provide conflict detection. However, careful thought must be given to the schema used, and the access patterns used, to verify that the complete system behaves within specified limits.

Each of the NDB$EPOCH() and NDB$EPOCH_TRANS() functions can take an optional parameter; this is the number of bits to use to represent the lower 32 bits of the epoch, and should be set to no less than 2587.
For the default values of these configuration parameters (2000 and 100 milliseconds, respectively), this gives a value of 5 bits, so the default value (6) should be sufficient, unless other values are used for `TimeBetweenGlobalCheckpoints`, `TimeBetweenEpochs`, or both. A value that is too small can result in false positives, while one that is too large could lead to excessive wasted space in the database.

Both `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` insert entries for conflicting rows into the relevant exceptions tables, provided that these tables have been defined according to the same exceptions table schema rules as described elsewhere in this section (see `NDB$OLD(column_name)`). You need to create any exceptions table before creating the table with which it is to be used.

As with the other conflict detection functions discussed in this section, `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are activated by including relevant entries in the `mysql.ndb_replication` table (see The `ndb_replication` system table). The roles of the primary and secondary NDB Clusters in this scenario are fully determined by `mysql.ndb_replication` table entries.

Because the conflict detection algorithms employed by `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are asymmetric, you must use different values for the primary slave’s and secondary slave’s `server_id` entries.

Prior to NDB 7.2.17, conflict between `DELETE` operations were handled like those for `UPDATE` operations, and within the same epoch were considered in conflict. In NDB 7.2.17 and later, a conflict between `DELETE` operations alone is not sufficient to trigger a conflict using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()`, and the relative placement within epochs does not matter. (Bug #18459944)

**Conflict detection status variables.** NDB 7.2.1 introduces several status variables that can be used to monitor `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` conflict detection. You can see how many rows have been found in conflict by `NDB$EPOCH()` since this slave was last restarted from the current value of the `Ndb_conflict_fn_epoch` system status variable.

`Ndb_conflict_fn_epoch_trans` provides the number of rows that have been found directly in conflict by `NDB$EPOCH_TRANS()`; the number of rows actually realigned, including those affected due to their membership in or dependency on the same transactions as other conflicting rows, is given by `Ndb_conflict_trans_row_reject_count`.

For more information, see NDB Cluster Status Variables.

**Limitations on NDB$EPOCH().** The following limitations currently apply when using `NDB$EPOCH()` to perform conflict detection:

- Conflicts are detected using NDB Cluster epoch boundaries, with granularity proportional to `TimeBetweenEpochs` (default: 100 milliseconds). The minimum conflict window is the minimum time during which concurrent updates to the same data on both clusters always report a conflict. This is always a nonzero length of time, and is roughly proportional to $2 \times \text{latency + queueing + TimeBetweenEpochs}$. This implies that—assuming the default for `TimeBetweenEpochs` and ignoring any latency between clusters (as well as any queuing delays)—the minimum conflict window size is approximately 200 milliseconds. This minimum window should be considered when looking at expected application “race” patterns.

- Additional storage is required for tables using the `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions; from 1 to 32 bits extra space per row is required, depending on the value passed to the function.

- Conflicts between delete operations may result in divergence between the primary and secondary. When a row is deleted on both clusters concurrently, the conflict can be detected, but is not recorded, since the row is deleted. This means that further conflicts during the propagation of any subsequent realignment operations will not be detected, which can lead to divergence.
NDB Cluster Replication Conflict Resolution

Deletes should be externally serialized, or routed to one cluster only. Alternatively, a separate row should be updated transactionally with such deletes and any inserts that follow them, so that conflicts can be tracked across row deletes. This may require changes in applications.

- Only two NDB Clusters in a circular “active-active” configuration are currently supported when using NDB $EPOCH() or NDB$EPOCH_TRANS() for conflict detection.

- Tables having BLOB or TEXT columns are not currently supported with NDB$EPOCH() or NDB $EPOCH_TRANS().

**NDB$EPOCH_TRANS().** NDB$EPOCH_TRANS() extends the NDB$EPOCH() function, and, like NDB $EPOCH(), is available beginning with NDB 7.2.1. Conflicts are detected and handled in the same way using the “primary wins all” rule (see NDB$EPOCH() and NDB$EPOCH_TRANS()) but with the extra condition that any other rows updated in the same transaction in which the conflict occurred are also regarded as being in conflict. In other words, where NDB$EPOCH() realigns individual conflicting rows on the secondary, NDB$EPOCH_TRANS() realigns conflicting transactions.

In addition, any transactions which are detectably dependent on a conflicting transaction are also regarded as being in conflict, these dependencies being determined by the contents of the secondary cluster's binary log. Since the binary log contains only data modification operations (inserts, updates, and deletes), only overlapping data modifications are used to determine dependencies between transactions.

NDB$EPOCH_TRANS() is subject to the same conditions and limitations as NDB$EPOCH(), and in addition requires that Version 2 binary log row events are used (log_bin_use_v1_row_events equal to 0), which adds a storage overhead of 2 bytes per event in the binary log. In addition, all transaction IDs must be recorded in the secondary's binary log (--ndb-log-transaction-id option), which adds a further variable overhead (up to 13 bytes per row).

See NDB$EPOCH() and NDB$EPOCH_TRANS().

**Status information.** A server status variable Ndb_conflict_fn_max provides a count of the number of times that a row was not applied on the current SQL node due to “greatest timestamp wins” conflict resolution since the last time that mysqld was started.

The number of times that a row was not applied as the result of “same timestamp wins” conflict resolution on a given mysqld since the last time it was restarted is given by the global status variable Ndb_conflict_fn_old. In addition to incrementing Ndb_conflict_fn_old, the primary key of the row that was not used is inserted into an exceptions table, as explained later in this section.

**Conflict resolution exceptions table.** To use the NDB$OLD() conflict resolution function, it is also necessary to create an exceptions table corresponding to each NDB table for which this type of conflict resolution is to be employed. This is also true when using NDB$EPOCH() or NDB$EPOCH_TRANS() in NDB 7.2.1 and later. The name of this table is that of the table for which conflict resolution is to be applied, with the string $EX appended. (For example, if the name of the original table is mytable, the name of the corresponding exceptions table name should be mytable$EX.) This table is created as follows:

```sql
CREATE TABLE original_table$EX  
  (server_id INT UNSIGNED,
   master_server_id INT UNSIGNED,
   master_epoch BIGINT UNSIGNED,
   count INT UNSIGNED,
   original_table_pk_columns,
   [additional_columns,]
  PRIMARY KEY(server_id, master_server_id, master_epoch, count)
```
The first four columns are required. The names of the first four columns and the columns matching the original table's primary key columns are not critical; however, we suggest for reasons of clarity and consistency, that you use the names shown here for the server_id, master_server_id, master_epoch, and count columns, and that you use the same names as in the original table for the columns matching those in the original table's primary key.

Following these columns, the columns making up the original table's primary key should be copied in the order in which they are used to define the primary key of the original table. The data types for the columns duplicating the primary key columns of the original table should be the same as (or larger than) those of the original columns.

Additional columns may optionally be defined following the copied primary key columns, but not before any of them; any such extra columns cannot be NOT NULL. The exceptions table's primary key must be defined as shown.

The exceptions table must use the NDB storage engine. An example that uses NDB$OLD() with an exceptions table is shown later in this section.

Important

The mysql.ndb_replication table is read when a data table is set up for replication, so the row corresponding to a table to be replicated must be inserted into mysql.ndb_replication before the table to be replicated is created.

Examples

The following examples assume that you have already a working NDB Cluster replication setup, as described in Section 18.6.5, “Preparing the NDB Cluster for Replication”, and Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”.

NDB$MAX() example. Suppose you wish to enable “greatest timestamp wins” conflict resolution on table test.t1, using column mycol as the “timestamp”. This can be done using the following steps:

1. Make sure that you have started the master mysql with --ndb-log-update-as-write=OFF.
2. On the master, perform this INSERT statement:

   ```
   INSERT INTO mysql.ndb_replication
   VALUES ('test', 't1', 0, NULL, 'NDB$MAX(mycol)');
   ```

   Inserting a 0 into the server_id indicates that all SQL nodes accessing this table should use conflict resolution. If you want to use conflict resolution on a specific mysqld only, use the actual server ID.

   Inserting NULL into the binlog_type column has the same effect as inserting 0 (NBT_DEFAULT); the server default is used.

3. Create the test.t1 table:

   ```
   CREATE TABLE test.t1 (   
   mycol INT UNSIGNED,
   ) ENGINE=NDB;
   ```

   Now, when updates are done on this table, conflict resolution is applied, and the version of the row having the greatest value for mycol is written to the slave.
Note

Other `binlog_type` options—such as `NBT_UPDATED_ONLY_USE_UPDATE` should be used to control logging on the master using the `ndb_replication` table rather than by using command-line options.

**NDB$OLD() example.** Suppose an NDB table such as the one defined here is being replicated, and you wish to enable “same timestamp wins” conflict resolution for updates to this table:

```sql
CREATE TABLE test.t2  (  
a INT UNSIGNED NOT NULL,  
b CHAR(25) NOT NULL,  
columns,  
mycol INT UNSIGNED NOT NULL,  
columns,  
PRIMARY KEY pk (a, b)  
) ENGINE=NDB;
```

The following steps are required, in the order shown:

1. First—and prior to creating `test.t2`—you must insert a row into the `mysql.ndb_replication` table, as shown here:

   ```sql
   INSERT INTO mysql.ndb_replication
   VALUES ('test', 't2', 0, NULL, 'NDB$OLD(mycol)');
   ```

   Possible values for the `binlog_type` column are shown earlier in this section. The value `'NDB$OLD(mycol)'` should be inserted into the `conflict_fn` column.

2. Create an appropriate exceptions table for `test.t2`. The table creation statement shown here includes all required columns; any additional columns must be declared following these columns, and before the definition of the table’s primary key.

   ```sql
   CREATE TABLE test.t2$EX  (  
server_id INT UNSIGNED,  
master_server_id INT UNSIGNED,  
master_epoch BIGINT UNSIGNED,  
count INT UNSIGNED,  
a INT UNSIGNED NOT NULL,  
b CHAR(25) NOT NULL,  
[additional_columns,]  
PRIMARY KEY(server_id, master_server_id, master_epoch, count)  
) ENGINE=NDB;
   ```

3. Create the table `test.t2` as shown previously.

These steps must be followed for every table for which you wish to perform conflict resolution using `NDB$OLD()`. For each such table, there must be a corresponding row in `mysql.ndb_replication`, and there must be an exceptions table in the same database as the table being replicated.

### 18.7 NDB Cluster Release Notes

NDB Cluster release notes are no longer published in the MySQL Reference Manual.

Release notes for the changes in each release of NDB Cluster are located at NDB Cluster 7.2 Release Notes.
Chapter 19 Partitioning

Table of Contents

19.1 Overview of Partitioning in MySQL .............................................................. 2595
19.2 Partitioning Types .......................................................... 2598
  19.2.1 RANGE Partitioning ....................................................... 2599
  19.2.2 LIST Partitioning ......................................................... 2604
  19.2.3 COLUMNS Partitioning .................................................. 2606
  19.2.4 HASH Partitioning ....................................................... 2614
  19.2.5 KEY Partitioning ......................................................... 2617
  19.2.6 Subpartitioning .......................................................... 2618
  19.2.7 How MySQL Partitioning Handles NULL ..................................... 2622
19.3 Partition Management .......................................................... 2626
  19.3.1 Management of RANGE and LIST Partitions ......................... 2627
  19.3.2 Management of HASH and KEY Partitions ............................. 2633
  19.3.3 Maintenance of Partitions ............................................ 2634
  19.3.4 Obtaining Information About Partitions .................................. 2635
19.4 Partition Pruning .......................................................... 2637
19.5 Restrictions and Limitations on Partitioning ........................................... 2640
  19.5.1 Partitioning Keys, Primary Keys, and Unique Keys .................... 2647
  19.5.2 Partitioning Limitations Relating to Storage Engines ................. 2650
  19.5.3 Partitioning Limitations Relating to Functions ....................... 2651
  19.5.4 Partitioning and Table-Level Locking ..................................... 2653

This chapter discusses MySQL’s implementation of user-defined partitioning. You can determine whether your MySQL Server supports partitioning by means of a SHOW VARIABLES statement such as this one:

```sql
mysql> SHOW VARIABLES LIKE '%partition%';
+-------------------+-------+
| have_partitioning  | YES   |
+-------------------+-------+
1 row in set (0.00 sec)
```

Note

The `have_partitioning` variable is deprecated, and removed in MySQL 5.6.1.

You can also check the output of the SHOW PLUGINS statement, like this:

```sql
mysql> SHOW PLUGINS;
+---------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
| Name    | Status    | Type      | Library   | License   |
|---------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
| partition | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
| ARCHIVE | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
| BLACKHOLE | ACTIVE   | STORAGE ENGINE | NULL     | GPL       |
| CSV     | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
| FEDERATED | DISABLED | STORAGE ENGINE | NULL     | GPL       |
| MEMORY  | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
| InnoDB  | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
| FED_MYSAM | ACTIVE  | STORAGE ENGINE | NULL     | GPL       |
| MyISAM  | ACTIVE    | STORAGE ENGINE | NULL     | GPL       |
```
You can also check the `INFORMATION_SCHEMA.PLUGINS` table with a query similar to this one:

```sql
mysql> SELECT
> PLUGIN_NAME as Name,
> PLUGIN_VERSION as Version,
> PLUGIN_STATUS as Status
> FROM INFORMATION_SCHEMA.PLUGINS
> WHERE PLUGIN_TYPE='STORAGE ENGINE';
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Version</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>binlog</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>CSV</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>MEMORY</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>MRG_MYISAM</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>MyISAM</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>PERFORMANCE_SCHEMA</td>
<td>0.1</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>BLACKHOLE</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>ARCHIVE</td>
<td>3.0</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>InnoDB</td>
<td>5.6</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>partition</td>
<td>1.0</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

In either case, if you do not see the `partition` plugin listed with the value `ACTIVE` for the `Status` column in the output (shown in bold text in each of the examples just given), then your version of MySQL was not built with partitioning support.

MySQL 5.5 Community binaries provided by Oracle include partitioning support. For information about partitioning support offered in MySQL Enterprise Edition binaries, see Chapter 25, *MySQL Enterprise Edition*.

To enable partitioning if you are compiling MySQL 5.5 from source, the build must be configured with the `--with-partition-storage-engine` option. For more information, see Section 2.9, “Installing MySQL from Source”.

If your MySQL binary is built with partitioning support, nothing further needs to be done to enable it (for example, no special entries are required in your `my.cnf` file).

If you want to disable partitioning support, you can start the MySQL Server with the `--skip-partition` option, in which case the value of `have_partitioning` is `DISABLED`. When partitioning support is disabled, you can see any existing partitioned tables and drop them (although doing this is not advised), but you cannot otherwise manipulate them or access their data.


MySQL supports several types of partitioning as well as subpartitioning; see Section 19.2, “Partitioning Types”, and Section 19.2.6, “Subpartitioning”.


Section 19.3.3, “Maintenance of Partitions”, discusses table maintenance commands for use with partitioned tables.

The `PARTITIONS` table in the `INFORMATION_SCHEMA` database provides information about partitions and partitioned tables. See Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”, for more
Overview of Partitioning in MySQL

information; for some examples of queries against this table, see Section 19.2.7, “How MySQL Partitioning Handles NULL”.

For known issues with partitioning in MySQL 5.5, see Section 19.5, “Restrictions and Limitations on Partitioning”.

You may also find the following resources to be useful when working with partitioned tables.

Additional Resources. Other sources of information about user-defined partitioning in MySQL include the following:

• MySQL Partitioning Forum
  This is the official discussion forum for those interested in or experimenting with MySQL Partitioning technology. It features announcements and updates from MySQL developers and others. It is monitored by members of the Partitioning Development and Documentation Teams.

• Mikael Ronström's Blog
  MySQL Partitioning Architect and Lead Developer Mikael Ronström frequently posts articles here concerning his work with MySQL Partitioning and NDB Cluster.

• PlanetMySQL
  A MySQL news site featuring MySQL-related blogs, which should be of interest to anyone using my MySQL. We encourage you to check here for links to blogs kept by those working with MySQL Partitioning, or to have your own blog added to those covered.

MySQL 5.5 binaries are available from https://dev.mysql.com/downloads/mysql/5.5.html. However, for the latest partitioning bugfixes and feature additions, you can obtain the source from our GitHub repository. To enable partitioning, the build must be configured with the -DWITH_PARTITION_STORAGE_ENGINE option. For more information about building MySQL, see Section 2.9, “Installing MySQL from Source”. If you have problems compiling a partitioning-enabled MySQL 5.5 build, check the MySQL Partitioning Forum and ask for assistance there if you do not find a solution to your problem already posted.

19.1 Overview of Partitioning in MySQL

This section provides a conceptual overview of partitioning in MySQL 5.5.

For information on partitioning restrictions and feature limitations, see Section 19.5, “Restrictions and Limitations on Partitioning”.

The SQL standard does not provide much in the way of guidance regarding the physical aspects of data storage. The SQL language itself is intended to work independently of any data structures or media underlying the schemas, tables, rows, or columns with which it works. Nonetheless, most advanced database management systems have evolved some means of determining the physical location to be used for storing specific pieces of data in terms of the file system, hardware or even both. In MySQL, the InnoDB storage engine has long supported the notion of a tablespace, and the MySQL Server, even prior to the introduction of partitioning, could be configured to employ different physical directories for storing different databases (see Section 8.12.3, “Using Symbolic Links”, for an explanation of how this is done).

Partitioning takes this notion a step further, by enabling you to distribute portions of individual tables across a file system according to rules which you can set largely as needed. In effect, different portions of a table are stored as separate tables in different locations. The user-selected rule by which the division of data is accomplished is known as a partitioning function, which in MySQL can be the modulus, simple matching against a set of ranges or value lists, an internal hashing function, or a linear hashing function. The function is selected according to the partitioning type specified by the user, and takes as its parameter the value
Overview of Partitioning in MySQL

of a user-supplied expression. This expression can be a column value, a function acting on one or more column values, or a set of one or more column values, depending on the type of partitioning that is used.

In the case of **RANGE, LIST, and [LINEAR] HASH** partitioning, the value of the partitioning column is passed to the partitioning function, which returns an integer value representing the number of the partition in which that particular record should be stored. This function must be nonconstant and nonrandom. It may not contain any queries, but may use an SQL expression that is valid in MySQL, as long as that expression returns either **NULL** or an integer **intval** such that

\[-\text{MAXVALUE} \leq intval \leq \text{MAXVALUE}\]

(\text{MAXVALUE} is used to represent the least upper bound for the type of integer in question. \text{-MAXVALUE} represents the greatest lower bound.)

For **[LINEAR] KEY, RANGE COLUMNS, and LIST COLUMNS** partitioning, the partitioning expression consists of a list of one or more columns.

For **[LINEAR] KEY** partitioning, the partitioning function is supplied by MySQL.

For more information about permitted partitioning column types and partitioning functions, see Section 19.2, “Partitioning Types”, as well as Section 13.1.17, “CREATE TABLE Statement”, which provides partitioning syntax descriptions and additional examples. For information about restrictions on partitioning functions, see Section 19.5.3, “Partitioning Limitations Relating to Functions”.

This is known as **horizontal partitioning**—that is, different rows of a table may be assigned to different physical partitions. MySQL 5.5 does not support **vertical partitioning**, in which different columns of a table are assigned to different physical partitions. There are no plans at this time to introduce vertical partitioning into MySQL.

For information about determining whether your MySQL Server binary supports user-defined partitioning, see Chapter 19, Partitioning.

For creating partitioned tables, you can use most storage engines that are supported by your MySQL server; the MySQL partitioning engine runs in a separate layer and can interact with any of these. In MySQL 5.5, all partitions of the same partitioned table must use the same storage engine; for example, you cannot use **MyISAM** for one partition and **InnoDB** for another. However, there is nothing preventing you from using different storage engines for different partitioned tables on the same MySQL server or even in the same database.

MySQL partitioning cannot be used with the **MERGE, CSV, or FEDERATED** storage engines.

Partitioning by **KEY** or **LINEAR KEY** is possible with **NDBCLUSTER**, but other types of user-defined partitioning are not supported for tables using this storage engine. In addition, an **NDBCLUSTER** table that employs user-defined partitioning must have an explicit primary key, and any columns referenced in the table’s partitioning expression must be part of the primary key. However, if no columns are listed in the **PARTITION BY KEY** or **PARTITION BY LINEAR KEY** clause of the **CREATE TABLE** or **ALTER TABLE** statement used to create or modify a user-partitioned **NDBCLUSTER** table, then the table is not required to have an explicit primary key. For more information, see Section 18.1.7.1, “Noncompliance with SQL Syntax in NDB Cluster”.

To employ a particular storage engine for a partitioned table, it is necessary only to use the **[STORAGE] ENGINE** option just as you would for a nonpartitioned table. However, you should keep in mind that **[STORAGE] ENGINE** (and other table options) need to be listed before any partitioning options are used in a **CREATE TABLE** statement. This example shows how to create a table that is partitioned by hash into 6 partitions and which uses the **InnoDB** storage engine:

```
CREATE TABLE ti (id INT, amount DECIMAL(7,2), tr_date DATE)
    ENGINE=INNODB
```
PARTITION BY HASH( MONTH(tr_date) )
PARTITIONS 6;

Each **PARTITION** clause can include a **[STORAGE] ENGINE** option, but in MySQL 5.5 this has no effect.

**Important**
Partitioning applies to all data and indexes of a table; you cannot partition only the data and not the indexes, or vice versa, nor can you partition only a portion of the table.

Data and indexes for each partition can be assigned to a specific directory using the **DATA DIRECTORY** and **INDEX DIRECTORY** options for the **PARTITION** clause of the **CREATE TABLE** statement used to create the partitioned table.

The **DATA DIRECTORY** and **INDEX DIRECTORY** options have no effect when defining partitions for tables using the **InnoDB** storage engine.

**DATA DIRECTORY** and **INDEX DIRECTORY** are not supported for individual partitions or subpartitions on Windows. These options are ignored on Windows, except that a warning is generated.

All columns used in the table’s partitioning expression must be part of every unique key that the table may have, including any primary key. This means that a table such as this one, created by the following SQL statement, cannot be partitioned:

```sql
CREATE TABLE tnp (
    id INT NOT NULL AUTO_INCREMENT,
    ref BIGINT NOT NULL,
    name VARCHAR(255),
    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
);
```

Because the keys **pk** and **uk** have no columns in common, there are no columns available for use in a partitioning expression. Possible workarounds in this situation include adding the **name** column to the table’s primary key, adding the **id** column to **uk**, or simply removing the unique key altogether. See Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”, for more information.

In addition, **MAX_ROWS** and **MIN_ROWS** can be used to determine the maximum and minimum numbers of rows, respectively, that can be stored in each partition. The **MAX_ROWS** option can be useful for causing NDB Cluster tables to be created with extra partitions, thus allowing for greater storage of hash indexes. See the documentation for the **DataMemory** data node configuration parameter, as well as Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

Some advantages of partitioning are listed here:

- *Partitioning makes it possible to store more data in one table than can be held on a single disk or file system partition.*

- Data that loses its usefulness can often be easily removed from a partitioned table by dropping the partition (or partitions) containing only that data. Conversely, the process of adding new data can in some cases be greatly facilitated by adding one or more new partitions for storing specifically that data.

- Some queries can be greatly optimized in virtue of the fact that data satisfying a given **WHERE** clause can be stored only on one or more partitions, which automatically excludes any remaining partitions from the search. Because partitions can be altered after a partitioned table has been created, you can reorganize your data to enhance frequent queries that may not have been often used when the partitioning scheme was first set up. This ability to exclude non-matching partitions (and thus any rows they contain) is often referred to as *partition pruning*. For more information, see Section 19.4, “Partition Pruning”.  

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**Overview of Partitioning in MySQL**

2597
19.2 Partitioning Types

This section discusses the types of partitioning which are available in MySQL 5.5. These include the types listed here:

- **RANGE partitioning.** This type of partitioning assigns rows to partitions based on column values falling within a given range. See Section 19.2.1, “RANGE Partitioning”. MySQL 5.5 adds an extension, **RANGE COLUMNS**, to this type. See Section 19.2.3.1, “RANGE COLUMNS partitioning”.

- **LIST partitioning.** Similar to partitioning by **RANGE**, except that the partition is selected based on columns matching one of a set of discrete values. See Section 19.2.2, “LIST Partitioning”. MySQL 5.5 adds an extension, **LIST COLUMNS**., to this type. See Section 19.2.3.2, “LIST COLUMNS partitioning”.

- **HASH partitioning.** With this type of partitioning, a partition is selected based on the value returned by a user-defined expression that operates on column values in rows to be inserted into the table. The function may consist of any expression valid in MySQL that yields a nonnegative integer value. An extension to this type, **LINEAR HASH**, is also available. See Section 19.2.4, “HASH Partitioning”.

- **KEY partitioning.** This type of partitioning is similar to partitioning by **HASH**, except that only one or more columns to be evaluated are supplied, and the MySQL server provides its own hashing function. These columns can contain other than integer values, since the hashing function supplied by MySQL guarantees an integer result regardless of the column data type. An extension to this type, **LINEAR KEY**, is also available. See Section 19.2.5, “KEY Partitioning”.

A very common use of database partitioning is to segregate data by date. Some database systems support explicit date partitioning, which MySQL does not implement in 5.5. However, it is not difficult in MySQL to create partitioning schemes based on **DATE**, **TIME**, or **DATETIME** columns, or based on expressions making use of such columns.

When partitioning by **KEY** or **LINEAR KEY**, you can use a **DATE**, **TIME**, or **DATETIME** column as the partitioning column without performing any modification of the column value. For example, this table creation statement is perfectly valid in MySQL:

```sql
CREATE TABLE members (  
    firstname VARCHAR(25) NOT NULL,  
    lastname VARCHAR(25) NOT NULL,  
    username VARCHAR(16) NOT NULL,  
    email VARCHAR(35),  
    joined DATE NOT NULL  
)  
PARTITION BY KEY(joined)  
PARTITIONS 6;
```

In MySQL 5.5, it is also possible to use a **DATE** or **DATETIME** column as the partitioning column using **RANGE COLUMNS** and **LIST COLUMNS** partitioning.

MySQL’s other partitioning types, however, require a partitioning expression that yields an integer value or **NULL**. If you wish to use date-based partitioning by **RANGE**, **LIST**, **HASH**, or **LINEAR HASH**, you can simply employ a function that operates on a **DATE**, **TIME**, or **DATETIME** column and returns such a value, as shown here:

```sql
CREATE TABLE members (  
    firstname VARCHAR(25) NOT NULL,  
    lastname VARCHAR(25) NOT NULL,  
    username VARCHAR(16) NOT NULL,  
    email VARCHAR(35),  
    joined DATE NOT NULL  
)  
PARTITION BY RANGE( YEAR(joined) ) (  
    2598
```
PARTITION p0 VALUES LESS THAN (1960),
PARTITION p1 VALUES LESS THAN (1970),
PARTITION p2 VALUES LESS THAN (1980),
PARTITION p3 VALUES LESS THAN (1990),
PARTITION p4 VALUES LESS THAN MAXVALUE
);

Additional examples of partitioning using dates may be found in the following sections of this chapter:

- Section 19.2.1, “RANGE Partitioning”
- Section 19.2.4, “HASH Partitioning”
- Section 19.2.4.1, “LINEAR HASH Partitioning”

For more complex examples of date-based partitioning, see the following sections:

- Section 19.4, “Partition Pruning”
- Section 19.2.6, “Subpartitioning”

MySQL partitioning is optimized for use with the `TO_DAYS()`, `YEAR()`, and `TO_SECONDS()` functions. However, you can use other date and time functions that return an integer or `NULL`, such as `WEEKDAY()`, `DAYOFYEAR()`, or `MONTH()`. See Section 12.6, “Date and Time Functions”, for more information about such functions.

It is important to remember—regardless of the type of partitioning that you use—that partitions are always numbered automatically and in sequence when created, starting with 0. When a new row is inserted into a partitioned table, it is these partition numbers that are used in identifying the correct partition. For example, if your table uses 4 partitions, these partitions are numbered 0, 1, 2, and 3. For the RANGE and LIST partitioning types, it is necessary to ensure that there is a partition defined for each partition number. For HASH partitioning, the user-supplied expression must evaluate to an integer value greater than 0. For KEY partitioning, this issue is taken care of automatically by the hashing function which the MySQL server employs internally.

Names of partitions generally follow the rules governing other MySQL identifiers, such as those for tables and databases. However, you should note that partition names are not case-sensitive. For example, the following `CREATE TABLE` statement fails as shown:

```sql
mysql> CREATE TABLE t2 (val INT)
    -> PARTITION BY LIST(val)(
    ->   PARTITION mypart VALUES IN (1,3,5),
    ->   PARTITION MyPart VALUES IN (2,4,6)
    ->);
ERROR 1488 (HY000): Duplicate partition name mypart
```

Failure occurs because MySQL sees no difference between the partition names `mypart` and `MyPart`.

When you specify the number of partitions for the table, this must be expressed as a positive, nonzero integer literal with no leading zeros, and may not be an expression such as `0.8E+01` or `6–2`, even if it evaluates to an integer value. Decimal fractions are not permitted.

In the sections that follow, we do not necessarily provide all possible forms for the syntax that can be used for creating each partition type; this information may be found in Section 13.1.17, “CREATE TABLE Statement”.

### 19.2.1 RANGE Partitioning

A table that is partitioned by range is partitioned in such a way that each partition contains rows for which the partitioning expression value lies within a given range. Ranges should be contiguous but
not overlapping, and are defined using the `VALUES LESS THAN` operator. For the next few examples, suppose that you are creating a table such as the following to hold personnel records for a chain of 20 video stores, numbered 1 through 20:

```sql
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
);
```

**Note**

The `employees` table used here has no primary or unique keys. While the examples work as shown for purposes of the present discussion, you should keep in mind that tables are extremely likely in practice to have primary keys, unique keys, or both, and that allowable choices for partitioning columns depend on the columns used for these keys, if any are present. For a discussion of these issues, see Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”.

This table can be partitioned by range in a number of ways, depending on your needs. One way would be to use the `store_id` column. For instance, you might decide to partition the table 4 ways by adding a `PARTITION BY RANGE` clause as shown here:

```sql
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (store_id) (
    PARTITION p0 VALUES LESS THAN (6),
    PARTITION p1 VALUES LESS THAN (11),
    PARTITION p2 VALUES LESS THAN (16),
    PARTITION p3 VALUES LESS THAN (21)
);
```

In this partitioning scheme, all rows corresponding to employees working at stores 1 through 5 are stored in partition `p0`, to those employed at stores 6 through 10 are stored in partition `p1`, and so on. Note that each partition is defined in order, from lowest to highest. This is a requirement of the `PARTITION BY RANGE` syntax; you can think of it as being analogous to a series of `if ... elseif ...` statements in C or Java in this regard.

It is easy to determine that a new row containing the data `(72, 'Mitchell', 'Wilson', '1998-06-25', NULL, 13)` is inserted into partition `p2`, but what happens when your chain adds a 21st store? Under this scheme, there is no rule that covers a row whose `store_id` is greater than 20, so an error results because the server does not know where to place it. You can keep this from occurring by using a “catchall” `VALUES LESS THAN` clause in the `CREATE TABLE` statement that provides for all values greater than the highest value explicitly named:

```sql
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    store_id INT NOT NULL
);
```

2600
RANGE Partitioning

Note

Another way to avoid an error when no matching value is found is to use the IGNORE keyword as part of the INSERT statement. For an example, see Section 19.2.2, “LIST Partitioning”. Also see Section 13.2.5, “INSERT Statement”, for general information about IGNORE.

MAXVALUE represents an integer value that is always greater than the largest possible integer value (in mathematical language, it serves as a least upper bound). Now, any rows whose store_id column value is greater than or equal to 16 (the highest value defined) are stored in partition p3. At some point in the future—when the number of stores has increased to 25, 30, or more—you can use an ALTER TABLE statement to add new partitions for stores 21-25, 26-30, and so on (see Section 19.3, “Partition Management”, for details of how to do this).

In much the same fashion, you could partition the table based on employee job codes—that is, based on ranges of job_code column values. For example—assuming that two-digit job codes are used for regular (in-store) workers, three-digit codes are used for office and support personnel, and four-digit codes are used for management positions—you could create the partitioned table using the following statement:

```
CREATE TABLE employees ( 
    id INT NOT NULL, 
    fname VARCHAR(30), 
    lname VARCHAR(30), 
    hired DATE NOT NULL DEFAULT '1970-01-01', 
    separated DATE NOT NULL DEFAULT '9999-12-31', 
    job_code INT NOT NULL, 
    store_id INT NOT NULL 
) 
PARTITION BY RANGE (job_code) ( 
    PARTITION p0 VALUES LESS THAN (100), 
    PARTITION p1 VALUES LESS THAN (1000), 
    PARTITION p2 VALUES LESS THAN (10000) 
); 
```

In this instance, all rows relating to in-store workers would be stored in partition p0, those relating to office and support staff in p1, and those relating to managers in partition p2.

It is also possible to use an expression in VALUES LESS THAN clauses. However, MySQL must be able to evaluate the expression's return value as part of a LESS THAN (<) comparison.

Rather than splitting up the table data according to store number, you can use an expression based on one of the two DATE columns instead. For example, let us suppose that you wish to partition based on the year that each employee left the company; that is, the value of YEAR(separated). An example of a CREATE TABLE statement that implements such a partitioning scheme is shown here:

```
CREATE TABLE employees ( 
    id INT NOT NULL, 
    fname VARCHAR(30), 
    lname VARCHAR(30), 
    hired DATE NOT NULL DEFAULT '1970-01-01', 
    separated DATE NOT NULL DEFAULT '9999-12-31', 
    job_code INT NOT NULL, 
    store_id INT NOT NULL 
) 
PARTITION BY RANGE (year(separated)) ( 
    PARTITION p0 VALUES LESS THAN (1970), 
    PARTITION p1 VALUES LESS THAN (1980), 
    PARTITION p2 VALUES LESS THAN (1990) 
); 
```
In this scheme, for all employees who left before 1991, the rows are stored in partition \texttt{p0}; for those who left in the years 1991 through 1995, in \texttt{p1}; for those who left in the years 1996 through 2000, in \texttt{p2}; and for any workers who left after the year 2000, in \texttt{p3}.

It is also possible to partition a table by \texttt{RANGE}, based on the value of a \texttt{TIMESTAMP} column, using the \texttt{UNIX_TIMESTAMP()} function, as shown in this example:

```sql
CREATE TABLE quarterly_report_status (  
    report_id INT NOT NULL,  
    report_status VARCHAR(20) NOT NULL,  
    report_updated TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
) PARTITION BY RANGE ( UNIX_TIMESTAMP(report_updated) ) (  
    PARTITION p0 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-01-01 00:00:00') ),  
    PARTITION p1 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-04-01 00:00:00') ),  
    PARTITION p2 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-07-01 00:00:00') ),  
    PARTITION p3 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-10-01 00:00:00') ),  
    PARTITION p4 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-01-01 00:00:00') ),  
    PARTITION p5 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-04-01 00:00:00') ),  
    PARTITION p6 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-07-01 00:00:00') ),  
    PARTITION p7 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-10-01 00:00:00') ),  
    PARTITION p8 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') ),  
    PARTITION p9 VALUES LESS THAN (MAXVALUE)
);
```

Any other expressions involving \texttt{TIMESTAMP} values are not permitted. (See Bug \#42849.)

Range partitioning is particularly useful when one or more of the following conditions is true:

- You want or need to delete “old” data. If you are using the partitioning scheme shown previously for the \texttt{employees} table, you can simply use \texttt{ALTER TABLE employees DROP PARTITION p0;} to delete all rows relating to employees who stopped working for the firm prior to 1991. (See Section 13.1.7, “\texttt{ALTER TABLE} Statement”, and Section 19.3, “Partition Management”, for more information.) For a table with a great many rows, this can be much more efficient than running a \texttt{DELETE} query such as \texttt{DELETE FROM employees WHERE YEAR(separated) <= 1990;}.

- You want to use a column containing date or time values, or containing values arising from some other series.

- You frequently run queries that depend directly on the column used for partitioning the table. For example, when executing a query such as \texttt{EXPLAIN PARTITIONS SELECT COUNT(*) FROM employees WHERE separated BETWEEN '2000-01-01' AND '2000-12-31' GROUP BY store_id;} MySQL can quickly determine that only partition \texttt{p2} needs to be scanned because the remaining partitions cannot contain any records satisfying the \texttt{WHERE} clause. See Section 19.4, “Partition Pruning”, for more information about how this is accomplished.

A variant on this type of partitioning, \texttt{RANGE COLUMNS} partitioning, was introduced in MySQL 5.5.0. Partitioning by \texttt{RANGE COLUMNS} makes it possible to employ multiple columns for defining partitioning ranges that apply both to placement of rows in partitions and for determining the inclusion or exclusion of specific partitions when performing partition pruning. See Section 19.2.3.1, “\texttt{RANGE COLUMNS}\texttt{ partitioning}”, for more information.
Partitioning schemes based on time intervals. If you wish to implement a partitioning scheme based on ranges or intervals of time in MySQL 5.5, you have two options:

1. Partition the table by **RANGE**, and for the partitioning expression, employ a function operating on a **DATE**, **TIME**, or **DATETIME** column and returning an integer value, as shown here:

```sql
CREATE TABLE members (  
    firstname VARCHAR(25) NOT NULL,  
    lastname VARCHAR(25) NOT NULL,  
    username VARCHAR(16) NOT NULL,  
    email VARCHAR(35),  
    joined DATE NOT NULL  
)  
PARTITION BY RANGE( YEAR(joined) ) (  
    PARTITION p0 VALUES LESS THAN (1960),  
    PARTITION p1 VALUES LESS THAN (1970),  
    PARTITION p2 VALUES LESS THAN (1980),  
    PARTITION p3 VALUES LESS THAN (1990),  
    PARTITION p4 VALUES LESS THAN MAXVALUE  
);
```

Beginning with MySQL 5.5.1, it is also possible to partition a table by **RANGE** based on the value of a **TIMESTAMP** column, using the **UNIX_TIMESTAMP()** function, as shown in this example:

```sql
CREATE TABLE quarterly_report_status (  
    report_id INT NOT NULL,  
    report_status VARCHAR(20) NOT NULL,  
    report_updated TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP  
)  
PARTITION BY RANGE ( UNIX_TIMESTAMP(report_updated) ) (  
    PARTITION p0 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-01-01 00:00:00') ),  
    PARTITION p1 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-04-01 00:00:00') ),  
    PARTITION p2 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-07-01 00:00:00') ),  
    PARTITION p3 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-10-01 00:00:00') ),  
    PARTITION p4 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-01-01 00:00:00') ),  
    PARTITION p5 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-04-01 00:00:00') ),  
    PARTITION p6 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-07-01 00:00:00') ),  
    PARTITION p7 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-10-01 00:00:00') ),  
    PARTITION p8 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') ),  
    PARTITION p9 VALUES LESS THAN (MAXVALUE)  
);
```

Also beginning with MySQL 5.5.1, any other expressions involving **TIMESTAMP** values are not permitted. (See Bug #42849.)

**Note**

It is also possible in MySQL 5.5.1 and later to use **UNIX_TIMESTAMP(timestamp_column)** as a partitioning expression for tables that are partitioned by **LIST**. However, it is usually not practical to do so.

2. Partition the table by **RANGE COLUMNS**, using a **DATE** or **DATETIME** column as the partitioning column. For example, the `members` table could be defined using the `joined` column directly, as shown here:

```sql
CREATE TABLE members (  
    firstname VARCHAR(25) NOT NULL,  
    lastname VARCHAR(25) NOT NULL,  
    username VARCHAR(16) NOT NULL,  
    email VARCHAR(35),  
    joined DATE NOT NULL  
)  
PARTITION BY RANGE COLUMNS(joined) (  
    PARTITION p0 VALUES LESS THAN ('1960-01-01'),  
    PARTITION p1 VALUES LESS THAN ('1970-01-01'),
```

2603
LIST Partitioning

PARTITION p2 VALUES LESS THAN ('1980-01-01'),
PARTITION p3 VALUES LESS THAN ('1990-01-01'),
PARTITION p4 VALUES LESS THAN MAXVALUE
);

Note
The use of partitioning columns employing date or time types other than DATE or DATETIME is not supported with RANGE COLUMNS.

19.2.2 LIST Partitioning

List partitioning in MySQL is similar to range partitioning in many ways. As in partitioning by RANGE, each partition must be explicitly defined. The chief difference between the two types of partitioning is that, in list partitioning, each partition is defined and selected based on the membership of a column value in one of a set of value lists, rather than in one of a set of contiguous ranges of values. This is done by using PARTITION BY LIST(expr) where expr is a column value or an expression based on a column value and returning an integer value, and then defining each partition by means of a VALUES IN (value_list), where value_list is a comma-separated list of integers.

Note
In MySQL 5.5, it is possible to match against only a list of integers (and possibly NULL—see Section 19.2.7, “How MySQL Partitioning Handles NULL”) when partitioning by LIST.

However, beginning with MySQL 5.5.0, other column types may be used in value lists when employing LIST COLUMN partitioning, which is described later in this section.

Unlike the case with partitions defined by range, list partitions do not need to be declared in any particular order. For more detailed syntactical information, see Section 13.1.17, “CREATE TABLE Statement”.

For the examples that follow, we assume that the basic definition of the table to be partitioned is provided by the CREATE TABLE statement shown here:

```
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT,  
store_id INT
);
```

(This is the same table used as a basis for the examples in Section 19.2.1, “RANGE Partitioning”.)

Suppose that there are 20 video stores distributed among 4 franchises as shown in the following table.

<table>
<thead>
<tr>
<th>Region</th>
<th>Store ID Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>3, 5, 6, 9, 17</td>
</tr>
<tr>
<td>East</td>
<td>1, 2, 10, 11, 19, 20</td>
</tr>
<tr>
<td>West</td>
<td>4, 12, 13, 14, 18</td>
</tr>
<tr>
<td>Central</td>
<td>7, 8, 15, 16</td>
</tr>
</tbody>
</table>

To partition this table in such a way that rows for stores belonging to the same region are stored in the same partition, you could use the CREATE TABLE statement shown here:
CREATE TABLE employees (  id INT NOT NULL,  fname VARCHAR(30),  lname VARCHAR(30),  hired DATE NOT NULL DEFAULT '1970-01-01',  separated DATE NOT NULL DEFAULT '9999-12-31',  job_code INT,  store_id INT )  PARTITION BY LIST(store_id) {    PARTITION pNorth VALUES IN (3,5,6,9,17),    PARTITION pEast VALUES IN (1,2,10,11,19,20),    PARTITION pWest VALUES IN (4,12,13,14,18),    PARTITION pCentral VALUES IN (7,8,15,16)  };

This makes it easy to add or drop employee records relating to specific regions to or from the table. For instance, suppose that all stores in the West region are sold to another company. Beginning with MySQL 5.5.0, all rows relating to employees working at stores in that region can be deleted with the query `ALTER TABLE employees TRUNCATE PARTITION pWest`, which can be executed much more efficiently than the equivalent `DELETE` statement `DELETE FROM employees WHERE store_id IN (4,12,13,14,18);`. (Using `ALTER TABLE employees DROP PARTITION pWest` would also delete all of these rows, but would also remove the partition `pWest` from the definition of the table; you would need to use an `ALTER TABLE ... ADD PARTITION` statement to restore the table’s original partitioning scheme.)

As with `RANGE` partitioning, it is possible to combine `LIST` partitioning with partitioning by hash or key to produce a composite partitioning (subpartitioning). See Section 19.2.6, “Subpartitioning”.

Unlike the case with `RANGE` partitioning, there is no “catch-all” such as `MAXVALUE`; all expected values for the partitioning expression should be covered in `PARTITION ... VALUES IN (...)` clauses. An `INSERT` statement containing an unmatched partitioning column value fails with an error, as shown in this example:

```
mysql> CREATE TABLE h2 (  -> c1 INT,  -> c2 INT  -> )  -> PARTITION BY LIST(c1) (  -> PARTITION p0 VALUES IN (1, 4, 7),  -> PARTITION p1 VALUES IN (2, 5, 8)  -> );
Query OK, 0 rows affected (0.11 sec)
mysql> INSERT INTO h2 VALUES (3, 5);
ERROR 1525 (HY000): Table has no partition for value 3
```

When inserting multiple rows using a single `INSERT` statement the behavior depends on whether the table uses a transactional storage engine. For an `InnoDB` table, the statement is considered a single transaction, so the presence of any unmatched values causes the statement to fail completely, and no rows are inserted. For a table using a nontransactional storage engine such as `MyISAM`, any rows coming before the row containing the unmatched value are inserted, but any coming after it are not.

You can cause this type of error to be ignored by using the `IGNORE` keyword. If you do so, rows containing unmatched partitioning column values are not inserted, but any rows with matching values are inserted, and no errors are reported:

```
mysql> TRUNCATE h2;
Query OK, 1 row affected (0.00 sec)
mysql> SELECT * FROM h2;
Empty set (0.00 sec)
```
MySQL 5.5 provides support for `LIST COLUMNS` partitioning. This is a variant of `LIST` partitioning that enables you to use columns of types other than integer types for partitioning columns, as well as to use multiple columns as partitioning keys. For more information, see Section 19.2.3.2, “LIST COLUMNS partitioning”.

19.2.3 COLUMNS Partitioning

The next two sections discuss COLUMNS partitioning, which are variants on RANGE and LIST partitioning that were introduced in MySQL 5.5.0. COLUMNS partitioning enables the use of multiple columns in partitioning keys. All of these columns are taken into account both for the purpose of placing rows in partitions and for the determination of which partitions are to be checked for matching rows in partition pruning.

In addition, both RANGE COLUMNS partitioning and LIST COLUMNS partitioning support the use of non-integer columns for defining value ranges or list members. The permitted data types are shown in the following list:

- All integer types: `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT (INTEGER)`, and `BIGINT`. (This is the same as with partitioning by RANGE and LIST.)
  - Other numeric data types (such as `DECIMAL` or `FLOAT`) are not supported as partitioning columns.
  - `DATE` and `DATETIME`.
  - Columns using other data types relating to dates or times are not supported as partitioning columns.
  - The following string types: `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY`.
  - `TEXT` and `BLOB` columns are not supported as partitioning columns.

The discussions of RANGE COLUMNS and LIST COLUMNS partitioning in the next two sections assume that you are already familiar with partitioning based on ranges and lists as supported in MySQL 5.1 and later; for more information about these, see Section 19.2.1, “RANGE Partitioning”, and Section 19.2.2, “LIST Partitioning”, respectively.

19.2.3.1 RANGE COLUMNS partitioning

Range columns partitioning is similar to range partitioning, but enables you to define partitions using ranges based on multiple column values. In addition, you can define the ranges using columns of types other than integer types.

RANGE COLUMNS partitioning differs significantly from RANGE partitioning in the following ways:

- RANGE COLUMNS does not accept expressions, only names of columns.
• **RANGE COLUMNS** accepts a list of one or more columns.

**RANGE COLUMNS** partitions are based on comparisons between *tuples* (lists of column values) rather than comparisons between scalar values. Placement of rows in **RANGE COLUMNS** partitions is also based on comparisons between tuples; this is discussed further later in this section.

• **RANGE COLUMNS** partitioning columns are not restricted to integer columns; string, DATE and DATETIME columns can also be used as partitioning columns. (See Section 19.2.3, “COLUMNS Partitioning”, for details.)

The basic syntax for creating a table partitioned by **RANGE COLUMNS** is shown here:

```sql
CREATE TABLE table_name
PARTITIONED BY RANGE COLUMNS(column_list) {
    PARTITION partition_name VALUES LESS THAN (value_list)[,]
    PARTITION partition_name VALUES LESS THAN (value_list)][, ...
}

column_list:
    column_name[, column_name][, ...]

value_list:
    value[, value][, ...]
```

Note

Not all **CREATE TABLE** options that can be used when creating partitioned tables are shown here. For complete information, see Section 13.1.17, “CREATE TABLE Statement”.

In the syntax just shown, **column_list** is a list of one or more columns (sometimes called a *partitioning column list*), and **value_list** is a list of values (that is, it is a *partition definition value list*). A **value_list** must be supplied for each partition definition, and each **value_list** must have the same number of values as the **column_list** has columns. Generally speaking, if you use *N* columns in the **COLUMNS** clause, then each **VALUES LESS THAN** clause must also be supplied with a list of *N* values.

The elements in the partitioning column list and in the value list defining each partition must occur in the same order. In addition, each element in the value list must be of the same data type as the corresponding element in the column list. However, the order of the column names in the partitioning column list and the value lists does not have to be the same as the order of the table column definitions in the main part of the **CREATE TABLE** statement. As with table partitioned by **RANGE**, you can use **MAXVALUE** to represent a value such that any legal value inserted into a given column is always less than this value. Here is an example of a **CREATE TABLE** statement that helps to illustrate all of these points:

```sql
mysql> CREATE TABLE rcx (  
    -> a INT,  
    -> b INT,  
    -> c CHAR(3),  
    -> d INT  
    -> )  
    -> PARTITION BY RANGE COLUMNS(a,d,c) {  
    -> PARTITION p0 VALUES LESS THAN (5,10,'ggg'),  
    -> PARTITION p1 VALUES LESS THAN (10,20,'mmm'),  
    -> PARTITION p2 VALUES LESS THAN (15,30,'sss'),  
    -> PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)  
    -> };  
Query OK, 0 rows affected (0.15 sec)
```

Table **rcx** contains the columns **a**, **b**, **c**, **d**. The partitioning column list supplied to the **COLUMNS** clause uses 3 of these columns, in the order **a**, **d**, **c**. Each value list used to define a partition contains 3 values in
the same order; that is, each value list tuple has the form \((\text{INT, INT, CHAR(3)})\), which corresponds to the data types used by columns \(a\), \(d\), and \(c\) (in that order).

Placement of rows into partitions is determined by comparing the tuple from a row to be inserted that matches the column list in the \texttt{COLUMNS} clause with the tuples used in the \texttt{VALUES LESS THAN} clauses to define partitions of the table. Because we are comparing tuples (that is, lists or sets of values) rather than scalar values, the semantics of \texttt{VALUES LESS THAN} as used with \texttt{RANGE COLUMNS} partitions differs somewhat from the case with simple \texttt{RANGE} partitions. In \texttt{RANGE} partitioning, a row generating an expression value that is equal to a limiting value in a \texttt{VALUES LESS THAN} is never placed in the corresponding partition; however, when using \texttt{RANGE COLUMNS} partitioning, it is sometimes possible for a row whose partitioning column list's first element is equal in value to the that of the first element in a \texttt{VALUES LESS THAN} value list to be placed in the corresponding partition.

Consider the \texttt{RANGE} partitioned table created by this statement:

```
cREATE TABLE r1 (  
a INT,  
b INT  
)  
PARTITION BY RANGE (a)  
  (PARTITION p0 VALUES LESS THAN (5),  
    PARTITION p1 VALUES LESS THAN (MAXVALUE));
```

If we insert 3 rows into this table such that the column value for \(a\) is \(5\) for each row, all 3 rows are stored in partition \(p1\) because the \(a\) column value is in each case not less than 5, as we can see by executing the proper query against the \texttt{INFORMATION_SCHEMA.PARTITIONS} table:

```
mysql> INSERT INTO r1 VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0
```

```
mysql> SELECT PARTITION_NAME,TABLE_ROWS  
  -> FROM INFORMATION_SCHEMA.PARTITIONS  
  -> WHERE TABLE_NAME = 'r1';
+----------------+------------+
| PARTITION_NAME | TABLE_ROWS |
+----------------+------------+
| p0             |          0 |
| p1             |          3 |
+----------------+------------+
2 rows in set (0.00 sec)
```

Now consider a similar table \texttt{rc1} that uses \texttt{RANGE COLUMNS} partitioning with both columns \(a\) and \(b\) referenced in the \texttt{COLUMNS} clause, created as shown here:

```
cREATE TABLE rc1 (  
a INT,  
b INT  
)  
PARTITION BY RANGE COLUMNS(a, b)  
  (PARTITION p0 VALUES LESS THAN (5, 12),  
    PARTITION p3 VALUES LESS THAN (MAXVALUE, MAXVALUE));
```

If we insert exactly the same rows into \texttt{rc1} as we just inserted into \texttt{r1}, the distribution of the rows is quite different:

```
mysql> INSERT INTO rc1 VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0
```

```
mysql> SELECT PARTITION_NAME,TABLE_ROWS  
  -> FROM INFORMATION_SCHEMA.PARTITIONS  
  -> WHERE TABLE_NAME = 'rc1';
+----------------+------------+
| PARTITION_NAME | TABLE_ROWS |
+----------------+------------+
| p0             |          0 |
| p1             |          3 |
+----------------+------------+
2 rows in set (0.00 sec)
```
This is because we are comparing rows rather than scalar values. We can compare the row values inserted with the limiting row value from the `VALUES THAN LESS THAN` clause used to define partition `p0` in table `rc1`, like this:

```
mysql> SELECT (5,10) < (5,12), (5,11) < (5,12), (5,12) < (5,12);
```

```
+-----------------+-----------------+-----------------+
| (5,10) < (5,12) | (5,11) < (5,12) | (5,12) < (5,12) |
+-----------------+-----------------+-----------------+
|               1 |               1 |               0 |
+-----------------+-----------------+-----------------+
1 row in set (0.00 sec)
```

The 2 tuples `(5,10)` and `(5,11)` evaluate as less than `(5,12)`, so they are stored in partition `p0`. Since 5 is not less than 5 and 12 is not less than 12, `(5,12)` is considered not less than `(5,12)`, and is stored in partition `p1`.

The `SELECT` statement in the preceding example could also have been written using explicit row constructors, like this:

```
SELECT ROW(5,10) < ROW(5,12), ROW(5,11) < ROW(5,12), ROW(5,12) < ROW(5,12);
```

For more information about the use of row constructors in MySQL, see `Section 13.2.10.5, “Row Subqueries”`.

For a table partitioned by `RANGE COLUMNS` using only a single partitioning column, the storing of rows in partitions is the same as that of an equivalent table that is partitioned by `RANGE`. The following `CREATE TABLE` statement creates a table partitioned by `RANGE COLUMNS` using 1 partitioning column:

```
CREATE TABLE rx (
  a INT,
  b INT
) PARTITION BY RANGE COLUMNS (a) (
  PARTITION p0 VALUES LESS THAN (5),
  PARTITION p1 VALUES LESS THAN (MAXVALUE)
);
```

If we insert the rows `(5,10)`, `(5,11)`, and `(5,12)` into this table, we can see that their placement is the same as it is for the table `rc1` we created and populated earlier:

```
mysql> INSERT INTO rx VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0
```

```
mysql> SELECT PARTITION_NAME,TABLE_ROWS
  -> FROM INFORMATION_SCHEMA.PARTITIONS
  -> WHERE TABLE_NAME = 'rx';
```

```
+--------------+----------------+------------+
| TABLE_SCHEMA | PARTITION_NAME | TABLE_ROWS |
+--------------+----------------+------------+
| p            | p0             |          0 |
| p            | p1             |          3 |
+--------------+----------------+------------+
2 rows in set (0.00 sec)
```

2609
It is also possible to create tables partitioned by `RANGE_COLUMNS` where limiting values for one or more columns are repeated in successive partition definitions. You can do this as long as the tuples of column values used to define the partitions are strictly increasing. For example, each of the following `CREATE TABLE` statements is valid:

```sql
CREATE TABLE rc2 (a INT, b INT)
PARTITION BY RANGE_COLUMNS(a,b) {
    PARTITION p0 VALUES LESS THAN (0,10),
    PARTITION p1 VALUES LESS THAN (10,20),
    PARTITION p2 VALUES LESS THAN (10,30),
    PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE)
};
CREATE TABLE rc3 (a INT, b INT)
PARTITION BY RANGE_COLUMNS(a,b) {
    PARTITION p0 VALUES LESS THAN (0,10),
    PARTITION p1 VALUES LESS THAN (10,20),
    PARTITION p2 VALUES LESS THAN (10,30),
    PARTITION p3 VALUES LESS THAN (10,35),
    PARTITION p4 VALUES LESS THAN (20,40),
    PARTITION p5 VALUES LESS THAN (MAXVALUE,MAXVALUE)
};
CREATE TABLE rc4 (a INT, b INT, c INT)
PARTITION BY RANGE_COLUMNS(a,b,c) {
    PARTITION p0 VALUES LESS THAN (0,25,50),
    PARTITION p1 VALUES LESS THAN (10,20,100),
    PARTITION p2 VALUES LESS THAN (10,30,50)
    PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)
};
```

The following statement also succeeds, even though it might appear at first glance that it would not, since the limiting value of column `b` is 25 for partition `p0` and 20 for partition `p1`, and the limiting value of column `c` is 100 for partition `p1` and 50 for partition `p2`:

```sql
CREATE TABLE rc4 (a INT, b INT, c INT)
PARTITION BY RANGE_COLUMNS(a,b,c) {
    PARTITION p0 VALUES LESS THAN (0,25,50),
    PARTITION p1 VALUES LESS THAN (10,20,100),
    PARTITION p2 VALUES LESS THAN (10,30,50)
    PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)
};
```

When designing tables partitioned by `RANGE_COLUMNS`, you can always test successive partition definitions by comparing the desired tuples using the `mysql` client, like this:

```sql
mysql> SELECT (0,25,50) < (10,20,100), (10,20,100) < (10,30,50);
+-------------------------+---------------------+
| (0,25,50) < (10,20,100) | (10,20,100) < (10,30,50) |
|                       1 |                        1 |
+-------------------------+---------------------+
1 row in set (0.00 sec)
```

If a `CREATE TABLE` statement contains partition definitions that are not in strictly increasing order, it fails with an error, as shown in this example:

```sql
mysql> CREATE TABLE rcf (a INT, b INT, c INT)
```
When you get such an error, you can deduce which partition definitions are invalid by making “less than” comparisons between their column lists. In this case, the problem is with the definition of partition p2 because the tuple used to define it is not less than the tuple used to define partition p3, as shown here:

```
mysql> SELECT (0,25,50) < (20,20,100), (20,20,100) < (10,30,50);
+-------------------------+--------------------------+
| (0,25,50) < (20,20,100) | (20,20,100) < (10,30,50) |
+-------------------------+--------------------------+
|                       1 |                        0 |
+-------------------------+--------------------------+
1 row in set (0.00 sec)
```

It is also possible for MAXVALUE to appear for the same column in more than one VALUES LESS THAN clause when using RANGE COLUMNS. However, the limiting values for individual columns in successive partition definitions should otherwise be increasing, there should be no more than one partition defined where MAXVALUE is used as the upper limit for all column values, and this partition definition should appear last in the list of PARTITION ... VALUES LESS THAN clauses. In addition, you cannot use MAXVALUE as the limiting value for the first column in more than one partition definition.

As stated previously, it is also possible with RANGE COLUMNS partitioning to use non-integer columns as partitioning columns. (See Section 19.2.3, “COLUMNS Partitioning”, for a complete listing of these.) Consider a table named employees (which is not partitioned), created using the following statement:

```
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT NOT NULL,  
store_id INT NOT NULL  
);
```

Using RANGE COLUMNS partitioning, you can create a version of this table that stores each row in one of four partitions based on the employee's last name, like this:

```
CREATE TABLE employees_by_lname (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT NOT NULL,  
store_id INT NOT NULL  
)  
PARTITION BY RANGE COLUMNS (lname) (  
PARTITION p0 VALUES LESS THAN ('g'),  
PARTITION p1 VALUES LESS THAN ('m'),  
PARTITION p2 VALUES LESS THAN ('t'),  
PARTITION p3 VALUES LESS THAN (MAXVALUE)  
);
```

Alternatively, you could cause the employees table as created previously to be partitioned using this scheme by executing the following ALTER TABLE statement:
Column Partitioning

```
ALTER TABLE employees PARTITION BY RANGE COLUMNS (lname) {
    PARTITION p0 VALUES LESS THAN ('g'),
    PARTITION p1 VALUES LESS THAN ('m'),
    PARTITION p2 VALUES LESS THAN ('t'),
    PARTITION p3 VALUES LESS THAN (MAXVALUE);
};
```

Note

Because different character sets and collations have different sort orders, the character sets and collations in use may effect which partition of a table partitioned by `RANGE COLUMNS` a given row is stored in when using string columns as partitioning columns. In addition, changing the character set or collation for a given database, table, or column after such a table is created may cause changes in how rows are distributed. For example, when using a case-sensitive collation, 'and' sorts before 'Andersen', but when using a collation that is case-insensitive, the reverse is true.

For information about how MySQL handles character sets and collations, see Chapter 10, Character Sets, Collations, Unicode.

Similarly, you can cause the `employees` table to be partitioned in such a way that each row is stored in one of several partitions based on the decade in which the corresponding employee was hired using the `ALTER TABLE` statement shown here:

```
ALTER TABLE employees PARTITION BY RANGE COLUMNS (hired) {
    PARTITION p0 VALUES LESS THAN ('1970-01-01'),
    PARTITION p1 VALUES LESS THAN ('1980-01-01'),
    PARTITION p2 VALUES LESS THAN ('1990-01-01'),
    PARTITION p3 VALUES LESS THAN ('2000-01-01'),
    PARTITION p4 VALUES LESS THAN ('2010-01-01'),
    PARTITION p5 VALUES LESS THAN (MAXVALUE);
};
```

See Section 13.1.17, “CREATE TABLE Statement”, for additional information about `PARTITION BY RANGE COLUMNS` syntax.

19.2.3.2 LIST COLUMNS partitioning

MySQL 5.5 provides support for `LIST COLUMNS` partitioning. This is a variant of `LIST` partitioning that enables the use of multiple columns as partition keys, and for columns of data types other than integer types to be used as partitioning columns; you can use string types, `DATE` and `DATETIME` columns. (For more information about permitted data types for `COLUMNS` partitioning columns, see Section 19.2.3, “COLUMNS Partitioning”.)

Suppose that you have a business that has customers in 12 cities which, for sales and marketing purposes, you organize into 4 regions of 3 cities each as shown in the following table:

<table>
<thead>
<tr>
<th>Region</th>
<th>Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oskarshamn, Högby, Mönsterås</td>
</tr>
<tr>
<td>2</td>
<td>Vimmerby, Hultsfred, Västervik</td>
</tr>
<tr>
<td>3</td>
<td>Nässjö, Eksjö, Vetlanda</td>
</tr>
<tr>
<td>4</td>
<td>Uppvidinge, Alvesta, Växjo</td>
</tr>
</tbody>
</table>

With `LIST COLUMNS` partitioning, you can create a table for customer data that assigns a row to any of 4 partitions corresponding to these regions based on the name of the city where a customer resides, as shown here:
CREATE TABLE customers_1 (  
    first_name VARCHAR(25),  
    last_name VARCHAR(25),  
    street_1 VARCHAR(30),  
    street_2 VARCHAR(30),  
    city VARCHAR(15),  
    renewal DATE
)  
PARTITION BY LIST COLUMNS(city) (  
    PARTITION pRegion_1 VALUES IN('Oskarshamn', 'Högsby', 'Mönsterås'),  
    PARTITION pRegion_2 VALUES IN('Vimmerby', 'Hultsfred', 'Västervik'),  
    PARTITION pRegion_3 VALUES IN('Nässjö', 'Eksjö', 'Vetlanda'),  
    PARTITION pRegion_4 VALUES IN('Uppvidinge', 'Alvesta', 'Växjö')
);

As with partitioning by `RANGE COLUMNS`, you do not need to use expressions in the `COLUMNS()` clause to convert column values into integers. (In fact, the use of expressions other than column names is not permitted with `COLUMNS()`.)

It is also possible to use `DATE` and `DATETIME` columns, as shown in the following example that uses the same name and columns as the `customers_1` table shown previously, but employs `LIST COLUMNS` partitioning based on the `renewal` column to store rows in one of 4 partitions depending on the week in February 2010 the customer's account is scheduled to renew:

CREATE TABLE customers_2 (  
    first_name VARCHAR(25),  
    last_name VARCHAR(25),  
    street_1 VARCHAR(30),  
    street_2 VARCHAR(30),  
    city VARCHAR(15),  
    renewal DATE
)  
PARTITION BY LIST COLUMNS(renewal) (  
    PARTITION pWeek_1 VALUES IN('2010-02-01', '2010-02-02', '2010-02-03', '2010-02-04', '2010-02-05', '2010-02-06', '2010-02-07'),  
    PARTITION pWeek_2 VALUES IN('2010-02-08', '2010-02-09', '2010-02-10', '2010-02-11', '2010-02-12', '2010-02-13', '2010-02-14'),  
    PARTITION pWeek_3 VALUES IN('2010-02-15', '2010-02-16', '2010-02-17', '2010-02-18', '2010-02-19', '2010-02-20', '2010-02-21'),  
    PARTITION pWeek_4 VALUES IN('2010-02-22', '2010-02-23', '2010-02-24', '2010-02-25', '2010-02-26', '2010-02-27', '2010-02-28')
);

This works, but becomes cumbersome to define and maintain if the number of dates involved grows very large; in such cases, it is usually more practical to employ `RANGE` or `RANGE COLUMNS` partitioning instead. In this case, since the column we wish to use as the partitioning key is a `DATE` column, we use `RANGE COLUMNS` partitioning, as shown here:

CREATE TABLE customers_3 (  
    first_name VARCHAR(25),  
    last_name VARCHAR(25),  
    street_1 VARCHAR(30),  
    street_2 VARCHAR(30),  
    city VARCHAR(15),  
    renewal DATE
)  
PARTITION BY RANGE COLUMNS(renewal) (  
    PARTITION pWeek_1 VALUES LESS THAN('2010-02-09'),  
    PARTITION pWeek_2 VALUES LESS THAN('2010-02-15'),  
    PARTITION pWeek_3 VALUES LESS THAN('2010-02-22'),  
    PARTITION pWeek_4 VALUES LESS THAN('2010-03-01')
);

See Section 19.2.3.1, “RANGE COLUMNS partitioning”, for more information.
In addition (as with RANGE COLUMNS partitioning), you can use multiple columns in the COLUMNS() clause.

See Section 13.1.17, "CREATE TABLE Statement", for additional information about PARTITION BY LIST COLUMNS() syntax.

19.2.4 HASH Partitioning

Partitioning by HASH is used primarily to ensure an even distribution of data among a predetermined number of partitions. With range or list partitioning, you must specify explicitly into which partition a given column value or set of column values is to be stored; with hash partitioning, MySQL takes care of this for you, and you need only specify a column value or expression based on a column value to be hashed and the number of partitions into which the partitioned table is to be divided.

To partition a table using HASH partitioning, it is necessary to append to the CREATE TABLE statement a PARTITION BY HASH (expr) clause, where expr is an expression that returns an integer. This can simply be the name of a column whose type is one of MySQL's integer types. In addition, you most likely want to follow this with PARTITIONS num, where num is a positive integer representing the number of partitions into which the table is to be divided.

Note

For simplicity, the tables in the examples that follow do not use any keys. You should be aware that, if a table has any unique keys, every column used in the partitioning expression for this table must be part of every unique key, including the primary key. See Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”, for more information.

The following statement creates a table that uses hashing on the store_id column and is divided into 4 partitions:

```sql
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT,  
store_id INT
)  
PARTITION BY HASH(store_id)  
PARTITIONS 4;
```

If you do not include a PARTITIONS clause, the number of partitions defaults to 1.

Using the PARTITIONS keyword without a number following it results in a syntax error.

You can also use an SQL expression that returns an integer for expr. For instance, you might want to partition based on the year in which an employee was hired. This can be done as shown here:

```sql
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT,  
store_id INT
)  
PARTITION BY HASH( YEAR(hired) )  
PARTITIONS 4;
```
**expr** must return a nonconstant, nonrandom integer value (in other words, it should be varying but deterministic), and must not contain any prohibited constructs as described in Section 19.5, “Restrictions and Limitations on Partitioning”. You should also keep in mind that this expression is evaluated each time a row is inserted or updated (or possibly deleted); this means that very complex expressions may give rise to performance issues, particularly when performing operations (such as batch inserts) that affect a great many rows at one time.

The most efficient hashing function is one which operates upon a single table column and whose value increases or decreases consistently with the column value, as this allows for “pruning” on ranges of partitions. That is, the more closely that the expression varies with the value of the column on which it is based, the more efficiently MySQL can use the expression for hash partitioning.

For example, where `date_col` is a column of type `DATE`, then the expression `TO_DAYS(date_col)` is said to vary directly with the value of `date_col`, because for every change in the value of `date_col`, the value of the expression changes in a consistent manner. The variance of the expression `YEAR(date_col)` with respect to `date_col` is not quite as direct as that of `TO_DAYS(date_col)`, because not every possible change in `date_col` produces an equivalent change in `YEAR(date_col)`. Even so, `YEAR(date_col)` is a good candidate for a hashing function, because it varies directly with a portion of `date_col` and there is no possible change in `date_col` that produces a disproportionate change in `YEAR(date_col)`.

By way of contrast, suppose that you have a column named `int_col` whose type is `INT`. Now consider the expression `POW(5-int_col, 3) + 6`. This would be a poor choice for a hashing function because a change in the value of `int_col` is not guaranteed to produce a proportional change in the value of the expression. Changing the value of `int_col` by a given amount can produce widely differing changes in the value of the expression. For example, changing `int_col` from 5 to 6 produces a change of -1 in the value of the expression, but changing the value of `int_col` from 6 to 7 produces a change of -7 in the expression value.

In other words, the more closely the graph of the column value versus the value of the expression follows a straight line as traced by the equation $y = cx$ where $c$ is some nonzero constant, the better the expression is suited to hashing. This has to do with the fact that the more nonlinear an expression is, the more uneven the distribution of data among the partitions it tends to produce.

In theory, pruning is also possible for expressions involving more than one column value, but determining which of such expressions are suitable can be quite difficult and time-consuming. For this reason, the use of hashing expressions involving multiple columns is not particularly recommended.

When `PARTITION BY HASH` is used, MySQL determines which partition of `num` partitions to use based on the modulus of the result of the expression. In other words, for a given expression `expr`, the partition in which the record is stored is partition number $N$, where $N = \text{MOD}(\text{expr}, \text{num})$. Suppose that table `t1` is defined as follows, so that it has 4 partitions:

```sql
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY HASH( YEAR(col3) )
    PARTITIONS 4;
```

If you insert a record into `t1` whose `col3` value is ‘2005-09-15’, then the partition in which it is stored is determined as follows:

```sql
MOD(YEAR('2005-09-01'),4)
- MOD(2005,4)
- 1
```

MySQL 5.5 also supports a variant of `HASH` partitioning known as *linear hashing* which employs a more complex algorithm for determining the placement of new rows inserted into the partitioned table. See Section 19.2.4.1, “LINEAR HASH Partitioning”, for a description of this algorithm.
The user-supplied expression is evaluated each time a record is inserted or updated. It may also—depending on the circumstances—be evaluated when records are deleted.

19.2.4.1 LINEAR HASH Partitioning

MySQL also supports linear hashing, which differs from regular hashing in that linear hashing utilizes a linear powers-of-two algorithm whereas regular hashing employs the modulus of the hashing function's value.

Syntactically, the only difference between linear-hash partitioning and regular hashing is the addition of the `LINEAR` keyword in the `PARTITION BY` clause, as shown here:

```
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(30),  
lname VARCHAR(30),  
hired DATE NOT NULL DEFAULT '1970-01-01',  
separated DATE NOT NULL DEFAULT '9999-12-31',  
job_code INT,  
store_id INT  
)  
PARTITION BY LINEAR HASH(YEAR(hired))  
PARTITIONS 4;
```

Given an expression `expr`, the partition in which the record is stored when linear hashing is used is partition number `N` from among `num` partitions, where `N` is derived according to the following algorithm:

1. Find the next power of 2 greater than `num`. We call this value `V`; it can be calculated as:

   \[ V = \text{POWER}(2, \text{CEILING}(\log_2(num))) \]

   (Suppose that `num` is 13. Then \( \log_2(13) \) is 3.7004397181411. \( \text{CEILING}(3.7004397181411) \) is 4, and \( V = \text{POWER}(2, 4) \), which is 16.)

2. Set `N = F(column_list) \& (V - 1)`.

3. While `N >= num`:
   • Set `V = V / 2`
   • Set `N = N \& (V - 1)`

Suppose that the table `t1`, using linear hash partitioning and having 6 partitions, is created using this statement:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)  
PARTITION BY LINEAR HASH(YEAR(col3))  
PARTITIONS 6;
```

Now assume that you want to insert two records into `t1` having the `col3` column values '2003-04-14' and '1998-10-19'. The partition number for the first of these is determined as follows:

\[
V = \text{POWER}(2, \text{CEILING}(\log_2(6))) = 8 \\
n = \text{YEAR}('2003-04-14') \& (8 - 1) \\
= 2003 \& 7 \\
= 3
\]

(\( 3 > 6 \) is FALSE: record stored in partition #3)

The number of the partition where the second record is stored is calculated as shown here:

\[
V = 8 \\
n = \text{YEAR}('1998-10-19') \& (8 - 1)
\]
KEY Partitioning

The advantage in partitioning by linear hash is that the adding, dropping, merging, and splitting of partitions is made much faster, which can be beneficial when dealing with tables containing extremely large amounts (terabytes) of data. The disadvantage is that data is less likely to be evenly distributed between partitions as compared with the distribution obtained using regular hash partitioning.

19.2.5 KEY Partitioning

Partitioning by key is similar to partitioning by hash, except that where hash partitioning employs a user-defined expression, the hashing function for key partitioning is supplied by the MySQL server. NDB Cluster uses MD5() for this purpose; for tables using other storage engines, the server employs its own internal hashing function which is based on the same algorithm as PASSWORD().

The syntax rules for CREATE TABLE ... PARTITION BY KEY are similar to those for creating a table that is partitioned by hash. The major differences are listed here:

- **KEY** is used rather than **HASH**.
- **KEY** takes only a list of zero or more column names. Any columns used as the partitioning key must comprise part or all of the table's primary key, if the table has one. Where no column name is specified as the partitioning key, the table's primary key is used, if there is one. For example, the following CREATE TABLE statement is valid in MySQL 5.5:

  ```sql
  CREATE TABLE k1 (
    id INT NOT NULL PRIMARY KEY,
    name VARCHAR(20)
  )
  PARTITION BY KEY()
  PARTITIONS 2;
  ```

  If there is no primary key but there is a unique key, then the unique key is used for the partitioning key:

  ```sql
  CREATE TABLE k1 (    
    id INT NOT NULL,
    name VARCHAR(20),
    UNIQUE KEY (id)
  )
  PARTITION BY KEY()
  PARTITIONS 2;
  ```

  However, if the unique key column were not defined as **NOT NULL**, then the previous statement would fail.

  In both of these cases, the partitioning key is the **id** column, even though it is not shown in the output of SHOW CREATE TABLE or in the PARTITION_EXPRESSION column of the INFORMATION_SCHEMA.PARTITIONS table.

  Unlike the case with other partitioning types, columns used for partitioning by **KEY** are not restricted to integer or **NULL** values. For example, the following CREATE TABLE statement is valid:

  ```sql
  CREATE TABLE tm1 (    
  ```
Subpartitioning

The preceding statement would not be valid, were a different partitioning type to be specified. (In this case, simply using `PARTITION BY KEY()` would also be valid and have the same effect as `PARTITION BY KEY(s1)`, since `s1` is the table’s primary key.)

For additional information about this issue, see Section 19.5, “Restrictions and Limitations on Partitioning”.

---

**Note**

Tables using the `NDBCLUSTER` storage engine are implicitly partitioned by `KEY`, again using the table's primary key as the partitioning key. In the event that the NDB Cluster table has no explicit primary key, the “hidden” primary key generated by the `NDBCLUSTER` storage engine for each NDB Cluster table is used as the partitioning key.

If you define an explicit partitioning scheme for an `NDBCLUSTER` table, the table must have an explicit primary key, and any columns used in the partitioning expression must be part of this key. However, if the table uses an “empty” partitioning expression—that is, `PARTITION BY KEY()` with no column references—then no explicit primary key is required.

You can observe this partitioning using the `ndb_desc` utility (with the `-p` option).

---

**Important**

For a key-partitioned table, you cannot execute an `ALTER TABLE DROP PRIMARY KEY`, as doing so generates the error `ERROR 1466 (HY000): Field in list of fields for partition function not found in table`. This is not an issue for NDB Cluster tables which are partitioned by `KEY`; in such cases, the table is reorganized using the “hidden” primary key as the table's new partitioning key. See Chapter 18, MySQL NDB Cluster 7.2.

---

It is also possible to partition a table by linear key. Here is a simple example:

```sql
CREATE TABLE tk (  
  col1 INT NOT NULL,  
  col2 CHAR(5),  
  col3 DATE  
)  
PARTITION BY LINEAR KEY (col1)  
PARTITIONS 3;
```

Using `LINEAR` has the same effect on `KEY` partitioning as it does on `HASH` partitioning, with the partition number being derived using a powers-of-two algorithm rather than modulo arithmetic. See Section 19.2.4.1, “LINEAR HASH Partitioning”, for a description of this algorithm and its implications.

---

**19.2.6 Subpartitioning**

Subpartitioning—also known as *composite partitioning*—is the further division of each partition in a partitioned table. Consider the following `CREATE TABLE` statement:

```sql
CREATE TABLE ts (id INT, purchased DATE)
```
PARTITION BY RANGE( YEAR(purchased) )
SUBPARTITION BY HASH( TO_DAYS(purchased) )
SUBPARTITIONS 2 {
    PARTITION p0 VALUES LESS THAN (1990),
    PARTITION p1 VALUES LESS THAN (2000),
    PARTITION p2 VALUES LESS THAN MAXVALUE
};

Table ts has 3 RANGE partitions. Each of these partitions—p0, p1, and p2—is further divided into 2 subpartitions. In effect, the entire table is divided into 3 * 2 = 6 partitions. However, due to the action of the PARTITION BY RANGE clause, the first 2 of these store only those records with a value less than 1990 in the purchased column.

In MySQL 5.5, it is possible to subpartition tables that are partitioned by RANGE or LIST. Subpartitions may use either HASH or KEY partitioning. This is also known as composite partitioning.

Note

SUBPARTITION BY HASH and SUBPARTITION BY KEY generally follow the same syntax rules as PARTITION BY HASH and PARTITION BY KEY, respectively. An exception to this is that SUBPARTITION BY KEY (unlike PARTITION BY KEY) does not currently support a default column, so the column used for this purpose must be specified, even if the table has an explicit primary key. This is a known issue which we are working to address; see Issues with subpartitions, for more information and an example.

It is also possible to define subpartitions explicitly using SUBPARTITION clauses to specify options for individual subpartitions. For example, a more verbose fashion of creating the same table ts as shown in the previous example would be:

CREATE TABLE ts (id INT, purchased DATE)
PARTITION BY RANGE( YEAR(purchased) )
SUBPARTITION BY HASH( TO_DAYS(purchased) ) {
    PARTITION p0 VALUES LESS THAN (1990) {
        SUBPARTITION s0,
        SUBPARTITION s1
    },
    PARTITION p1 VALUES LESS THAN (2000) {
        SUBPARTITION s2,
        SUBPARTITION s3
    },
    PARTITION p2 VALUES LESS THAN MAXVALUE {
        SUBPARTITION s4,
        SUBPARTITION s5
    }
};

Some syntactical items of note are listed here:

• Each partition must have the same number of subpartitions.

• If you explicitly define any subpartitions using SUBPARTITION on any partition of a partitioned table, you must define them all. In other words, the following statement will fail:

CREATE TABLE ts (id INT, purchased DATE)
PARTITION BY RANGE( YEAR(purchased) )
SUBPARTITION BY HASH( TO_DAYS(purchased) ) {
    PARTITION p0 VALUES LESS THAN (1990) {
        SUBPARTITION s0,
        SUBPARTITION s1
    },

Subpartitioning

This statement would still fail even if it included a **SUBPARTITIONS 2** clause.

- Each **SUBPARTITION** clause must include (at a minimum) a name for the subpartition. Otherwise, you may set any desired option for the subpartition or allow it to assume its default setting for that option.

- Subpartition names must be unique across the entire table. For example, the following `CREATE TABLE` statement is valid in MySQL 5.5:

```sql
CREATE TABLE ts (id INT, purchased DATE)
PARTITION BY RANGE( YEAR(purchased) )
  SUBPARTITION BY HASH( TO_DAYS(purchased) )
    PARTITION p0 VALUES LESS THAN (1990) (SUBPARTITION s0,
    SUBPARTITION s1 ),
    PARTITION p1 VALUES LESS THAN (2000) (SUBPARTITION s2,
    SUBPARTITION s3 ),
    PARTITION p2 VALUES LESS THAN MAXVALUE (SUBPARTITION s4,
    SUBPARTITION s5 )
  );
```

Subpartitions can be used with especially large **MyISAM** tables to distribute data and indexes across many disks. Suppose that you have 6 disks mounted as `/disk0`, `/disk1`, `/disk2`, and so on. Now consider the following example:

```sql
CREATE TABLE ts (id INT, purchased DATE)
  ENGINE = MYISAM
PARTITION BY RANGE( YEAR(purchased) )
  SUBPARTITION BY HASH( TO_DAYS(purchased) )
    PARTITION p0 VALUES LESS THAN (1990) (SUBPARTITION s0
    DATA DIRECTORY = '/disk0/data'
    INDEX DIRECTORY = '/disk0/idx',
    SUBPARTITION s1
    DATA DIRECTORY = '/disk1/data'
    INDEX DIRECTORY = '/disk1/idx'
  ),
    PARTITION p1 VALUES LESS THAN (2000) (SUBPARTITION s2
    DATA DIRECTORY = '/disk2/data'
    INDEX DIRECTORY = '/disk2/idx',
    SUBPARTITION s3
    DATA DIRECTORY = '/disk3/data'
    INDEX DIRECTORY = '/disk3/idx'
  ),
    PARTITION p2 VALUES LESS THAN MAXVALUE (SUBPARTITION s4
    DATA DIRECTORY = '/disk4/data'
    INDEX DIRECTORY = '/disk4/idx',
    SUBPARTITION s5
    DATA DIRECTORY = '/disk5/data'
    INDEX DIRECTORY = '/disk5/idx'
  );
```
In this case, a separate disk is used for the data and for the indexes of each RANGE. Many other variations are possible; another example might be:

```sql
CREATE TABLE ts (id INT, purchased DATE)
  ENGINE = MYISAM
  PARTITION BY RANGE(YEAR(purchased))
  SUBPARTITION BY HASH( TO_DAYS(purchased) ) {
    PARTITION p0 VALUES LESS THAN (1990) {
      SUBPARTITION s0a
        DATA DIRECTORY = '/disk0'
        INDEX DIRECTORY = '/disk1',
      SUBPARTITION s0b
        DATA DIRECTORY = '/disk2'
        INDEX DIRECTORY = '/disk3'
    },
    PARTITION p1 VALUES LESS THAN (2000) {
      SUBPARTITION s1a
        DATA DIRECTORY = '/disk4/data'
        INDEX DIRECTORY = '/disk4/idx',
      SUBPARTITION s1b
        DATA DIRECTORY = '/disk5/data'
        INDEX DIRECTORY = '/disk5/idx'
    },
    PARTITION p2 VALUES LESS THAN MAXVALUE {
      SUBPARTITION s2a,
      SUBPARTITION s2b
    }
  };
```

Here, the storage is as follows:

- Rows with purchased dates from before 1990 take up a vast amount of space, so are split up 4 ways, with a separate disk dedicated to the data and to the indexes for each of the two subpartitions (s0a and s0b) making up partition p0. In other words:
  - The data for subpartition s0a is stored on /disk0.
  - The indexes for subpartition s0a are stored on /disk1.
  - The data for subpartition s0b is stored on /disk2.
  - The indexes for subpartition s0b are stored on /disk3.

- Rows containing dates ranging from 1990 to 1999 (partition p1) do not require as much room as those from before 1990. These are split between 2 disks (/disk4 and /disk5) rather than 4 disks as with the legacy records stored in p0:
  - Data and indexes belonging to p1’s first subpartition (s1a) are stored on /disk4—the data in /disk4/data, and the indexes in /disk4/idx.
  - Data and indexes belonging to p1’s second subpartition (s1b) are stored on /disk5—the data in /disk5/data, and the indexes in /disk5/idx.

- Rows reflecting dates from the year 2000 to the present (partition p2) do not take up as much space as required by either of the two previous ranges. Currently, it is sufficient to store all of these in the default location.

In future, when the number of purchases for the decade beginning with the year 2000 grows to a point where the default location no longer provides sufficient space, the corresponding rows can be moved using an ALTER TABLE ... REORGANIZE PARTITION statement. See Section 19.3, “Partition Management”, for an explanation of how this can be done.
How MySQL Partitioning Handles NULL

The DATA DIRECTORY and INDEX DIRECTORY options are not permitted in partition definitions when the NO_DIR_IN_CREATE server SQL mode is in effect. Beginning with MySQL 5.5.5, these options are also not permitted when defining subpartitions (Bug #42954).

19.2.7 How MySQL Partitioning Handles NULL

Partitioning in MySQL does nothing to disallow NULL as the value of a partitioning expression, whether it is a column value or the value of a user-supplied expression. Even though it is permitted to use NULL as the value of an expression that must otherwise yield an integer, it is important to keep in mind that NULL is not a number. MySQL's partitioning implementation treats NULL as being less than any non-NULL value, just as ORDER BY does.

This means that treatment of NULL varies between partitioning of different types, and may produce behavior which you do not expect if you are not prepared for it. This being the case, we discuss in this section how each MySQL partitioning type handles NULL values when determining the partition in which a row should be stored, and provide examples for each.

Handling of NULL with RANGE partitioning. If you insert a row into a table partitioned by RANGE such that the column value used to determine the partition is NULL, the row is inserted into the lowest partition. Consider these two tables in a database named p, created as follows:

```
mysql> CREATE TABLE t1 (  
-> c1 INT,  
-> c2 VARCHAR(20)  
-> )  
-> PARTITION BY RANGE(c1) (  
-> PARTITION p0 VALUES LESS THAN (0),  
-> PARTITION p1 VALUES LESS THAN (10),  
-> PARTITION p2 VALUES LESS THAN MAXVALUE  
-> );
Query OK, 0 rows affected (0.09 sec)
mysql> CREATE TABLE t2 (  
-> c1 INT,  
-> c2 VARCHAR(20)  
-> )  
-> PARTITION BY RANGE(c1) (  
-> PARTITION p0 VALUES LESS THAN (-5),  
-> PARTITION p1 VALUES LESS THAN (0),  
-> PARTITION p2 VALUES LESS THAN (10),  
-> PARTITION p3 VALUES LESS THAN MAXVALUE  
-> );
Query OK, 0 rows affected (0.09 sec)
```

You can see the partitions created by these two CREATE TABLE statements using the following query against the PARTITIONS table in the INFORMATION_SCHEMA database:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH  
> FROM INFORMATION_SCHEMA.PARTITIONS  
> WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
| t1         | p0             |          0 |              0 |           0 |
| t1         | p1             |          0 |              0 |           0 |
| t1         | p2             |          0 |              0 |           0 |
| t2         | p0             |          0 |              0 |           0 |
| t2         | p1             |          0 |              0 |           0 |
| t2         | p2             |          0 |              0 |           0 |
| t2         | p3             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
7 rows in set (0.00 sec)
```
How MySQL Partitioning Handles NULL

(For more information about this table, see Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”). Now let us populate each of these tables with a single row containing a NULL in the column used as the partitioning key, and verify that the rows were inserted using a pair of SELECT statements:

```
mysql> INSERT INTO t1 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO t2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM t1;
+------+--------+
<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>mothra</td>
</tr>
</tbody>
</table>
+------+--------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
+------+--------+
<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>mothra</td>
</tr>
</tbody>
</table>
+------+--------+
1 row in set (0.00 sec)
```

You can see which partitions are used to store the inserted rows by rerunning the previous query against INFORMATION_SCHEMA.PARTITIONS and inspecting the output:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
> FROM INFORMATION_SCHEMA.PARTITIONS
> WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>PARTITION_NAME</th>
<th>TABLE_ROWS</th>
<th>AVG_ROW_LENGTH</th>
<th>DATA_LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>p0</td>
<td>1</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>t1</td>
<td>p1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>t1</td>
<td>p2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>t2</td>
<td>p0</td>
<td>1</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>t2</td>
<td>p1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>t2</td>
<td>p2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>t2</td>
<td>p3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
+------------+----------------+------------+----------------+-------------+
7 rows in set (0.01 sec)
```

You can also demonstrate that these rows were stored in the lowest partition of each table by dropping these partitions, and then re-running the SELECT statements:

```
mysql> ALTER TABLE t1 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> ALTER TABLE t2 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> SELECT * FROM t1;
Empty set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

(For more information on ALTER TABLE ... DROP PARTITION, see Section 13.1.7, “ALTER TABLE Statement”.)

NULL is also treated in this way for partitioning expressions that use SQL functions. Suppose that we define a table using a CREATE TABLE statement such as this one:
CREATE TABLE tndate (
  id INT,
  dt DATE
)
PARTITION BY RANGE( YEAR(dt) ) (
  PARTITION p0 VALUES LESS THAN (1990),
  PARTITION p1 VALUES LESS THAN (2000),
  PARTITION p2 VALUES LESS THAN MAXVALUE
);

As with other MySQL functions, \texttt{YEAR(NULL)} returns \texttt{NULL}. A row with a \texttt{dt} column value of \texttt{NULL} is treated as though the partitioning expression evaluated to a value less than any other value, and so is inserted into partition \texttt{p0}.

### Handling of NULL with LIST partitioning.

A table that is partitioned by \texttt{LIST} admits \texttt{NULL} values if and only if one of its partitions is defined using that value-list that contains \texttt{NULL}. The converse of this is that a table partitioned by \texttt{LIST} which does not explicitly use \texttt{NULL} in a value list rejects rows resulting in a \texttt{NULL} value for the partitioning expression, as shown in this example:

```sql
mysql> CREATE TABLE ts1 (
  -> c1 INT,
  -> c2 VARCHAR(20)
  -> )
  -> PARTITION BY LIST(c1) (
  ->  PARTITION p0 VALUES IN (0, 3, 6),
  ->  PARTITION p1 VALUES IN (1, 4, 7),
  ->  PARTITION p2 VALUES IN (2, 5, 8)
  -> );
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO ts1 VALUES (9, 'mothra');
ERROR 1504 (HY000): Table has no partition for value 9

mysql> INSERT INTO ts1 VALUES (NULL, 'mothra');
ERROR 1504 (HY000): Table has no partition for value NULL
```

Only rows having a \texttt{c1} value between 0 and 8 inclusive can be inserted into \texttt{ts1}. \texttt{NULL} falls outside this range, just like the number 9. We can create tables \texttt{ts2} and \texttt{ts3} having value lists containing \texttt{NULL}, as shown here:

```sql
mysql> CREATE TABLE ts2 (
  -> c1 INT,
  -> c2 VARCHAR(20)
  -> )
  -> PARTITION BY LIST(c1) (
  ->  PARTITION p0 VALUES IN (0, 3, 6),
  ->  PARTITION p1 VALUES IN (1, 4, 7),
  ->  PARTITION p2 VALUES IN (2, 5, 8),
  ->  PARTITION p3 VALUES IN (NULL)
  -> );
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE ts3 (
  -> c1 INT,
  -> c2 VARCHAR(20)
  -> )
  -> PARTITION BY LIST(c1) (
  ->  PARTITION p0 VALUES IN (0, 3, 6),
  ->  PARTITION p1 VALUES IN (1, 4, 7, NULL),
  ->  PARTITION p2 VALUES IN (2, 5, 8)
  -> );
Query OK, 0 rows affected (0.01 sec)
```

When defining value lists for partitioning, you can (and should) treat \texttt{NULL} just as you would any other value. For example, both \texttt{VALUES IN (NULL)} and \texttt{VALUES IN (1, 4, 7, NULL)} are valid, as are
VALUES IN (1, NULL, 4, 7), VALUES IN (NULL, 1, 4, 7), and so on. You can insert a row having NULL for column c1 into each of the tables ts2 and ts3:

```sql
mysql> INSERT INTO ts2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO ts3 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)
```

By issuing the appropriate query against INFORMATION_SCHEMA.PARTITIONS, you can determine which partitions were used to store the rows just inserted (we assume, as in the previous examples, that the partitioned tables were created in the p database):

```sql
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
   > FROM INFORMATION_SCHEMA.PARTITIONS
   > WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 'ts_';
```

As shown earlier in this section, you can also verify which partitions were used for storing the rows by deleting these partitions and then performing a SELECT.

Handling of NULL with HASH and KEY partitioning. NULL is handled somewhat differently for tables partitioned by HASH or KEY. In these cases, any partition expression that yields a NULL value is treated as though its return value were zero. We can verify this behavior by examining the effects on the file system of creating a table partitioned by HASH and populating it with a record containing appropriate values. Suppose that you have a table th (also in the p database) created using the following statement:

```sql
mysql> CREATE TABLE th (c1 INT, c2 VARCHAR(20) PARTITION BY HASH(c1)
   > PARTITIONS 2;
Query OK, 0 rows affected (0.00 sec)
```

The partitions belonging to this table can be viewed using the query shown here:

```sql
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
   > FROM INFORMATION_SCHEMA.PARTITIONS
   > WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME = 'th';
```

TABLE_ROWS for each partition is 0. Now insert two rows into th whose c1 column values are NULL and 0, and verify that these rows were inserted, as shown here:

```sql
mysql> INSERT INTO th VALUES (NULL, 'mothra'), (0, 'gigan');
```

2625
Recall that for any integer \( N \), the value of \( \text{NULL MOD } N \) is always \( \text{NULL} \). For tables that are partitioned by \( \text{HASH} \) or \( \text{KEY} \), this result is treated for determining the correct partition as \( 0 \). Checking the \text{INFORMATION_SCHEMA.PARTITIONS} table once again, we can see that both rows were inserted into partition \( p0 \):

If you repeat this example using \( \text{PARTITION BY KEY} \) in place of \( \text{PARTITION BY HASH} \) in the definition of the table, you can verify easily that \( \text{NULL} \) is also treated like \( 0 \) for this type of partitioning.

### 19.3 Partition Management

MySQL 5.5 provides a number of ways to modify partitioned tables. It is possible to add, drop, redefine, merge, or split existing partitions. All of these actions can be carried out using the partitioning extensions to the \text{ALTER TABLE} statement. There are also ways to obtain information about partitioned tables and partitions. We discuss these topics in the sections that follow.

- For information about partition management in tables partitioned by \( \text{RANGE} \) or \( \text{LIST} \), see Section 19.3.1, “Management of RANGE and LIST Partitions”.
- For a discussion of managing \( \text{HASH} \) and \( \text{KEY} \) partitions, see Section 19.3.2, “Management of HASH and KEY Partitions”.
- See Section 19.3.4, “Obtaining Information About Partitions”, for a discussion of mechanisms provided in MySQL 5.5 for obtaining information about partitioned tables and partitions.
- For a discussion of performing maintenance operations on partitions, see Section 19.3.3, “Maintenance of Partitions”.

**Note**

In MySQL 5.5, all partitions of a partitioned table must have the same number of subpartitions, and it is not possible to change the subpartitioning once the table has been created.

To change a table’s partitioning scheme, it is necessary only to use the \text{ALTER TABLE} statement with a \text{partition_options} clause. This clause has the same syntax as that as used with \text{CREATE TABLE} for creating a partitioned table, and always begins with the keywords \text{PARTITION BY}. Suppose that you have a table partitioned by range using the following \text{CREATE TABLE} statement:
19.3. Management of RANGE and LIST Partitions

Adding and dropping of range and list partitions are handled in a similar fashion, so we discuss the management of both sorts of partitioning in this section. For information about working with tables that are partitioned by hash or key, see Section 19.3.2, “Management of HASH and KEY Partitions”.

Dropping a partition from a table that is partitioned by either RANGE or by LIST can be accomplished using the ALTER TABLE statement with the DROP PARTITION option. Suppose that you have created a table that is partitioned by range and then populated with 10 records using the following CREATE TABLE and INSERT statements:

```sql
mysql> CREATE TABLE tr (id INT, name VARCHAR(50), purchased DATE)
   -> PARTITION BY RANGE( YEAR(purchased) ) {
   -> PARTITION p0 VALUES LESS THAN (1990),
   -> PARTITION p1 VALUES LESS THAN (1995),
   -> PARTITION p2 VALUES LESS THAN (2000),
   -> PARTITION p3 VALUES LESS THAN (2005),
   -> PARTITION p4 VALUES LESS THAN (2010),
   -> PARTITION p5 VALUES LESS THAN (2015)
   -> };
Query OK, 0 rows affected (0.28 sec)
```

```sql
mysql> INSERT INTO tr VALUES
   -> (1, 'desk organiser', '2003-10-15'),
   -> (2, 'alarm clock', '1997-11-05'),
   -> (3, 'chair', '2009-03-10'),
   -> (4, 'bookcase', '1989-01-10'),
   -> (5, 'exercise bike', '2014-05-09'),
   -> (6, 'sofa', '1987-06-05'),
```

At this point, you have a table that is partitioned by range and populated with 10 records. To drop a partition from this table, you can use the ALTER TABLE statement with the DROP PARTITION option, like this:

```sql
mysql> ALTER TABLE tr DROP PARTITION p3;
Query OK, 0 rows affected (0.03 sec)
```

For example, if you wish to drop all partitions except for the first two partitions, you can use the following statement:

```sql
mysql> ALTER TABLE tr DROP PARTITION p0, p2, p3, p4, p5;
Query OK, 0 rows affected (0.03 sec)
```

This will leave you with a table that is partitioned by range and has only two partitions.

Beginning with MySQL 5.5.0, it is possible to delete all rows from one or more selected partitions using ALTER TABLE ... TRUNCATE PARTITION.
You can see which items should have been inserted into partition `p2` as shown here:

```sql
mysql> SELECT * FROM tr
    -> WHERE purchased BETWEEN '1995-01-01' AND '1999-12-31';
```

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
<th>purchased</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>alarm clock</td>
<td>1997-11-05</td>
</tr>
<tr>
<td>10</td>
<td>lava lamp</td>
<td>1998-12-25</td>
</tr>
</tbody>
</table>

2 rows in set (0.00 sec)

To drop the partition named `p2`, execute the following command:

```sql
mysql> ALTER TABLE tr DROP PARTITION p2;
```

Query OK, 0 rows affected (0.03 sec)

**Note**

The `NDBCLUSTER` storage engine does not support `ALTER TABLE ... DROP PARTITION`. It does, however, support the other partitioning-related extensions to `ALTER TABLE` that are described in this chapter.

It is very important to remember that, *when you drop a partition, you also delete all the data that was stored in that partition*. You can see that this is the case by re-running the previous `SELECT` query:

```sql
mysql> SELECT * FROM tr
    -> WHERE purchased BETWEEN '1995-01-01' AND '1999-12-31';
```

Empty set (0.00 sec)

Because of this, you must have the `DROP` privilege for a table before you can execute `ALTER TABLE ... DROP PARTITION` on that table.

If you wish to drop all data from all partitions while preserving the table definition and its partitioning scheme, use the `TRUNCATE TABLE` statement. (See [Section 13.1.33, “TRUNCATE TABLE Statement”](#).)

If you intend to change the partitioning of a table *without* losing data, use `ALTER TABLE ... REORGANIZE PARTITION` instead. See below or in [Section 13.1.7, “ALTER TABLE Statement”](#), for information about `REORGANIZE PARTITION`.

If you now execute a `SHOW CREATE TABLE` statement, you can see how the partitioning makeup of the table has been changed:

```sql
mysql> SHOW CREATE TABLE tr;
```

```
CREATE TABLE `tr` (  `id` int(11) DEFAULT NULL,  `name` varchar(50) DEFAULT NULL,  `purchased` date DEFAULT NULL) ENGINE=InnoDB DEFAULT CHARSET=latin1
        PARTITION BY RANGE ( YEAR(purchased))
```
When you insert new rows into the changed table with `purchased` column values between '1995-01-01' and '2004-12-31' inclusive, those rows will be stored in partition p3. You can verify this as follows:

```sql
mysql> INSERT INTO tr VALUES (11, 'pencil holder', '1995-07-12');
Query OK, 1 row affected (0.00 sec)
mysql> SELECT * FROM tr WHERE purchased BETWEEN '1995-01-01' AND '2004-12-31';
+------+----------------+------------+
<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
<th>purchased</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>desk organiser</td>
<td>2003-10-15</td>
</tr>
<tr>
<td>11</td>
<td>pencil holder</td>
<td>1995-07-12</td>
</tr>
</tbody>
</table>
+------+----------------+------------+
2 rows in set (0.00 sec)
```

Dropping LIST partitions uses exactly the same `ALTER TABLE ... DROP PARTITION` syntax as used for dropping RANGE partitions. However, there is one important difference in the effect this has on your use of the table afterward: You can no longer insert into the table any rows having any of the values that were included in the value list defining the deleted partition. (See Section 19.2.2, “LIST Partitioning”, for an example.)

To add a new range or list partition to a previously partitioned table, use the `ALTER TABLE ... ADD PARTITION` statement. For tables which are partitioned by RANGE, this can be used to add a new range to the end of the list of existing partitions. Suppose that you have a partitioned table containing membership data for your organization, which is defined as follows:

```sql
CREATE TABLE members (
    id INT,
    fname VARCHAR(25),
    lname VARCHAR(25),
    dob DATE
) PARTITION BY RANGE( YEAR(dob) ) (
    PARTITION p0 VALUES LESS THAN (1980),
    PARTITION p1 VALUES LESS THAN (1990),
    PARTITION p2 VALUES LESS THAN (2000)
);
```

Suppose further that the minimum age for members is 16. As the calendar approaches the end of 2015, you realize that you will soon be admitting members who were born in 2000 (and later). You can modify the `members` table to accommodate new members born in the years 2000 to 2010 as shown here:

```sql
ALTER TABLE members ADD PARTITION (PARTITION p3 VALUES LESS THAN (2010));
```

With tables that are partitioned by range, you can use `ADD PARTITION` to add new partitions to the high end of the partitions list only. Trying to add a new partition in this manner between or before existing partitions results in an error as shown here:

```sql
mysql> ALTER TABLE members
```

2629
Management of RANGE and LIST Partitions

```sql
> ADD PARTITION (
   > PARTITION n VALUES LESS THAN (1970));
ERROR 1463 (HY000): VALUES LESS THAN value must be strictly increasing for each partition
```

You can work around this problem by reorganizing the first partition into two new ones that split the range between them, like this:

```sql
ALTER TABLE members
REORGANIZE PARTITION p0 INTO (  
   PARTITION n0 VALUES LESS THAN (1970),  
   PARTITION n1 VALUES LESS THAN (1980)
);
```

Using `SHOW CREATE TABLE` you can see that the `ALTER TABLE` statement has had the desired effect:

```sql
mysql> SHOW CREATE TABLE members\G
*************************** 1. row ***************************
Table: members
Create Table: CREATE TABLE `members` (
   `id` int(11) DEFAULT NULL,
   `fname` varchar(25) DEFAULT NULL,
   `lname` varchar(25) DEFAULT NULL,
   `dob` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY RANGE ( YEAR(dob))
   (PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,
   PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,
   PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,
   PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,
   PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) */
1 row in set (0.00 sec)
```

See also Section 13.1.7.1, “ALTER TABLE Partition Operations”.

You can also use `ALTER TABLE ... ADD PARTITION` to add new partitions to a table that is partitioned by `LIST`. Suppose a table `tt` is defined using the following `CREATE TABLE` statement:

```sql
CREATE TABLE tt (  
   id INT,
   data INT
)  
PARTITION BY LIST(data) {  
   PARTITION p0 VALUES IN (5, 10, 15),  
   PARTITION p1 VALUES IN (6, 12, 18)
};
```

You can add a new partition in which to store rows having the `data` column values 7, 14, and 21 as shown:

```sql
ALTER TABLE tt ADD PARTITION (PARTITION p2 VALUES IN (7, 14, 21));
```

Keep in mind that you cannot add a new `LIST` partition encompassing any values that are already included in the value list of an existing partition. If you attempt to do so, an error will result:

```sql
mysql> ALTER TABLE tt ADD PARTITION (PARTITION np VALUES IN (4, 8, 12));
ERROR 1465 (HY000): Multiple definition of same constant » in list partitioning
```

Because any rows with the `data` column value 12 have already been assigned to partition `p1`, you cannot create a new partition on table `tt` that includes 12 in its value list. To accomplish this, you could drop `p1`, and add `np` and then a new `p1` with a modified definition. However, as discussed earlier, this would result in the loss of all data stored in `p1`—and it is often the case that this is not what you really want to do.
Another solution might appear to be to make a copy of the table with the new partitioning and to copy the data into it using `CREATE TABLE ... SELECT ...`, then drop the old table and rename the new one, but this could be very time-consuming when dealing with a large amounts of data. This also might not be feasible in situations where high availability is a requirement.

You can add multiple partitions in a single `ALTER TABLE ... ADD PARTITION` statement as shown here:

```sql
CREATE TABLE employees (  
id INT NOT NULL,  
fname VARCHAR(50) NOT NULL,  
lname VARCHAR(50) NOT NULL,  
hired DATE NOT NULL  )  
PARTITION BY RANGE ( YEAR(hired) ) (  
PARTITION p1 VALUES LESS THAN (1991),  
PARTITION p2 VALUES LESS THAN (1996),  
PARTITION p3 VALUES LESS THAN (2001),  
PARTITION p4 VALUES LESS THAN (2005)  );
```

```sql
ALTER TABLE employees ADD PARTITION (  
PARTITION p5 VALUES LESS THAN (2010),  
PARTITION p6 VALUES LESS THAN MAXVALUE  );
```

Fortunately, MySQL's partitioning implementation provides ways to redefine partitions without losing data. Let us look first at a couple of simple examples involving `RANGE` partitioning. Recall the `members` table which is now defined as shown here:

```sql
mysql> SHOW CREATE TABLE members\G
```

```
*************************** 1. row ***************************
Table: members
Create Table: CREATE TABLE `members` (  
`id` int(11) DEFAULT NULL,  
`fname` varchar(25) DEFAULT NULL,  
`lname` varchar(25) DEFAULT NULL,  
`dob` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1  
/*!50100 PARTITION BY RANGE ( YEAR(dob))  
(PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,  
PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,  
PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,  
PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,  
PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) */
```

Suppose that you would like to move all rows representing members born before 1960 into a separate partition. As we have already seen, this cannot be done using `ALTER TABLE ... ADD PARTITION`. However, you can use another partition-related extension to `ALTER TABLE` to accomplish this:

```sql
ALTER TABLE members REORGANIZE PARTITION n0 INTO (  
PARTITION s0 VALUES LESS THAN (1960),  
PARTITION s1 VALUES LESS THAN (1970)  );
```

In effect, this command splits partition `p0` into two new partitions `s0` and `s1`. It also moves the data that was stored in `p0` into the new partitions according to the rules embodied in the two `PARTITION ... VALUES ...` clauses, so that `s0` contains only those records for which `YEAR(dob)` is less than 1960 and `s1` contains those rows in which `YEAR(dob)` is greater than or equal to 1960 but less than 1970.

A `REORGANIZE PARTITION` clause may also be used for merging adjacent partitions. You can reverse the effect of the previous statement on the `members` table as shown here:
ALTER TABLE members REORGANIZE PARTITION s0,s1 INTO (
  PARTITION p0 VALUES LESS THAN (1970)
);

No data is lost in splitting or merging partitions using `REORGANIZE PARTITION`. In executing the above statement, MySQL moves all of the records that were stored in partitions `s0` and `s1` into partition `p0`.

The general syntax for `REORGANIZE PARTITION` is shown here:

```
ALTER TABLE tbl_name 
REORGANIZE PARTITION partition_list
  INTO (partition_definitions);
```

Here, `tbl_name` is the name of the partitioned table, and `partition_list` is a comma-separated list of names of one or more existing partitions to be changed. `partition_definitions` is a comma-separated list of new partition definitions, which follow the same rules as for the `partition_definitions` list used in `CREATE TABLE`. You are not limited to merging several partitions into one, or to splitting one partition into many, when using `REORGANIZE PARTITION`. For example, you can reorganize all four partitions of the `members` table into two, like this:

```
ALTER TABLE members REORGANIZE PARTITION p0,p1,p2,p3 INTO {
  PARTITION m0 VALUES LESS THAN (1980),
  PARTITION m1 VALUES LESS THAN (2000)
};
```

You can also use `REORGANIZE PARTITION` with tables that are partitioned by `LIST`. Let us return to the problem of adding a new partition to the list-partitioned `tt` table and failing because the new partition had a value that was already present in the value-list of one of the existing partitions. We can handle this by adding a partition that contains only nonconflicting values, and then reorganizing the new partition and the existing one so that the value which was stored in the existing one is now moved to the new one:

```
ALTER TABLE tt ADD PARTITION (PARTITION np VALUES IN (4, 8));
ALTER TABLE tt REORGANIZE PARTITION p1,np INTO {
  PARTITION p1 VALUES IN (6, 18),
  PARTITION np VALUES in (4, 8, 12)
};
```

Here are some key points to keep in mind when using `ALTER TABLE ... REORGANIZE PARTITION` to repartition tables that are partitioned by `RANGE` or `LIST`:

- The `PARTITION` options used to determine the new partitioning scheme are subject to the same rules as those used with a `CREATE TABLE` statement.

  A new `RANGE` partitioning scheme cannot have any overlapping ranges; a new `LIST` partitioning scheme cannot have any overlapping sets of values.

- The combination of partitions in the `partition_definitions` list should account for the same range or set of values overall as the combined partitions named in the `partition_list`.

  For example, partitions `p1` and `p2` together cover the years 1980 through 1999 in the `members` table used as an example in this section. Any reorganization of these two partitions should cover the same range of years overall.

- For tables partitioned by `RANGE`, you can reorganize only adjacent partitions; you cannot skip range partitions.

  For instance, you could not reorganize the example `members` table using a statement beginning with `ALTER TABLE members REORGANIZE PARTITION p0,p2 INTO ...` because `p0` covers the years prior to 1970 and `p2` the years from 1990 through 1999 inclusive, so these are not adjacent partitions. (You cannot skip partition `p1` in this case.)
Management of HASH and KEY Partitions

- You cannot use `REORGANIZE PARTITION` to change the type of partitioning used by the table (for example, you cannot change `RANGE` partitions to `HASH` partitions or the reverse). You also cannot use this statement to change the partitioning expression or column. To accomplish either of these tasks without dropping and re-creating the table, you can use `ALTER TABLE ... PARTITION BY ...`, as shown here:

```
ALTER TABLE members
  PARTITION BY HASH( YEAR(dob) )
PARTITIONS 8;
```

### 19.3.2 Management of HASH and KEY Partitions

Tables which are partitioned by hash or by key are very similar to one another with regard to making changes in a partitioning setup, and both differ in a number of ways from tables which have been partitioned by range or list. For that reason, this section addresses the modification of tables partitioned by hash or by key only. For a discussion of adding and dropping of partitions of tables that are partitioned by range or list, see Section 19.3.1, “Management of RANGE and LIST Partitions”.

You cannot drop partitions from tables that are partitioned by `HASH` or `KEY` in the same way that you can from tables that are partitioned by `RANGE` or `LIST`. However, you can merge `HASH` or `KEY` partitions using the `ALTER TABLE ... COALESCE PARTITION` statement. Suppose that you have a table containing data about clients, which is divided into twelve partitions. The `clients` table is defined as shown here:

```
CREATE TABLE clients (
  id INT,
  fname VARCHAR(30),
  lname VARCHAR(30),
  signed DATE
)
PARTITION BY HASH( MONTH(signed) )
PARTITIONS 12;
```

To reduce the number of partitions from twelve to eight, execute the following `ALTER TABLE` command:

```
mysql> ALTER TABLE clients COALESCE PARTITION 4;
Query OK, 0 rows affected (0.02 sec)
```

COALESCE works equally well with tables that are partitioned by `HASH`, `KEY`, `LINEAR HASH`, or `LINEAR KEY`. Here is an example similar to the previous one, differing only in that the table is partitioned by `LINEAR KEY`:

```
mysql> CREATE TABLE clients_lk (
  id INT,
  fname VARCHAR(30),
  lname VARCHAR(30),
  signed DATE
)
PARTITION BY LINEAR KEY(signed)
PARTITIONS 12;
```

To reduce the number of partitions from twelve to eight, execute the following `ALTER TABLE` command:

```
mysql> ALTER TABLE clients_lk COALESCE PARTITION 4;
Query OK, 0 rows affected (0.06 sec)
```

The number following `COALESCE PARTITION` is the number of partitions to merge into the remainder—in other words, it is the number of partitions to remove from the table.

If you attempt to remove more partitions than the table has, the result is an error like the one shown:

```
mysql> ALTER TABLE clients COALESCE PARTITION 18;
ERROR 1478 (HY000): Cannot remove all partitions, use DROP TABLE instead
```
To increase the number of partitions for the `clients` table from 12 to 18, use `ALTER TABLE ... ADD PARTITION` as shown here:

```sql
ALTER TABLE clients ADD PARTITION PARTITIONS 6;
```

### 19.3.3 Maintenance of Partitions

A number of table and partition maintenance tasks can be carried out using SQL statements intended for such purposes on partitioned tables in MySQL 5.5.

Table maintenance of partitioned tables can be accomplished using the statements `CHECK TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, and `REPAIR TABLE`, which are supported for partitioned tables.

You can use a number of extensions to `ALTER TABLE` for performing operations of this type on one or more partitions directly, as described in the following list:

- **Rebuilding partitions.** Rebuilds the partition; this has the same effect as dropping all records stored in the partition, then reinserting them. This can be useful for purposes of defragmentation.
  
  Example:
  ```sql
  ALTER TABLE t1 REBUILD PARTITION p0, p1;
  ```

- **Optimizing partitions.** If you have deleted a large number of rows from a partition or if you have made many changes to a partitioned table with variable-length rows (that is, having `VARCHAR`, `BLOB`, or `TEXT` columns), you can use `ALTER TABLE ... OPTIMIZE PARTITION` to reclaim any unused space and to defragment the partition data file.
  
  Example:
  ```sql
  ALTER TABLE t1 OPTIMIZE PARTITION p0, p1;
  ```

  Using `OPTIMIZE PARTITION` on a given partition is equivalent to running `CHECK PARTITION`, `ANALYZE PARTITION`, and `REPAIR PARTITION` on that partition.

  Some MySQL storage engines, including `InnoDB`, do not support per-partition optimization; in these cases, `ALTER TABLE ... OPTIMIZE PARTITION` rebuilds the entire table. In MySQL 5.5.30 and later, running this statement on such a table causes the entire table to be rebuilt and analyzed, and an appropriate warning to be issued. (Bug #11751825, Bug #42822) Use `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION` instead, to avoid this issue.

- **Analyzing partitions.** This reads and stores the key distributions for partitions.
  
  Example:
  ```sql
  ALTER TABLE t1 ANALYZE PARTITION p3;
  ```

- **Repairing partitions.** This repairs corrupted partitions.
  
  Example:
  ```sql
  ALTER TABLE t1 REPAIR PARTITION p0,p1;
  ```

- **Checking partitions.** You can check partitions for errors in much the same way that you can use `CHECK TABLE` with nonpartitioned tables.
  
  Example:
  ```sql
  ALTER TABLE trb3 CHECK PARTITION p1;
  ```
Obtaining Information About Partitions

This command will tell you if the data or indexes in partition p1 of table t1 are corrupted. If this is the case, use \texttt{ALTER TABLE ... REPAIR PARTITION} to repair the partition.

Each of the statements in the list just shown also supports the keyword \texttt{ALL} in place of the list of partition names. Using \texttt{ALL} causes the statement to act on all partitions in the table.

The use of \texttt{mysqlcheck} and \texttt{myisamchk} is not supported with partitioned tables.

Beginning with MySQL 5.5.0, you can also truncate partitions using \texttt{ALTER TABLE ... TRUNCATE PARTITION}. This statement can be used to delete all rows from one or more partitions in much the same way that \texttt{TRUNCATE TABLE} deletes all rows from a table.

\texttt{ALTER TABLE ... TRUNCATE PARTITION ALL} truncates all partitions in the table.

\texttt{ANALYZE, CHECK, OPTIMIZE, REBUILD, REPAIR, and TRUNCATE} operations are not supported for subpartitions.

19.3.4 Obtaining Information About Partitions

This section discusses obtaining information about existing partitions, which can be done in a number of ways. Methods of obtaining such information include the following:

- Using the \texttt{SHOW CREATE TABLE} statement to view the partitioning clauses used in creating a partitioned table.
- Using the \texttt{SHOW TABLE STATUS} statement to determine whether a table is partitioned.
- Querying the \texttt{INFORMATION_SCHEMA.PARTITIONS} table.
- Using the statement \texttt{EXPLAIN PARTITIONS SELECT} to see which partitions are used by a given \texttt{SELECT}.

As discussed elsewhere in this chapter, \texttt{SHOW CREATE TABLE} includes in its output the \texttt{PARTITION BY} clause used to create a partitioned table. For example:

```
mysql> SHOW CREATE TABLE trb3;
+-----------------------------------+
| Table: trb3                       |
| Create Table: CREATE TABLE 'trb3' ( |
|     'id' int(11) default NULL,     |
|     'name' varchar(50) default NULL,|
|     'purchased' date default NULL  |
| ) ENGINE=MyISAM DEFAULT CHARSET=latin1 |
| PARTITION BY RANGE (YEAR(purchased)) |
|     PARTITION p0 VALUES LESS THAN (1990) ENGINE = MyISAM, |
|     PARTITION p1 VALUES LESS THAN (1995) ENGINE = MyISAM, |
|     PARTITION p2 VALUES LESS THAN (2000) ENGINE = MyISAM, |
|     PARTITION p3 VALUES LESS THAN (2005) ENGINE = MyISAM |
| )                                  |
+-----------------------------------+
1 row in set (0.00 sec)
```

The output from \texttt{SHOW TABLE STATUS} for partitioned tables is the same as that for nonpartitioned tables, except that the \texttt{Create_options} column contains the string \texttt{partitioned}. The \texttt{Engine} column contains the name of the storage engine used by all partitions of the table. (See Section 13.7.5.37, “SHOW TABLE STATUS Statement”, for more information about this statement.)

You can also obtain information about partitions from \texttt{INFORMATION_SCHEMA}, which contains a \texttt{PARTITIONS} table. See Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”.
Obtaining Information About Partitions

It is possible to determine which partitions of a partitioned table are involved in a given SELECT query using EXPLAIN PARTITIONS. The PARTITIONS keyword adds a partitions column to the output of EXPLAIN listing the partitions from which records would be matched by the query.

Suppose that you have a table `trb1` created and populated as follows:

```
CREATE TABLE trb1 (id INT, name VARCHAR(50), purchased DATE)
    PARTITION BY RANGE(id)
    (
    PARTITION p0 VALUES LESS THAN (3),
    PARTITION p1 VALUES LESS THAN (7),
    PARTITION p2 VALUES LESS THAN (9),
    PARTITION p3 VALUES LESS THAN (11)
    );

INSERT INTO trb1 VALUES
    (1, 'desk organiser', '2003-10-15'),
    (2, 'CD player', '1993-11-05'),
    (3, 'TV set', '1996-03-10'),
    (4, 'bookcase', '1982-01-10'),
    (5, 'exercise bike', '2004-05-09'),
    (6, 'sofa', '1987-06-05'),
    (7, 'popcorn maker', '2001-11-22'),
    (8, 'aquarium', '1992-08-04'),
    (9, 'study desk', '1984-09-16'),
    (10, 'lava lamp', '1998-12-25');
```

You can see which partitions are used in a query such as `SELECT * FROM trb1;`, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1\G
*************************** 1. row ***************************
id: 1
select_type: SIMPLE
table: trb1
partitions: p0,p1,p2,p3
type: ALL
possible_keys: NULL
key: NULL
key_len: NULL
ref: NULL
rows: 10
Extra: Using filesort
```

In this case, all four partitions are searched. However, when a limiting condition making use of the partitioning key is added to the query, you can see that only those partitions containing matching values are scanned, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1 WHERE id < 5\G
*************************** 1. row ***************************
id: 1
select_type: SIMPLE
table: trb1
partitions: p0,p1
type: ALL
possible_keys: NULL
key: NULL
key_len: NULL
ref: NULL
rows: 10
Extra: Using where
```

EXPLAIN PARTITIONS provides information about keys used and possible keys, just as with the standard EXPLAIN SELECT statement:
You should take note of the following restrictions and limitations on `EXPLAIN PARTITIONS`:

- You cannot use the `PARTITIONS` and `EXTENDED` keywords together in the same `EXPLAIN ... SELECT` statement. Attempting to do so produces a syntax error.

- If `EXPLAIN PARTITIONS` is used to examine a query against a nonpartitioned table, no error is produced, but the value of the `partitions` column is always `NULL`.

The `rows` column of `EXPLAIN PARTITIONS` output displays the total number of rows in the table.

See also Section 13.8.2, “EXPLAIN Statement”.

19.4 Partition Pruning

This section discusses an optimization known as *partition pruning*. The core concept behind partition pruning is relatively simple, and can be described as “Do not scan partitions where there can be no matching values”. Suppose that you have a partitioned table `t1` defined by this statement:

```
CREATE TABLE t1 (  
  fname VARCHAR(50) NOT NULL,  
  lname VARCHAR(50) NOT NULL,  
  region_code TINYINT UNSIGNED NOT NULL,  
  dob DATE NOT NULL  
)  
PARTITION BY RANGE( region_code ) (  
  PARTITION p0 VALUES LESS THAN (64),  
  PARTITION p1 VALUES LESS THAN (128),  
  PARTITION p2 VALUES LESS THAN (192),  
  PARTITION p3 VALUES LESS THAN MAXVALUE  
);
```

Consider the case where you wish to obtain results from a `SELECT` statement such as this one:

```
SELECT fname, lname, region_code, dob  
FROM t1  
WHERE region_code > 125 AND region_code < 130;
```

It is easy to see that none of the rows which ought to be returned will be in either of the partitions `p0` or `p3`; that is, we need to search only in partitions `p1` and `p2` to find matching rows. By doing so, it is possible to expend much less time and effort in finding matching rows than would be required to scan all partitions in the table. This “cutting away” of unneeded partitions is known as *pruning*. When the optimizer can make use of partition pruning in performing this query, execution of the query can be an order of magnitude faster than the same query against a nonpartitioned table containing the same column definitions and data.
Partition Pruning

Note

When pruning is performed on a partitioned MyISAM table, all partitions are opened, whether or not they are examined, due to the design of the MyISAM storage engine. This means that you must have a sufficient number of file descriptors available to cover all partitions of the table. See MyISAM and partition file descriptor usage.

This limitation does not apply to partitioned tables using other MySQL storage engines such as InnoDB.

The optimizer can perform pruning whenever a WHERE condition can be reduced to either one of the following two cases:

- \( \text{partition\_column} = \text{constant} \)
- \( \text{partition\_column} \ \text{IN} \ (\text{constant1}, \text{constant2}, \ldots, \text{constantN}) \)

In the first case, the optimizer simply evaluates the partitioning expression for the value given, determines which partition contains that value, and scans only this partition. In many cases, the equal sign can be replaced with another arithmetic comparison, including \(<\), \(\geq\), \(\leq\), and \(\neq\). Some queries using BETWEEN in the WHERE clause can also take advantage of partition pruning. See the examples later in this section.

In the second case, the optimizer evaluates the partitioning expression for each value in the list, creates a list of matching partitions, and then scans only the partitions in this partition list.

MySQL 5.5 and later can apply partition pruning to SELECT, DELETE, and UPDATE statements. An INSERT statement also accesses only one partition per inserted row; this is true even for a table that is partitioned by HASH or KEY although this is not currently shown in the output of EXPLAIN.

Pruning can also be applied to short ranges, which the optimizer can convert into equivalent lists of values. For instance, in the previous example, the WHERE clause can be converted to WHERE region\_code IN (126, 127, 128, 129). Then the optimizer can determine that the first two values in the list are found in partition p1, the remaining two values in partition p2, and that the other partitions contain no relevant values and so do not need to be searched for matching rows.

Beginning with MySQL 5.5.0, the optimizer can also perform pruning for WHERE conditions that involve comparisons of the preceding types on multiple columns for tables that use RANGE_COLUMNS or LIST_COLUMNS partitioning.

This type of optimization can be applied whenever the partitioning expression consists of an equality or a range which can be reduced to a set of equalities, or when the partitioning expression represents an increasing or decreasing relationship. Pruning can also be applied for tables partitioned on a DATE or DATETIME column when the partitioning expression uses the YEAR() or TO\_DAYS() function. In addition, in MySQL 5.5, pruning can be applied for such tables when the partitioning expression uses the TO\_SECONDS() function.

Suppose that table t2, defined as shown here, is partitioned on a DATE column:

```sql
CREATE TABLE t2 (  
  fname VARCHAR(50) NOT NULL,  
  lname VARCHAR(50) NOT NULL,  
  region\_code TINYINT UNSIGNED NOT NULL,  
  dob DATE NOT NULL  
)  
PARTITION BY RANGE( YEAR(dob) ) (  
  PARTITION d0 VALUES LESS THAN (1970),  
  PARTITION d1 VALUES LESS THAN (1975),  
)  
```
Partition Pruning

```sql
PARTITION d2 VALUES LESS THAN (1980),
PARTITION d3 VALUES LESS THAN (1985),
PARTITION d4 VALUES LESS THAN (1990),
PARTITION d5 VALUES LESS THAN (2000),
PARTITION d6 VALUES LESS THAN (2005),
PARTITION d7 VALUES LESS THAN MAXVALUE
);
```

The following statements using `t2` can make use of partition pruning:

```sql
SELECT * FROM t2 WHERE dob = '1982-06-23';
UPDATE t2 SET region_code = 8 WHERE dob BETWEEN '1991-02-15' AND '1997-04-25';
DELETE FROM t2 WHERE dob >= '1984-06-21' AND dob <= '1999-06-21'
```

In the case of the last statement, the optimizer can also act as follows:

1. **Find the partition containing the low end of the range.**
   
   ```sql
   YEAR('1984-06-21') yields the value 1984, which is found in partition d3.
   ```

2. **Find the partition containing the high end of the range.**
   
   ```sql
   YEAR('1999-06-21') evaluates to 1999, which is found in partition d5.
   ```

3. **Scan only these two partitions and any partitions that may lie between them.**
   
   In this case, this means that only partitions d3, d4, and d5 are scanned. The remaining partitions may be safely ignored (and are ignored).

**Important**

Invalid `DATE` and `DATETIME` values referenced in the `WHERE` condition of a statement against a partitioned table are treated as `NULL`. This means that a query such as `SELECT * FROM partitioned_table WHERE date_column < '2008-12-00'` does not return any values (see Bug #40972).

So far, we have looked only at examples using `RANGE` partitioning, but pruning can be applied with other partitioning types as well.

Consider a table that is partitioned by `LIST`, where the partitioning expression is increasing or decreasing, such as the table `t3` shown here. (In this example, we assume for the sake of brevity that the `region_code` column is limited to values between 1 and 10 inclusive.)

```sql
CREATE TABLE t3 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
) PARTITION BY LIST(region_code) (
    PARTITION r0 VALUES IN (1, 3),
    PARTITION r1 VALUES IN (2, 5, 8),
    PARTITION r2 VALUES IN (4, 9),
    PARTITION r3 VALUES IN (6, 7, 10)
);
```

For a statement such as `SELECT * FROM t3 WHERE region_code BETWEEN 1 AND 3`, the optimizer determines in which partitions the values 1, 2, and 3 are found (`r0` and `r1`) and skips the remaining ones (`r2` and `r3`).

2639
Restrictions and Limitations on Partitioning

For tables that are partitioned by HASH or [LINEAR] KEY, partition pruning is also possible in cases in which the WHERE clause uses a simple = relation against a column used in the partitioning expression. Consider a table created like this:

```sql
CREATE TABLE t4 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
) PARTITION BY KEY(region_code)
PARTITIONS 8;
```

A statement that compares a column value with a constant can be pruned:

```sql
UPDATE t4 WHERE region_code = 7;
```

Pruning can also be employed for short ranges, because the optimizer can turn such conditions into IN relations. For example, using the same table `t4` as defined previously, queries such as these can be pruned:

```sql
SELECT * FROM t4 WHERE region_code > 2 AND region_code < 6;
SELECT * FROM t4 WHERE region_code BETWEEN 3 AND 5;
```

In both these cases, the WHERE clause is transformed by the optimizer into WHERE region_code IN (3, 4, 5).

**Important**

This optimization is used only if the range size is smaller than the number of partitions. Consider this statement:

```sql
DELETE FROM t4 WHERE region_code BETWEEN 4 AND 12;
```

The range in the WHERE clause covers 9 values (4, 5, 6, 7, 8, 9, 10, 11, 12), but `t4` has only 8 partitions. This means that the DELETE cannot be pruned.

When a table is partitioned by HASH or [LINEAR] KEY, pruning can be used only on integer columns. For example, this statement cannot use pruning because `dob` is a DATE column:

```sql
SELECT * FROM t4 WHERE dob >= '2001-04-14' AND dob <= '2005-10-15';
```

However, if the table stores year values in an INT column, then a query having WHERE year_col >= 2001 AND year_col <= 2005 can be pruned.

**Note**

In MySQL 5.1, a query against a table partitioned by KEY and having a composite partitioning key could be pruned only if the query’s WHERE clause compared every column in the key to a constant. In MySQL 5.5, it is possible to prune queries against such tables even if the WHERE clause does not reference every column in the partitioning key.

19.5 Restrictions and Limitations on Partitioning

This section discusses current restrictions and limitations on MySQL partitioning support.

**Prohibited constructs.** The following constructs are not permitted in partitioning expressions:
Restrictions and Limitations on Partitioning

• Stored procedures, stored functions, UDFs, or plugins.

• Declared variables or user variables.

For a list of SQL functions which are permitted in partitioning expressions, see Section 19.5.3, “Partitioning Limitations Relating to Functions”.

**Arithmetic and logical operators.** Use of the arithmetic operators +, −, and * is permitted in partitioning expressions. However, the result must be an integer value or NULL (except in the case of [LINEAR] KEY partitioning, as discussed elsewhere in this chapter; see Section 19.2, “Partitioning Types”, for more information).

The DIV operator is also supported, and the / operator is not permitted. (Bug #30188, Bug #33182)

The bit operators |, &, ^, <<, >>, and ~ are not permitted in partitioning expressions.

**HANDLER statements.** In MySQL 5.5, the HANDLER statement is not supported with partitioned tables.

**Server SQL mode.** Tables employing user-defined partitioning do not preserve the SQL mode in effect at the time that they were created. As discussed in Section 5.1.10, “Server SQL Modes”, the results of many MySQL functions and operators may change according to the server SQL mode. Therefore, a change in the SQL mode at any time after the creation of partitioned tables may lead to major changes in the behavior of such tables, and could easily lead to corruption or loss of data. For these reasons, it is strongly recommended that you never change the server SQL mode after creating partitioned tables.

**Examples.** The following examples illustrate some changes in behavior of partitioned tables due to a change in the server SQL mode:

1. **Error handling.** Suppose that you create a partitioned table whose partitioning expression is one such as column DIV 0 or column MOD 0, as shown here:

   ```sql
   mysql> CREATE TABLE tn (c1 INT)
   -> PARTITION BY LIST(1 DIV c1) {
   ->     PARTITION p0 VALUES IN (NULL),
   ->     PARTITION p1 VALUES IN (1)
   -> };
   Query OK, 0 rows affected (0.05 sec)
   ```

   The default behavior for MySQL is to return NULL for the result of a division by zero, without producing any errors:

   ```sql
   mysql> SELECT @@sql_mode;
   +------------+
   | @@sql_mode |
   +------------+
   |            |
   +------------+
   1 row in set (0.00 sec)
   ```

   ```sql
   mysql> SELECT @@sql_mode;
   +------------+
   | @@sql_mode |
   +------------+
   |            |
   +------------+
   1 row in set (0.00 sec)
   ```

   ```sql
   mysql> INSERT INTO tn VALUES (NULL), (0), (1);
   Query OK, 3 rows affected (0.00 sec)
   Records: 3  Duplicates: 0  Warnings: 0
   ```

   However, changing the server SQL mode to treat division by zero as an error and to enforce strict error handling causes the same INSERT statement to fail, as shown here:

   ```sql
   mysql> SET sql_mode='STRICT_ALL_TABLES,ERROR_FOR_DIVISION_BY_ZERO';
   Query OK, 0 rows affected (0.00 sec)
   ```

   ```sql
   mysql> INSERT INTO tn VALUES (NULL), (0), (1);
   ```
Restrictions and Limitations on Partitioning

2. **Table accessibility.** Sometimes a change in the server SQL mode can make partitioned tables unusable. The following `CREATE TABLE` statement can be executed successfully only if the `NO_UNSIGNED_SUBTRACTION` mode is in effect:

```sql
mysql> SELECT @@sql_mode;
+------------+
<table>
<thead>
<tr>
<th>@@sql_mode</th>
</tr>
</thead>
</table>
+------------+
1 row in set (0.00 sec)
mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
-> PARTITION BY RANGE(c1 - 10) (
->     PARTITION p0 VALUES LESS THAN (-5),
->     PARTITION p1 VALUES LESS THAN (0),
->     PARTITION p2 VALUES LESS THAN (5),
->     PARTITION p3 VALUES LESS THAN (10),
->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
-> );
ERROR 1563 (HY000): Partition constant is out of partition function domain
mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT @@sql_mode;
+-------------------------+
<table>
<thead>
<tr>
<th>@@sql_mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO_UNSIGNED_SUBTRACTION</td>
</tr>
</tbody>
</table>
+-------------------------+
1 row in set (0.00 sec)
mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
-> PARTITION BY RANGE(c1 - 10) (
->     PARTITION p0 VALUES LESS THAN (-5),
->     PARTITION p1 VALUES LESS THAN (0),
->     PARTITION p2 VALUES LESS THAN (5),
->     PARTITION p3 VALUES LESS THAN (10),
->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
-> );
Query OK, 0 rows affected (0.05 sec)
```

If you remove the `NO_UNSIGNED_SUBTRACTION` server SQL mode after creating `tu`, you may no longer be able to access this table:

```sql
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT * FROM tu;
ERROR 1563 (HY000): Partition constant is out of partition function domain
mysql> INSERT INTO tu VALUES (20);
ERROR 1563 (HY000): Partition constant is out of partition function domain
```

Server SQL modes also impact replication of partitioned tables. Differing SQL modes on master and slave can lead to partitioning expressions being evaluated differently; this can cause the distribution of data among partitions to be different in the master's and slave's copies of a given table, and may even cause inserts into partitioned tables that succeed on the master to fail on the slave. For best results, you should always use the same server SQL mode on the master and on the slave.

**Performance considerations.** Some effects of partitioning operations on performance are given in the following list:
Restrictions and Limitations on Partitioning

- **File system operations.** Partitioning and repartitioning operations (such as `ALTER TABLE` with `PARTITION BY ...`, `REORGANIZE PARTITION`, or `REMOVE PARTITIONING`) depend on file system operations for their implementation. This means that the speed of these operations is affected by such factors as file system type and characteristics, disk speed, swap space, file handling efficiency of the operating system, and MySQL server options and variables that relate to file handling. In particular, you should make sure that `large_files_support` is enabled and that `open_files_limit` is set properly. For partitioned tables using the MyISAM storage engine, increasing `myisam_max_sort_file_size` may improve performance; partitioning and repartitioning operations involving InnoDB tables may be made more efficient by enabling `innodb_file_per_table`.

  See also [Maximum number of partitions](#).

- **MyISAM and partition file descriptor usage.** For a partitioned MyISAM table, MySQL uses 2 file descriptors for each partition, for each such table that is open. This means that you need many more file descriptors to perform operations on a partitioned MyISAM table than on a table which is identical to it except that the latter table is not partitioned, particularly when performing `ALTER TABLE` operations.

  Assume a MyISAM table `t` with 100 partitions, such as the table created by this SQL statement:

  ```sql
  CREATE TABLE t (c1 VARCHAR(50))
  PARTITION BY KEY (c1) PARTITIONS 100
  ENGINE=MYISAM;
  ```

  **Note**

  For brevity, we use `KEY` partitioning for the table shown in this example, but file descriptor usage as described here applies to all partitioned MyISAM tables, regardless of the type of partitioning that is employed. Partitioned tables using other storage engines such as InnoDB are not affected by this issue.

  Now assume that you wish to repartition `t` so that it has 101 partitions, using the statement shown here:

  ```sql
  ALTER TABLE t PARTITION BY KEY (c1) PARTITIONS 101;
  ```

  To process this `ALTER TABLE` statement, MySQL uses 402 file descriptors—that is, two for each of the 100 original partitions, plus two for each of the 101 new partitions. This is because all partitions (old and new) must be opened concurrently during the reorganization of the table data. It is recommended that, if you expect to perform such operations, you should make sure that the `open_files_limit` system variable is not set too low to accommodate them.

- **Table locks.** The process executing a partitioning operation on a table takes a write lock on the table. Reads from such tables are relatively unaffected; pending `INSERT` and `UPDATE` operations are performed as soon as the partitioning operation has completed.

- **Storage engine.** Partitioning operations, queries, and update operations generally tend to be faster with MyISAM tables than with InnoDB or NDB tables.

- **Indexes; partition pruning.** As with nonpartitioned tables, proper use of indexes can speed up queries on partitioned tables significantly. In addition, designing partitioned tables and statements using these tables to take advantage of **partition pruning** can improve performance dramatically. See Section 19.4, “Partition Pruning”, for more information.

- **Performance with LOAD DATA.** In MySQL 5.5, `LOAD DATA` uses buffering to improve performance. You should be aware that the buffer uses 130 KB memory per partition to achieve this.

**Maximum number of partitions.**

The maximum possible number of partitions for a given table (that does not use the NDB storage engine) is 1024. This number includes subpartitions.
Restrictions and Limitations on Partitioning

The maximum possible number of user-defined partitions for a table using the `NDBCLUSTER` storage engine is determined according to the version of the NDB Cluster software being used, the number of data nodes, and other factors. See `NDB and user-defined partitioning`, for more information.

If, when creating tables with a large number of partitions (but less than the maximum), you encounter an error message such as `Got error ... from storage engine: Out of resources when opening file`, you may be able to address the issue by increasing the value of the `open_files_limit` system variable. However, this is dependent on the operating system, and may not be possible or advisable on all platforms; see `Section B.4.2.18, "File Not Found and Similar Errors"`, for more information. In some cases, using large numbers (hundreds) of partitions may also not be advisable due to other concerns, so using more partitions does not automatically lead to better results.

See also `File system operations`.

**Query cache not supported.**
The query cache is not supported for partitioned tables. Beginning with MySQL 5.5.23, the query cache is automatically disabled for queries involving partitioned tables, and cannot be enabled for such queries. (Bug #53775)

**Per-partition key caches.**
In MySQL 5.5, key caches are supported for partitioned `MyISAM` tables, using the `CACHE INDEX` and `LOAD INDEX INTO CACHE` statements. Key caches may be defined for one, several, or all partitions, and indexes for one, several, or all partitions may be preloaded into key caches.

**Foreign keys not supported for partitioned InnoDB tables.**
Partitioned tables using the `InnoDB` storage engine do not support foreign keys. More specifically, this means that the following two statements are true:

1. No definition of an `InnoDB` table employing user-defined partitioning may contain foreign key references; no `InnoDB` table whose definition contains foreign key references may be partitioned.
2. No `InnoDB` table definition may contain a foreign key reference to a user-partitioned table; no `InnoDB` table with user-defined partitioning may contain columns referenced by foreign keys.

The scope of the restrictions just listed includes all tables that use the `InnoDB` storage engine. `CREATE TABLE` and `ALTER TABLE` statements that would result in tables violating these restrictions are not allowed.

**`ALTER TABLE ... ORDER BY`.** An `ALTER TABLE ... ORDER BY column` statement run against a partitioned table causes ordering of rows only within each partition.

**Effects on REPLACE statements by modification of primary keys.** It can be desirable in some cases (see `Section 19.5.1, "Partitioning Keys, Primary Keys, and Unique Keys"`) to modify a table’s primary key. Be aware that, if your application uses `REPLACE` statements and you do this, the results of these statements can be drastically altered. See `Section 13.2.8, "REPLACE Statement"`, for more information and an example.

**FULLTEXT indexes.**
Partitioned tables do not support `FULLTEXT` indexes or searches. This includes partitioned tables employing the `MyISAM` storage engine.

**Spatial columns.** Columns with spatial data types such as `POINT` or `GEOMETRY` cannot be used in partitioned tables.

**Temporary tables.**
Restrictions and Limitations on Partitioning

Temporary tables cannot be partitioned. (Bug #17497)

**Log tables.** It is not possible to partition the log tables; an `ALTER TABLE ... PARTITION BY ...` statement on such a table fails with an error.

**Data type of partitioning key.**
A partitioning key must be either an integer column or an expression that resolves to an integer. Expressions employing `ENUM` columns cannot be used. The column or expression value may also be `NULL`. (See Section 19.2.7, “How MySQL Partitioning Handles NULL”.)

There are two exceptions to this restriction:

1. When partitioning by `[LINEAR] KEY`, it is possible to use columns of any valid MySQL data type other than `TEXT` or `BLOB` as partitioning keys, because MySQL’s internal key-hashing functions produce the correct data type from these types. For example, the following two `CREATE TABLE` statements are valid:

   ```sql
   CREATE TABLE tkc (c1 CHAR)
   PARTITION BY KEY(c1)
   PARTITIONS 4;
   
   CREATE TABLE tke
   ( c1 ENUM('red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet') )
   PARTITION BY LINEAR KEY(c1)
   PARTITIONS 6;
   ```

2. When partitioning by `RANGE COLUMNS` or `LIST COLUMNS`, it is possible to use string, `DATE`, and `DATETIME` columns. For example, each of the following `CREATE TABLE` statements is valid:

   ```sql
   CREATE TABLE rc (c1 INT, c2 DATE)
   PARTITION BY RANGE COLUMNS(c2) (
      PARTITION p0 VALUES LESS THAN('1990-01-01'),
      PARTITION p1 VALUES LESS THAN('1995-01-01'),
      PARTITION p2 VALUES LESS THAN('2000-01-01'),
      PARTITION p3 VALUES LESS THAN('2005-01-01'),
      PARTITION p4 VALUES LESS THAN(MAXVALUE)
   );
   
   CREATE TABLE lc (c1 INT, c2 CHAR(1))
   PARTITION BY LIST COLUMNS(c2) (
      PARTITION p0 VALUES IN('a', 'd', 'g', 'j', 'm', 'p', 's', 'v', 'y'),
      PARTITION p1 VALUES IN('b', 'e', 'h', 'k', 'n', 'q', 't', 'w', 'z'),
      PARTITION p2 VALUES IN('c', 'f', 'i', 'l', 'o', 'r', 'u', 'x', NULL)
   );
   ```

Neither of the preceding exceptions applies to `BLOB` or `TEXT` column types.

**Subqueries.**
A partitioning key may not be a subquery, even if that subquery resolves to an integer value or `NULL`.

**Issues with subpartitions.**
Subpartitions must use `HASH` or `KEY` partitioning. Only `RANGE` and `LIST` partitions may be subpartitioned; `HASH` and `KEY` partitions cannot be subpartitioned.

**SUBPARTITION BY KEY** requires that the subpartitioning column or columns be specified explicitly, unlike the case with `PARTITION BY KEY`, where it can be omitted (in which case the table’s primary key column is used by default). Consider the table created by this statement:

```sql
CREATE TABLE ts (
   id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
   name VARCHAR(30)
);
```
Restrictions and Limitations on Partitioning

You can create a table having the same columns, partitioned by `KEY`, using a statement such as this one:

```
CREATE TABLE ts {
   id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
   name VARCHAR(30)
}
PARTITION BY KEY()
PARTITIONS 4;
```

The previous statement is treated as though it had been written like this, with the table's primary key column used as the partitioning column:

```
CREATE TABLE ts {
   id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
   name VARCHAR(30)
}
PARTITION BY KEY(id)
PARTITIONS 4;
```

However, the following statement that attempts to create a subpartitioned table using the default column as the subpartitioning column fails, and the column must be specified for the statement to succeed, as shown here:

```
mysql> CREATE TABLE ts {
   -> id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
   -> name VARCHAR(30)
   -> }
   -> PARTITION BY RANGE(id)
   -> SUBPARTITION BY KEY()
   -> SUBPARTITIONS 4
   -> {
   -> PARTITION p0 VALUES LESS THAN (100),
   -> PARTITION p1 VALUES LESS THAN (MAXVALUE)
   ->);
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use near ')
```

```
mysql> CREATE TABLE ts {
   -> id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
   -> name VARCHAR(30)
   -> }
   -> PARTITION BY RANGE(id)
   -> SUBPARTITION BY KEY(id)
   -> SUBPARTITIONS 4
   -> {
   -> PARTITION p0 VALUES LESS THAN (100),
   -> PARTITION p1 VALUES LESS THAN (MAXVALUE)
   ->
```

Query OK, 0 rows affected (0.07 sec)

This is a known issue (see Bug #51470).

**DELAYED option not supported.** Use of `INSERT DELAYED` to insert rows into a partitioned table is not supported. Attempting to do so fails with an error.

**DATA DIRECTORY and INDEX DIRECTORY options.** `DATA DIRECTORY` and `INDEX DIRECTORY` are subject to the following restrictions when used with partitioned tables:

- Table-level `DATA DIRECTORY` and `INDEX DIRECTORY` options are ignored (see Bug #32091).
- On Windows, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not supported for individual partitions or subpartitions (Bug #30459).
Partitioning Keys, Primary Keys, and Unique Keys

Repairing and rebuilding partitioned tables. The statements \texttt{CHECK TABLE}, \texttt{OPTIMIZE TABLE}, \texttt{ANALYZE TABLE}, and \texttt{REPAIR TABLE} are supported for partitioned tables.

In addition, you can use \texttt{ALTER TABLE ... REBUILD PARTITION} to rebuild one or more partitions of a partitioned table; \texttt{ALTER TABLE ... REORGANIZE PARTITION} also causes partitions to be rebuilt. See Section 13.1.7, “\texttt{ALTER TABLE Statement}”, for more information about these two statements.

\texttt{mysqlcheck, myisamchk, and myisampack} are not supported with partitioned tables.

19.5.1 Partitioning Keys, Primary Keys, and Unique Keys

This section discusses the relationship of partitioning keys with primary keys and unique keys. The rule governing this relationship can be expressed as follows: All columns used in the partitioning expression for a partitioned table must be part of every unique key that the table may have.

In other words, \textit{every unique key on the table must use every column in the table's partitioning expression}. (This also includes the table's primary key, since it is by definition a unique key. This particular case is discussed later in this section.) For example, each of the following table creation statements is invalid:

\begin{verbatim}
CREATE TABLE t1 (  
  col1 INT NOT NULL,  
  col2 DATE NOT NULL,  
  col3 INT NOT NULL,  
  col4 INT NOT NULL,  
  UNIQUE KEY (col1, col2)  
)  
PARTITION BY HASH(col3)  
PARTITIONS 4;

CREATE TABLE t2 (  
  col1 INT NOT NULL,  
  col2 DATE NOT NULL,  
  col3 INT NOT NULL,  
  col4 INT NOT NULL,  
  UNIQUE KEY (col1),  
  UNIQUE KEY (col3)  
)  
PARTITION BY HASH(col1 + col3)  
PARTITIONS 4;
\end{verbatim}

In each case, the proposed table would have at least one unique key that does not include all columns used in the partitioning expression.

Each of the following statements is valid, and represents one way in which the corresponding invalid table creation statement could be made to work:

\begin{verbatim}
CREATE TABLE t1 (  
  col1 INT NOT NULL,  
  col2 DATE NOT NULL,  
  col3 INT NOT NULL,  
  col4 INT NOT NULL,  
  UNIQUE KEY (col1, col2, col3)  
)  
PARTITION BY HASH(col3)  
PARTITIONS 4;

CREATE TABLE t2 (  
  col1 INT NOT NULL,  
  col2 DATE NOT NULL,  
  col3 INT NOT NULL,  
  col4 INT NOT NULL,  
  UNIQUE KEY (col1, col3)  
)  
PARTITION BY HASH(col1 + col3)  
PARTITIONS 4;
\end{verbatim}
Partitioning Keys, Primary Keys, and Unique Keys

This example shows the error produced in such cases:

```sql
mysql> CREATE TABLE t3 {
    ->    col1 INT NOT NULL,
    ->    col2 DATE NOT NULL,
    ->    col3 INT NOT NULL,
    ->    col4 INT NOT NULL,
    ->    UNIQUE KEY (col1, col2),
    ->    UNIQUE KEY (col3)
    -> } PARTITION BY HASH(col1 + col3)
    -> PARTITIONS 4;
ERROR 1491 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

The `CREATE TABLE` statement fails because both `col1` and `col3` are included in the proposed partitioning key, but neither of these columns is part of both of unique keys on the table. This shows one possible fix for the invalid table definition:

```sql
mysql> CREATE TABLE t3 {
    ->    col1 INT NOT NULL,
    ->    col2 DATE NOT NULL,
    ->    col3 INT NOT NULL,
    ->    col4 INT NOT NULL,
    ->    UNIQUE KEY (col1, col2, col3),
    ->    UNIQUE KEY (col3)
    -> } PARTITION BY HASH(col3)
    -> PARTITIONS 4;
Query OK, 0 rows affected (0.05 sec)
```

In this case, the proposed partitioning key `col3` is part of both unique keys, and the table creation statement succeeds.

The following table cannot be partitioned at all, because there is no way to include in a partitioning key any columns that belong to both unique keys:

```sql
CREATE TABLE t4 {
    col1 INT NOT NULL,
    col2 INT NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col3),
    UNIQUE KEY (col2, col4)
};
```

Since every primary key is by definition a unique key, this restriction also includes the table's primary key, if it has one. For example, the next two statements are invalid:

```sql
CREATE TABLE t5 {
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2)
} PARTITION BY HASH(col3)
PARTITIONS 4;
CREATE TABLE t6 {
    col1 INT NOT NULL,
```
Partitioning Keys, Primary Keys, and Unique Keys

In both cases, the primary key does not include all columns referenced in the partitioning expression. However, both of the next two statements are valid:

```sql
CREATE TABLE t7 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col3),
    UNIQUE KEY(col2)
) PARTITION BY HASH(YEAR(col2))
PARTITIONS 4;
```

```sql
CREATE TABLE t8 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col3, col4),
    UNIQUE KEY(col2, col1)
) PARTITION BY HASH(YEAR(col2))
PARTITIONS 4;
```

If a table has no unique keys—this includes having no primary key—then this restriction does not apply, and you may use any column or columns in the partitioning expression as long as the column type is compatible with the partitioning type.

For the same reason, you cannot later add a unique key to a partitioned table unless the key includes all columns used by the table’s partitioning expression. Consider the partitioned table created as shown here:

```sql
mysql> CREATE TABLE t_no_pk (c1 INT, c2 INT)
    -> PARTITION BY RANGE(c1) (;
    -> PARTITION p0 VALUES LESS THAN (10),
    -> PARTITION p1 VALUES LESS THAN (20),
    -> PARTITION p2 VALUES LESS THAN (30),
    -> PARTITION p3 VALUES LESS THAN (40)
    -> );
Query OK, 0 rows affected (0.12 sec)
```

It is possible to add a primary key to `t_no_pk` using either of these `ALTER TABLE` statements:

```sql
# possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1);
Query OK, 0 rows affected (0.13 sec)
Records: 0  Duplicates: 0  Warnings: 0

# drop this PK
mysql> ALTER TABLE t_no_pk DROP PRIMARY KEY;
Query OK, 0 rows affected (0.10 sec)
Records: 0  Duplicates: 0  Warnings: 0

# use another possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1, c2);
Query OK, 0 rows affected (0.12 sec)
Records: 0  Duplicates: 0  Warnings: 0
```
However, the next statement fails, because \texttt{c1} is part of the partitioning key, but is not part of the proposed primary key:

\begin{verbatim}
# fails with error 1503
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c2);
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table’s partitioning function
\end{verbatim}

Since \texttt{t_no_pk} has only \texttt{c1} in its partitioning expression, attempting to adding a unique key on \texttt{c2} alone fails. However, you can add a unique key that uses both \texttt{c1} and \texttt{c2}.

These rules also apply to existing nonpartitioned tables that you wish to partition using \texttt{ALTER TABLE ... PARTITION BY}. Consider a table \texttt{np_pk} created as shown here:

\begin{verbatim}
mysql> CREATE TABLE np_pk (  
-> id INT NOT NULL AUTO_INCREMENT,  
-> name VARCHAR(50),  
-> added DATE,  
-> PRIMARY KEY (id)  
-> );
Query OK, 0 rows affected (0.08 sec)
\end{verbatim}

The following \texttt{ALTER TABLE} statement fails with an error, because the \texttt{added} column is not part of any unique key in the table:

\begin{verbatim}
mysql> ALTER TABLE np_pk  
-> PARTITION BY HASH( TO_DAYS(added) )  
-> PARTITIONS 4;  
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table’s partitioning function
\end{verbatim}

However, this statement using the \texttt{id} column for the partitioning column is valid, as shown here:

\begin{verbatim}
mysql> ALTER TABLE np_pk  
-> PARTITION BY HASH(id)  
-> PARTITIONS 4;  
Query OK, 0 rows affected (0.11 sec)
\end{verbatim}

In the case of \texttt{np_pk}, the only column that may be used as part of a partitioning expression is \texttt{id}; if you wish to partition this table using any other column or columns in the partitioning expression, you must first modify the table, either by adding the desired column or columns to the primary key, or by dropping the primary key altogether.

### 19.5.2 Partitioning Limitations Relating to Storage Engines

The following limitations apply to the use of storage engines with user-defined partitioning of tables.

\textbf{MERGE storage engine.} User-defined partitioning and the \texttt{MERGE} storage engine are not compatible. Tables using the \texttt{MERGE} storage engine cannot be partitioned. Partitioned tables cannot be merged.

\textbf{FEDERATED storage engine.} Partitioning of \texttt{FEDERATED} tables is not supported; it is not possible to create partitioned \texttt{FEDERATED} tables.

\textbf{CSV storage engine.} Partitioned tables using the \texttt{CSV} storage engine are not supported; it is not possible to create partitioned \texttt{CSV} tables.
InnoDB storage engine. InnoDB foreign keys and MySQL partitioning are not compatible. Partitioned InnoDB tables cannot have foreign key references, nor can they have columns referenced by foreign keys. InnoDB tables which have or which are referenced by foreign keys cannot be partitioned.

InnoDB does not support the use of multiple disks for subpartitions. (This is currently supported only by MyISAM.)

In addition, ALTER TABLE ... OPTIMIZE PARTITION does not work correctly with partitioned tables that use the InnoDB storage engine. Use ALTER TABLE ... REBUILD PARTITION and ALTER TABLE ... ANALYZE PARTITION, instead, for such tables. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

User-defined partitioning and the NDB storage engine (NDB Cluster). Partitioning by KEY (including LINEAR KEY) is the only type of partitioning supported for the NDB storage engine. It is not possible under normal circumstances in MySQL NDB Cluster 7.2 or MySQL NDB Cluster 7.3 to create an NDB Cluster table using any partitioning type other than [LINEAR] KEY, and attempting to do so fails with an error.

Exception (not for production): It is possible to override this restriction by setting the new system variable on NDB Cluster SQL nodes to ON. If you choose to do this, you should be aware that tables using partitioning types other than [LINEAR] KEY are not supported in production. In such cases, you can create and use tables with partitioning types other than KEY or LINEAR KEY, but you do this entirely at your own risk.

The maximum number of partitions that can be defined for an NDB table depends on the number of data nodes and node groups in the cluster, the version of the NDB Cluster software in use, and other factors. See NDB and user-defined partitioning, for more information.

The maximum amount of fixed-size data that can be stored per partition in an NDB table is 16 GB.

CREATE TABLE and ALTER TABLE statements that would cause a user-partitioned NDB table not to meet either or both of the following two requirements are not permitted, and fail with an error:

1. The table must have an explicit primary key.
2. All columns listed in the table's partitioning expression must be part of the primary key.

Exception. If a user-partitioned NDB table is created using an empty column-list (that is, using PARTITION BY KEY() or PARTITION BY LINEAR KEY()), then no explicit primary key is required.

Upgrading partitioned tables. When performing an upgrade, tables which are partitioned by KEY and which use any storage engine other than NDB must be dumped and reloaded.

Same storage engine for all partitions. All partitions of a partitioned table must use the same storage engine and it must be the same storage engine used by the table as a whole. In addition, if one does not specify an engine on the table level, then one must do either of the following when creating or altering a partitioned table:

- Do not specify any engine for any partition or subpartition
- Specify the engine for all partitions or subpartitions

19.5.3 Partitioning Limitations Relating to Functions

This section discusses limitations in MySQL Partitioning relating specifically to functions used in partitioning expressions.

Only the MySQL functions shown in the following list are allowed in partitioning expressions:
Partitioning Limitations Relating to Functions

- `ABS()`
- `CEILING()` (see CEILING() and FLOOR())
- `DATEDIFF()`
- `DAY()`
- `DAYOFMONTH()`
- `DAYOFWEEK()`
- `DAYOFYEAR()`
- `EXTRACT()` (see EXTRACT() function with WEEK specifier)
- `FLOOR()` (see CEILING() and FLOOR())
- `HOUR()`
- `MICROSECOND()`
- `MINUTE()`
- `MOD()`
- `MONTH()`
- `QUARTER()`
- `SECOND()`
- `TIME_TO_SEC()`
- `TO_DAYS()`
- `TO_SECONDS()`
- `UNIX_TIMESTAMP()` (permitted beginning with MySQL 5.5.1 and fully supported beginning with MySQL 5.5.15, with `TIMESTAMP` columns)
- `WEEKDAY()`
- `YEAR()`
- `YEARWEEK()`

In MySQL 5.5, range optimization can be used for the `TO_DAYS()`, `TO_SECONDS()`, and `YEAR()` functions. In addition, beginning with MySQL 5.5.15, `UNIX_TIMESTAMP()` is treated as monotonic in partitioning expressions. See Section 19.4, "Partition Pruning", for more information.

CEILING() and FLOOR(). Each of these functions returns an integer only if it is passed an argument of an exact numeric type, such as one of the `INT` types or `DECIMAL`. This means, for example, that the following `CREATE TABLE` statement fails with an error, as shown here:

```sql
mysql> CREATE TABLE t (c FLOAT) PARTITION BY LIST( FLOOR(c) ) (-> PARTITION p0 VALUES IN (1,3,5),-> PARTITION p1 VALUES IN (2,4,6) -> );
```
ERROR 1490 (HY000): The PARTITION function returns the wrong type

**EXTRACT() function with WEEK specifier.** The value returned by the `EXTRACT()` function, when used as `EXTRACT(WEEK FROM col)`, depends on the value of the `default_week_format` system variable. For this reason, beginning with MySQL 5.5.9, `EXTRACT()` is no longer permitted as a partitioning function when it specifies the unit as `WEEK`. (Bug #54483)

See Section 12.5.2, “Mathematical Functions”, for more information about the return types of these functions, as well as Section 11.1, “Numeric Data Types”.

### 19.5.4 Partitioning and Table-Level Locking

For storage engines such as MyISAM that actually execute table-level locks when executing DML or DDL statements, such a statement affecting a partitioned table imposes a lock on the table as a whole; that is, all partitions are locked until the statement was finished. For example, a `SELECT` from a partitioned MyISAM table causes a lock on the entire table.

In practical terms, what this means is that the statements discussed later in this section tend to execute more slowly as the number of partitions increases. This limitation is greatly reduced in MySQL 5.6, with the introduction of *partition lock pruning* in MySQL 5.6.6.

This is not true for statements affecting partitioned tables using storage engines such as InnoDB, that employ row-level locking and do not actually perform (or need to perform) the locks prior to partition pruning.

The next few paragraphs discuss the effects of MySQL statements on partitioned tables using storage engines that employ table-level locks.

#### DML statements

- **SELECT** statements lock the entire table. **SELECT** statements containing unions or joins lock all tables named in the union or join.

- **UPDATE** also locks the entire table.

- **REPLACE** and **INSERT** (including **INSERT ... ON DUPLICATE KEY UPDATE**) lock the entire table.

- **INSERT ... SELECT** locks both the source table and the target table.

  **Note**

  **INSERT DELAYED** is not supported for partitioned tables.

- A **LOAD DATA** statement on a partitioned table locks the entire table.

A trigger on a partitioned table, once activated, locks the entire table.

#### DDL statements

- **CREATE VIEW** causes a lock on any partitioned table from which it reads.

- **ALTER TABLE** locks the affected partitioned table.

#### Other statements

- **LOCK TABLES** locks all partitions of a partitioned table.
Evaluating the `expr` in a `CALL stored_procedure(expr)` statement locks all partitions of any partitioned table referenced by `expr`.

`ALTER TABLE` also takes a metadata lock on the table level.
Chapter 20 Stored Objects

Table of Contents

20.1 Defining Stored Programs ........................................................................................................... 2656
20.2 Using Stored Routines .................................................................................................................. 2657
  20.2.1 Stored Routine Syntax ............................................................................................................ 2658
  20.2.2 Stored Routines and MySQL Privileges .................................................................................. 2658
  20.2.3 Stored Routine Metadata ....................................................................................................... 2659
  20.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID() ........................................ 2659
20.3 Using Triggers ............................................................................................................................... 2659
  20.3.1 Trigger Syntax and Examples ................................................................................................ 2660
  20.3.2 Trigger Metadata ................................................................................................................... 2660
20.4 Using the Event Scheduler .......................................................................................................... 2664
  20.4.1 Event Scheduler Overview .................................................................................................... 2665
  20.4.2 Event Scheduler Configuration ............................................................................................. 2666
  20.4.3 Event Syntax .......................................................................................................................... 2672
  20.4.4 Event Metadata ....................................................................................................................... 2667
  20.4.5 Event Scheduler Status .......................................................................................................... 2669
  20.4.6 The Event Scheduler and MySQL Privileges ........................................................................ 2669
20.5 Using Views ................................................................................................................................... 2672
  20.5.1 View Syntax ........................................................................................................................... 2672
  20.5.2 View Processing Algorithms ................................................................................................ 2673
  20.5.3 Updatable and Insertable Views ............................................................................................. 2674
  20.5.4 The View WITH CHECK OPTION Clause ............................................................................ 2676
  20.5.5 View Metadata ....................................................................................................................... 2676
20.6 Stored Object Access Control .................................................................................................... 2676
20.7 Stored Program Binary Logging .................................................................................................. 2679
20.8 Restrictions on Stored Programs ............................................................................................... 2685
20.9 Restrictions on Views .................................................................................................................... 2688

This chapter discusses stored database objects that are defined in terms of SQL code that is stored on the server for later execution.

Stored objects include these object types:

- Stored procedure: An object created with `CREATE PROCEDURE` and invoked using the `CALL` statement. A procedure does not have a return value but can modify its parameters for later inspection by the caller. It can also generate result sets to be returned to the client program.

- Stored function: An object created with `CREATE FUNCTION` and used much like a built-in function. You invoke it in an expression and it returns a value during expression evaluation.

- Trigger: An object created with `CREATE TRIGGER` that is associated with a table. A trigger is activated when a particular event occurs for the table, such as an insert or update.

- Event: An object created with `CREATE EVENT` and invoked by the server according to schedule.

- View: An object created with `CREATE VIEW` that when referenced produces a result set. A view acts as a virtual table.

Terminology used in this document reflects the stored object hierarchy:
• Stored routines include stored procedures and functions.
• Stored programs include stored routines, triggers, and events.
• Stored objects include stored programs and views.

This chapter describes how to use stored objects. The following sections provide additional information about SQL syntax for statements related to these objects:

• For each object type, there are CREATE, ALTER, and DROP statements that control which objects exist and how they are defined. See Section 13.1, “Data Definition Statements”.

• The CALL statement is used to invoke stored procedures. See Section 13.2.1, “CALL Statement”.

• Stored program definitions include a body that may use compound statements, loops, conditionals, and declared variables. See Section 13.6, “Compound-Statements”.

20.1 Defining Stored Programs

Each stored program contains a body that consists of an SQL statement. This statement may be a compound statement made up of several statements separated by semicolon (;) characters. For example, the following stored procedure has a body made up of a BEGIN ... END block that contains a SET statement and a REPEAT loop that itself contains another SET statement:

```
CREATE PROCEDURE dorepeat(p1 INT)
BEGIN
  SET @x = 0;
  REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
END;
```

If you use the mysql client program to define a stored program containing semicolon characters, a problem arises. By default, mysql itself recognizes the semicolon as a statement delimiter, so you must redefine the delimiter temporarily to cause mysql to pass the entire stored program definition to the server.

To redefine the mysql delimiter, use the delimiter command. The following example shows how to do this for the dorepeat() procedure just shown. The delimiter is changed to // to enable the entire definition to be passed to the server as a single statement, and then restored to ; before invoking the procedure. This enables the ; delimiter used in the procedure body to be passed through to the server rather than being interpreted by mysql itself.

```
mysql> delimiter //
mysql> CREATE PROCEDURE dorepeat(p1 INT)
    -> BEGIN
    -> SET @x = 0;
    -> REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
    -> END
    -> //
Query OK, 0 rows affected (0.00 sec)
mysql> delimiter ;
mysql> CALL dorepeat(1000);
Query OK, 0 rows affected (0.00 sec)
```

mysql> SELECT @x;
+------+
| @x   |
+------+
| 1001  |
+------+
1 row in set (0.00 sec)
Using Stored Routines

You can redefine the delimiter to a string other than `//`, and the delimiter can consist of a single character or multiple characters. You should avoid the use of the backslash (`\`) character because that is the escape character for MySQL.

The following is an example of a function that takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```sql
mysql> CREATE FUNCTION hello (s CHAR(20))
    -> RETURNS CHAR(50) DETERMINISTIC
    -> RETURN CONCAT('Hello, ',s,'!');
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT hello('world');
+----------------+
| hello('world') |
+----------------+
| Hello, world!  |
+----------------+
1 row in set (0.00 sec)
```

20.2 Using Stored Routines

MySQL supports stored routines (procedures and functions). A stored routine is a set of SQL statements that can be stored in the server. Once this has been done, clients don't need to keep reissuing the individual statements but can refer to the stored routine instead.

Stored routines require the `proc` table in the `mysql` database. This table is created during the MySQL installation procedure. If you are upgrading to MySQL 5.5 from an earlier version, be sure to update your grant tables to make sure that the `proc` table exists. See Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables".

Stored routines can be particularly useful in certain situations:

- When multiple client applications are written in different languages or work on different platforms, but need to perform the same database operations.

- When security is paramount. Banks, for example, use stored procedures and functions for all common operations. This provides a consistent and secure environment, and routines can ensure that each operation is properly logged. In such a setup, applications and users would have no access to the database tables directly, but can only execute specific stored routines.

Stored routines can provide improved performance because less information needs to be sent between the server and the client. The tradeoff is that this does increase the load on the database server because more of the work is done on the server side and less is done on the client (application) side. Consider this if many client machines (such as Web servers) are serviced by only one or a few database servers.

Stored routines also enable you to have libraries of functions in the database server. This is a feature shared by modern application languages that enable such design internally (for example, by using classes). Using these client application language features is beneficial for the programmer even outside the scope of database use.

MySQL follows the SQL:2003 syntax for stored routines, which is also used by IBM's DB2. All syntax described here is supported and any limitations and extensions are documented where appropriate.

Additional Resources

- You may find the Stored Procedures User Forum of use when working with stored procedures and functions.
20.2.1 Stored Routine Syntax

A stored routine is either a procedure or a function. Stored routines are created with the `CREATE PROCEDURE` and `CREATE FUNCTION` statements (see Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”). A procedure is invoked using a `CALL` statement (see Section 13.2.1, “CALL Statement”), and can only pass back values using output variables. A function can be called from inside a statement just like any other function (that is, by invoking the function’s name), and can return a scalar value. The body of a stored routine can use compound statements (see Section 13.6, “Compound-Statements”).

A stored routine can be dropped with the `DROP PROCEDURE` and `DROP FUNCTION` statements (see Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”), and altered with the `ALTER PROCEDURE` and `ALTER FUNCTION` statements (see Section 13.1.5, “ALTER PROCEDURE Statement”).

A stored procedure or function is associated with a particular database. This has several implications:

- When the routine is invoked, an implicit `USE db_name` is performed (and undone when the routine terminates). `USE` statements within stored routines are not permitted.

- You can qualify routine names with the database name. This can be used to refer to a routine that is not in the current database. For example, to invoke a stored procedure `p` or function `f` that is associated with the `test` database, you can say `CALL test.p()` or `test.f()`.

- When a database is dropped, all stored routines associated with it are dropped as well.

Recursion in stored procedures is permitted but disabled by default. To enable recursion, set the `max_sp_recursion_depth` server system variable to a value greater than zero. Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup. See Section 5.1.7, “Server System Variables”, for more information.

MySQL supports a very useful extension that enables the use of regular `SELECT` statements (that is, without using cursors or local variables) inside a stored procedure. The result set of such a query is simply sent directly to the client. Multiple `SELECT` statements generate multiple result sets, so the client must use a MySQL client library that supports multiple result sets. This means the client must use a client library from a version of MySQL at least as recent as 4.1. The client should also specify the `CLIENT_MULTI_RESULTS` option when it connects. For C programs, this can be done with the `mysql_real_connect()` C API function. See Section 23.7.6.52, “mysql_real_connect()”, and Section 23.7.15, “C API Multiple Statement Execution Support”.

20.2.2 Stored Routines and MySQL Privileges

The MySQL grant system takes stored routines into account as follows:

- The `CREATE ROUTINE` privilege is needed to create stored routines.
Stored Routine Metadata

- The `ALTER ROUTINE` privilege is needed to alter or drop stored routines. This privilege is granted automatically to the creator of a routine if necessary, and dropped from the creator when the routine is dropped.

- The `EXECUTE` privilege is required to execute stored routines. However, this privilege is granted automatically to the creator of a routine if necessary (and dropped from the creator when the routine is dropped). Also, the default `SQL SECURITY` characteristic for a routine is `DEFINER`, which enables users who have access to the database with which the routine is associated to execute the routine.

- If the `automatic_sp_privileges` system variable is 0, the `EXECUTE` and `ALTER ROUTINE` privileges are not automatically granted to and dropped from the routine creator.

- The creator of a routine is the account used to execute the `CREATE` statement for it. This might not be the same as the account named as the `DEFINER` in the routine definition.

The server manipulates the `mysql.proc` table in response to statements that create, alter, or drop stored routines. It is not supported that the server will notice manual manipulation of this table.

20.2.3 Stored Routine Metadata

Metadata about stored routines can be obtained as follows:

- Query the `ROUTINES` table of the `INFORMATION_SCHEMA` database. See Section 21.18, "The INFORMATION_SCHEMA ROUTINES Table".

- Use the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements to see routine definitions. See Section 13.7.5.11, "SHOW CREATE PROCEDURE Statement".

- Use the `SHOW PROCEDURE STATUS` and `SHOW FUNCTION STATUS` statements to see routine characteristics. See Section 13.7.5.29, "SHOW PROCEDURE STATUS Statement".

20.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID()

Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects (see Section 12.15, "Information Functions"). The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

- If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.

- For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements do not see a changed value.

20.3 Using Triggers

A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. Some uses for triggers are to perform checks of values to be inserted into a table or to perform calculations on values involved in an update.

A trigger is defined to activate when a statement inserts, updates, or deletes rows in the associated table. These row operations are trigger events. For example, rows can be inserted by `INSERT` or `LOAD DATA` statements, and an insert trigger activates for each inserted row. A trigger can be set to activate either before or after the trigger event. For example, you can have a trigger activate before each row that is inserted into a table or after each row that is updated.
Additional Resources

Important

MySQL triggers activate only for changes made to tables by SQL statements. This includes changes to base tables that underlie updatable views. Triggers do not activate for changes to tables made by APIs that do not transmit SQL statements to the MySQL Server. This means that triggers are not activated by updates made using the NDB API.

Triggers are not activated by changes in INFORMATION_SCHEMA or performance_schema tables. Those tables are actually views and triggers are not permitted on views.

To use triggers if you have upgraded to MySQL 5.5 from an older release that did not support triggers, you should upgrade your grant tables so that they contain the trigger-related privileges. See Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables".

The following sections describe the syntax for creating and dropping triggers, show some examples of how to use them, and indicate how to obtain trigger metadata.

Additional Resources

• You may find the Triggers User Forum of use when working with triggers.

• For answers to commonly asked questions regarding triggers in MySQL, see Section A.5, “MySQL 5.5 FAQ: Triggers”.

• There are some restrictions on the use of triggers; see Section 20.8, “Restrictions on Stored Programs”.

• Binary logging for triggers takes place as described in Section 20.7, “Stored Program Binary Logging”.

20.3.1 Trigger Syntax and Examples

To create a trigger or drop a trigger, use the CREATE TRIGGER or DROP TRIGGER statement, described in Section 13.1.19, “CREATE TRIGGER Statement”, and Section 13.1.30, “DROP TRIGGER Statement”.

Here is a simple example that associates a trigger with a table, to activate for INSERT operations. The trigger acts as an accumulator, summing the values inserted into one of the columns of the table.

```
mysql> CREATE TABLE account (acct_num INT, amount DECIMAL(10,2));
Query OK, 0 rows affected (0.03 sec)
mysql> CREATE TRIGGER ins_sum BEFORE INSERT ON account
    FOR EACH ROW SET @sum = @sum + NEW.amount;
Query OK, 0 rows affected (0.01 sec)
```

The CREATE TRIGGER statement creates a trigger named ins_sum that is associated with the account table. It also includes clauses that specify the trigger action time, the triggering event, and what to do when the trigger activates:

• The keyword BEFORE indicates the trigger action time. In this case, the trigger activates before each row inserted into the table. The other permitted keyword here is AFTER.

• The keyword INSERT indicates the trigger event; that is, the type of operation that activates the trigger. In the example, INSERT operations cause trigger activation. You can also create triggers for DELETE and UPDATE operations.

• The statement following FOR EACH ROW defines the trigger body; that is, the statement to execute each time the trigger activates, which occurs once for each row affected by the triggering event. In the
Trigger Syntax and Examples

example, the trigger body is a simple SET that accumulates into a user variable the values inserted into the amount column. The statement refers to the column as NEW.amount which means “the value of the amount column to be inserted into the new row.”

To use the trigger, set the accumulator variable to zero, execute an INSERT statement, and then see what value the variable has afterward:

```
mysql> SET @sum = 0;
mysql> INSERT INTO account VALUES(137,14.98),(141,1937.50),(97,-100.00);
mysql> SELECT @sum AS 'Total amount inserted';
+-----------------------+
<table>
<thead>
<tr>
<th>Total amount inserted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1852.48</td>
</tr>
</tbody>
</table>
+-----------------------+
```

In this case, the value of @sum after the INSERT statement has executed is 14.98 + 1937.50 - 100, or 1852.48.

To destroy the trigger, use a DROP TRIGGER statement. You must specify the schema name if the trigger is not in the default schema:

```
mysql> DROP TRIGGER test.ins_sum;
```

If you drop a table, any triggers for the table are also dropped.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

In addition to the requirement that trigger names be unique for a schema, there are other limitations on the types of triggers you can create. In particular, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two BEFORE UPDATE triggers for a table. To work around this, you can define a trigger that executes multiple statements by using the BEGIN ... END compound statement construct after FOR EACH ROW. (An example appears later in this section.)

Within the trigger body, the OLD and NEW keywords enable you to access columns in the rows affected by a trigger. OLD and NEW are MySQL extensions to triggers; they are not case-sensitive.

In an INSERT trigger, only NEW.col_name can be used; there is no old row. In a DELETE trigger, only OLD.col_name can be used; there is no new row. In an UPDATE trigger, you can use OLD.col_name to refer to the columns of a row before it is updated and NEW.col_name to refer to the columns of the row after it is updated.

A column named with OLD is read only. You can refer to it (if you have the SELECT privilege), but not modify it. You can refer to a column named with NEW if you have the SELECT privilege for it. In a BEFORE trigger, you can also change its value with SET NEW.col_name = value if you have the UPDATE privilege for it. This means you can use a trigger to modify the values to be inserted into a new row or used to update a row. (Such a SET statement has no effect in an AFTER trigger because the row change will have already occurred.)

In a BEFORE trigger, the NEW value for an AUTO_INCREMENT column is 0, not the sequence number that is generated automatically when the new row actually is inserted.

By using the BEGIN ... END construct, you can define a trigger that executes multiple statements. Within the BEGIN block, you also can use other syntax that is permitted within stored routines such as conditionals and loops. However, just as for stored routines, if you use the mysql program to define a trigger that executes multiple statements, it is necessary to redefine the mysql statement delimiter so
that you can use the `;` statement delimiter within the trigger definition. The following example illustrates these points. It defines an `UPDATE` trigger that checks the new value to be used for updating each row, and modifies the value to be within the range from 0 to 100. This must be a `BEFORE` trigger because the value must be checked before it is used to update the row:

```
mysql> delimiter //
mysql> CREATE TRIGGER upd_check BEFORE UPDATE ON account
    -> FOR EACH ROW
    -> BEGIN
    -> IF NEW.amount < 0 THEN
    -> SET NEW.amount = 0;
    -> ELSEIF NEW.amount > 100 THEN
    -> SET NEW.amount = 100;
    -> END IF;
    -> END; //
mysql> delimiter ;
```

It can be easier to define a stored procedure separately and then invoke it from the trigger using a simple `CALL` statement. This is also advantageous if you want to execute the same code from within several triggers.

There are limitations on what can appear in statements that a trigger executes when activated:

- The trigger cannot use the `CALL` statement to invoke stored procedures that return data to the client or that use dynamic SQL. (Stored procedures are permitted to return data to the trigger through `OUT` or `INOUT` parameters.)

- The trigger cannot use statements that explicitly or implicitly begin or end a transaction, such as `START TRANSACTION`, `COMMIT`, or `ROLLBACK`. (`ROLLBACK` to `SAVEPOINT` is permitted because it does not end a transaction.).

See also Section 20.8, “Restrictions on Stored Programs”.

MySQL handles errors during trigger execution as follows:

- If a `BEFORE` trigger fails, the operation on the corresponding row is not performed.

- A `BEFORE` trigger is activated by the attempt to insert or modify the row, regardless of whether the attempt subsequently succeeds.

- An `AFTER` trigger is executed only if any `BEFORE` triggers and the row operation execute successfully.

- An error during either a `BEFORE` or `AFTER` trigger results in failure of the entire statement that caused trigger invocation.

- For transactional tables, failure of a statement should cause rollback of all changes performed by the statement. Failure of a trigger causes the statement to fail, so trigger failure also causes rollback. For nontransactional tables, such rollback cannot be done, so although the statement fails, any changes performed prior to the point of the error remain in effect.

In MySQL 5.5, triggers can contain direct references to tables by name, such as the trigger named `testref` shown in this example:

```
CREATE TABLE test1(a1 INT);
CREATE TABLE test2(a2 INT);
CREATE TABLE test3(a3 INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
CREATE TABLE test4(
    a4 INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    b4 INT DEFAULT 0
);
```
Trigger Syntax and Examples

```
CREATE TRIGGER testref BEFORE INSERT ON test1
FOR EACH ROW
BEGIN
    INSERT INTO test2 SET a2 = NEW.a1;
    DELETE FROM test3 WHERE a3 = NEW.a1;
    UPDATE test4 SET b4 = b4 + 1 WHERE a4 = NEW.a1;
END;
```

```
INSERT INTO test3 (a3) VALUES
(NULL), (NULL), (NULL), (NULL), (NULL),
(NULL), (NULL), (NULL), (NULL), (NULL);

INSERT INTO test4 (a4) VALUES
(0), (0), (0), (0), (0), (0), (0), (0), (0), (0);
```

Suppose that you insert the following values into table `test1` as shown here:

```
mysql> INSERT INTO test1 VALUES
    (1), (3), (1), (7), (1), (8), (4), (4);
Query OK, 8 rows affected (0.01 sec)
Records: 8  Duplicates: 0  Warnings: 0
```

As a result, the four tables contain the following data:

```
mysql> SELECT * FROM test1;
+------+
| a1   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test2;
+------+
| a2   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test3;
+----+
| a3 |
+----+
|  2 |
|  5 |
|  6 |
|  9 |
+----+
```

2663
20.3.2 Trigger Metadata

Metadata about triggers can be obtained as follows:

- Query the TRIGGERS table of the INFORMATION_SCHEMA database. See Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”.
- Use the SHOW CREATE TRIGGER statement. See Section 13.7.5.13, “SHOW CREATE TRIGGER Statement”.
- Use the SHOW TRIGGERS statement. See Section 13.7.5.39, “SHOW TRIGGERS Statement”.

20.4 Using the Event Scheduler

The MySQL Event Scheduler manages the scheduling and execution of events, that is, tasks that run according to a schedule. The following discussion covers the Event Scheduler and is divided into the following sections:

- Section 20.4.1, “Event Scheduler Overview”, provides an introduction to and conceptual overview of MySQL Events.
- Section 20.4.3, “Event Syntax”, discusses the SQL statements for creating, altering, and dropping MySQL Events.
- Section 20.4.4, “Event Metadata”, shows how to obtain information about events and how this information is stored by the MySQL Server.
- Section 20.4.6, “The Event Scheduler and MySQL Privileges”, discusses the privileges required to work with events and the ramifications that events have with regard to privileges when executing.

Stored routines require the event table in the mysql database. This table is created during the MySQL 5.5 installation procedure. If you are upgrading to MySQL 5.5 from an earlier version, be sure to update your grant tables to make sure that the event table exists. See Section 2.11, “Upgrading MySQL”.

Additional Resources

- You may find the MySQL Event Scheduler User Forum of use when working with scheduled events.
- There are some restrictions on the use of events; see Section 20.8, “Restrictions on Stored Programs”.

2664
20.4.1 Event Scheduler Overview

MySQL Events are tasks that run according to a schedule. Therefore, we sometimes refer to them as scheduled events. When you create an event, you are creating a named database object containing one or more SQL statements to be executed at one or more regular intervals, beginning and ending at a specific date and time. Conceptually, this is similar to the idea of the Unix crontab (also known as a “cron job”) or the Windows Task Scheduler.

Scheduled tasks of this type are also sometimes known as “temporal triggers”, implying that these are objects that are triggered by the passage of time. While this is essentially correct, we prefer to use the term events to avoid confusion with triggers of the type discussed in Section 20.3, “Using Triggers”. Events should more specifically not be confused with “temporary triggers”. Whereas a trigger is a database object whose statements are executed in response to a specific type of event that occurs on a given table, a (scheduled) event is an object whose statements are executed in response to the passage of a specified time interval.

While there is no provision in the SQL Standard for event scheduling, there are precedents in other database systems, and you may notice some similarities between these implementations and that found in the MySQL Server.

MySQL Events have the following major features and properties:

• In MySQL, an event is uniquely identified by its name and the schema to which it is assigned.

• An event performs a specific action according to a schedule. This action consists of an SQL statement, which can be a compound statement in a BEGIN ... END block if desired (see Section 13.6, “Compound-Statements”). An event's timing can be either one-time or recurrent. A one-time event executes one time only. A recurrent event repeats its action at a regular interval, and the schedule for a recurring event can be assigned a specific start day and time, end day and time, both, or neither. (By default, a recurring event's schedule begins as soon as it is created, and continues indefinitely, until it is disabled or dropped.)

If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the GET_LOCK() function, or row or table locking.

• Users can create, modify, and drop scheduled events using SQL statements intended for these purposes. Syntactically invalid event creation and modification statements fail with an appropriate error message. A user may include statements in an event's action which require privileges that the user does not actually have. The event creation or modification statement succeeds but the event's action fails. See Section 20.4.6, “The Event Scheduler and MySQL Privileges” for details.

• Many of the properties of an event can be set or modified using SQL statements. These properties include the event's name, timing, persistence (that is, whether it is preserved following the expiration of its schedule), status (enabled or disabled), action to be performed, and the schema to which it is assigned. See Section 13.1.2, “ALTER EVENT Statement”.

The default definer of an event is the user who created the event, unless the event has been altered, in which case the definer is the user who issued the last ALTER EVENT statement affecting that event. An event can be modified by any user having the EVENT privilege on the database for which the event is defined. See Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

• An event's action statement may include most SQL statements permitted within stored routines. For restrictions, see Section 20.8, “Restrictions on Stored Programs".
20.4.2 Event Scheduler Configuration

Events are executed by a special event scheduler thread; when we refer to the Event Scheduler, we actually refer to this thread. When running, the event scheduler thread and its current state can be seen by users having the PROCESS privilege in the output of `SHOW PROCESSLIST`, as shown in the discussion that follows.

The global `event_scheduler` system variable determines whether the Event Scheduler is enabled and running on the server. It has one of these 3 values, which affect event scheduling as described here:

- **OFF**: The Event Scheduler is stopped. The event scheduler thread does not run, is not shown in the output of `SHOW PROCESSLIST`, and no scheduled events are executed. `OFF` is the default value for `event_scheduler`.

  When the Event Scheduler is stopped (`event_scheduler` is `OFF`), it can be started by setting the value of `event_scheduler` to `ON`. (See next item.)

- **ON**: The Event Scheduler is started; the event scheduler thread runs and executes all scheduled events.

  When the Event Scheduler is `ON`, the event scheduler thread is listed in the output of `SHOW PROCESSLIST` as a daemon process, and its state is represented as shown here:

  ```
  mysql> SHOW PROCESSLIST\G
  *************************** 1. row ***************************
  Id: 1
  User: root
  Host: localhost
  db: NULL
  Command: Query
  Time: 0
  State: NULL
  Info: show processlist
  *************************** 2. row ***************************
  Id: 2
  User: event_scheduler
  Host: localhost
  db: NULL
  Command: Daemon
  Time: 3
  State: Waiting for next activation
  Info: NULL
  2 rows in set (0.00 sec)
  ```

  Event scheduling can be stopped by setting the value of `event_scheduler` to `OFF`.

- **DISABLED**: This value renders the Event Scheduler nonoperational. When the Event Scheduler is `DISABLED`, the event scheduler thread does not run (and so does not appear in the output of `SHOW PROCESSLIST`). In addition, the Event Scheduler state cannot be changed at runtime.

If the Event Scheduler status has not been set to `DISABLED`, `event_scheduler` can be toggled between `ON` and `OFF` (using `SET`). It is also possible to use 0 for `OFF`, and 1 for `ON` when setting this variable. Thus, any of the following 4 statements can be used in the `mysql` client to turn on the Event Scheduler:

```plaintext
SET GLOBAL event_scheduler = ON;
SET @@GLOBAL.event_scheduler = ON;
SET GLOBAL event_scheduler = 1;
SET @@GLOBAL.event_scheduler = 1;
```

Similarly, any of these 4 statements can be used to turn off the Event Scheduler:

```plaintext
SET GLOBAL event_scheduler = OFF;
SET @@GLOBAL.event_scheduler = OFF;
```
**Event Syntax**

```sql
SET GLOBAL event_scheduler = 0;
SET @@GLOBAL.event_scheduler = 0;
```

Although `ON` and `OFF` have numeric equivalents, the value displayed for `event_scheduler` by `SELECT` or `SHOW VARIABLES` is always one of `OFF`, `ON`, or `DISABLED`. **DISABLED has no numeric equivalent.** For this reason, `ON` and `OFF` are usually preferred over `1` and `0` when setting this variable.

Note that attempting to set `event_scheduler` without specifying it as a global variable causes an error:

```sql
mysql< SET @@event_scheduler = OFF;
ERROR 1229 (HY000): Variable 'event_scheduler' is a GLOBAL variable and should be set with SET GLOBAL
```

---

**Important**

It is possible to set the Event Scheduler to `DISABLED` only at server startup. If `event_scheduler` is `ON` or `OFF`, you cannot set it to `DISABLED` at runtime. Also, if the Event Scheduler is set to `DISABLED` at startup, you cannot change the value of `event_scheduler` at runtime.

To disable the event scheduler, use one of the following two methods:

- As a command-line option when starting the server:
  ```
  --event-scheduler=DISABLED
  ```

- In the server configuration file (`.my.cnf`, or `my.ini` on Windows systems), include the line where it will be read by the server (for example, in a `[mysqld]` section):
  ```
  event_scheduler=DISABLED
  ```

To enable the Event Scheduler, restart the server without the `--event-scheduler=DISABLED` command-line option, or after removing or commenting out the line containing `event-scheduler=DISABLED` in the server configuration file, as appropriate. Alternatively, you can use `ON` (or `1`) or `OFF` (or `0`) in place of the `DISABLED` value when starting the server.

---

**Note**

You can issue event-manipulation statements when `event_scheduler` is set to `DISABLED`. No warnings or errors are generated in such cases (provided that the statements are themselves valid). However, scheduled events cannot execute until this variable is set to `ON` (or `1`). Once this has been done, the event scheduler thread executes all events whose scheduling conditions are satisfied.

Starting the MySQL server with the `--skip-grant-tables` option causes `event_scheduler` to be set to `DISABLED`, overriding any other value set either on the command line or in the `.my.cnf` or `my.ini` file (Bug #26807).

For SQL statements used to create, alter, and drop events, see Section 20.4.3, “Event Syntax”.

MySQL provides an `EVENTS` table in the `INFORMATION_SCHEMA` database. This table can be queried to obtain information about scheduled events which have been defined on the server. See Section 20.4.4, “Event Metadata”, and Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”, for more information.

For information regarding event scheduling and the MySQL privilege system, see Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

**20.4.3 Event Syntax**
Event Metadata

MySQL provides several SQL statements for working with scheduled events:

- New events are defined using the `CREATE EVENT` statement. See Section 13.1.11, “CREATE EVENT Statement”.

- The definition of an existing event can be changed by means of the `ALTER EVENT` statement. See Section 13.1.2, “ALTER EVENT Statement”.

- When a scheduled event is no longer wanted or needed, it can be deleted from the server by its definer using the `DROP EVENT` statement. See Section 13.1.22, “DROP EVENT Statement”. Whether an event persists past the end of its schedule also depends on its `ON COMPLETION` clause, if it has one. See Section 13.1.11, “CREATE EVENT Statement”.

An event can be dropped by any user having the `EVENT` privilege for the database on which the event is defined. See Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

20.4.4 Event Metadata

Metadata about events can be obtained as follows:

- Query the `event` table of the `mysql` database.

- Query the `EVENTS` table of the `INFORMATION_SCHEMA` database. See Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”.

- Use the `SHOW CREATE EVENT` statement. See Section 13.7.5.9, “SHOW CREATE EVENT Statement”.

- Use the `SHOW EVENTS` statement. See Section 13.7.5.19, “SHOW EVENTS Statement”.

Event Scheduler Time Representation

Each session in MySQL has a session time zone (STZ). This is the session `time_zone` value that is initialized from the server’s global `time_zone` value when the session begins but may be changed during the session.

The session time zone that is current when a `CREATE EVENT` or `ALTER EVENT` statement executes is used to interpret times specified in the event definition. This becomes the event time zone (ETZ); that is, the time zone that is used for event scheduling and is in effect within the event as it executes.

For representation of event information in the `mysql.event` table, the `execute_at`, `starts`, and `ends` times are converted to UTC and stored along with the event time zone. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. The `last_executed` time is also stored in UTC.

If you select information from `mysql.event`, the times just mentioned are retrieved as UTC values. These times can also be obtained by selecting from the `INFORMATION_SCHEMA.EVENTS` table or from `SHOW EVENTS`, but they are reported as ETZ values. Other times available from these sources indicate when an event was created or last altered; these are displayed as STZ values. The following table summarizes representation of event times.

<table>
<thead>
<tr>
<th>Value</th>
<th><code>mysql.event</code></th>
<th><code>INFORMATION_SCHEMA.EVENTS</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Execute at</td>
<td>UTC</td>
<td>ETZ</td>
</tr>
<tr>
<td>Starts</td>
<td>UTC</td>
<td>ETZ</td>
</tr>
<tr>
<td>Ends</td>
<td>UTC</td>
<td>ETZ</td>
</tr>
<tr>
<td>Last executed</td>
<td>UTC</td>
<td>ETZ</td>
</tr>
<tr>
<td>Created</td>
<td>STZ</td>
<td>STZ</td>
</tr>
</tbody>
</table>
20.4.5 Event Scheduler Status

The Event Scheduler writes information about event execution that terminates with an error or warning to the MySQL Server's error log. See Section 20.4.6, “The Event Scheduler and MySQL Privileges” for an example.

Information about the state of the Event Scheduler for debugging and troubleshooting purposes can be obtained by running `mysqladmin debug` (see Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”); after running this command, the server’s error log contains output relating to the Event Scheduler, similar to what is shown here:

```
Events status:
LLA = Last Locked At  LUA = Last Unlocked At
WOC = Waiting On Condition  DL = Data Locked

Event scheduler status:
State      : INITIALIZED
Thread id  : 0
LLA        : init_scheduler:313
LUA        : init_scheduler:318
WOC        : NO
Workers    : 0
Executed   : 0
Data locked: NO

Event queue status:
Element count   : 1
Data locked     : NO
Attempting lock : NO
LLA             : init_queue:148
LUA             : init_queue:168
WOC             : NO
Next activation : 0000-00-00 00:00:00
```

In statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For frequently executed events, it is possible for this to result in many logged messages. For example, for `SELECT ... INTO var_list` statements, if the query returns no rows, a warning with error code 1329 occurs (No data), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (Result consisted of more than one row). For either condition, you can avoid having the warnings be logged by declaring a condition handler; see Section 13.6.7.2, “DECLARE ... HANDLER Statement”. For statements that may retrieve multiple rows, another strategy is to use `LIMIT 1` to limit the result set to a single row.

20.4.6 The Event Scheduler and MySQL Privileges

To enable or disable the execution of scheduled events, it is necessary to set the value of the global `event_scheduler` system variable. This requires privileges sufficient to set global system variables. See Section 5.1.8.1, “System Variable Privileges”.

The `EVENT` privilege governs the creation, modification, and deletion of events. This privilege can be bestowed using `GRANT`. For example, this `GRANT` statement confers the `EVENT` privilege for the schema named `myschema` on the user `jon@ghidora`:

```
GRANT EVENT ON myschema.* TO jon@ghidora;
```

(We assume that this user account already exists, and that we wish for it to remain unchanged otherwise.)
To grant this same user the EVENT privilege on all schemas, use the following statement:

```
GRANT EVENT ON *.* TO jon@ghidora;
```

The EVENT privilege has global or schema-level scope. Therefore, trying to grant it on a single table results in an error as shown:

```
mysql> GRANT EVENT ON myschema.mytable TO jon@ghidora;
ERROR 1144 (42000): Illegal GRANT/REVOKE command; please consult the manual to see which privileges can be used
```

It is important to understand that an event is executed with the privileges of its definer, and that it cannot perform any actions for which its definer does not have the requisite privileges. For example, suppose that jon@ghidora has the EVENT privilege for myschema. Suppose also that this user has the SELECT privilege for myschema, but no other privileges for this schema. It is possible for jon@ghidora to create a new event such as this one:

```
CREATE EVENT e_store_ts
ON SCHEDULE EVERY 10 SECOND
DO
  INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
```

The user waits for a minute or so, and then performs a SELECT * FROM mytable; query, expecting to see several new rows in the table. Instead, the table is empty. Since the user does not have the INSERT privilege for the table in question, the event has no effect.

If you inspect the MySQL error log (hostname.err), you can see that the event is executing, but the action it is attempting to perform fails, as indicated by RetCode=0:

```
060209 22:39:44 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:39:54 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:39:54 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:40:04 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:40:04 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
```

Since this user very likely does not have access to the error log, it is possible to verify whether the event's action statement is valid by executing it directly:

```
mysql> INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
ERROR 1142 (42000): INSERT command denied to user 'jon'@'ghidora' for table 'mytable'
```

Inspection of the INFORMATION_SCHEMA.EVENTS table shows that e_store_ts exists and is enabled, but its LAST_EXECUTED column is NULL:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
> WHERE EVENT_NAME='e_store_ts'
> AND EVENT_SCHEMA='myschema'\G
*************************** 1. row ***************************
  EVENT_CATALOG: NULL
  EVENT_SCHEMA: myschema
  EVENT_NAME: e_store_ts
  DEFINER: jon@ghidora
  EVENT_BODY: SQL
  EVENT_DEFINITION: INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP())
  EVENT_TYPE: RECURRING
  EXECUTE_AT: NULL
  INTERVAL_VALUE: 5
  INTERVAL_FIELD: SECOND
  SQL_MODE: NULL
  STARTS: 0000-00-00 00:00:00
  ENDS: 0000-00-00 00:00:00
```
To rescind the `EVENT` privilege, use the `REVOKE` statement. In this example, the `EVENT` privilege on the schema `myschema` is removed from the `jon@ghidora` user account:

```sql
REVOKE EVENT ON myschema.* FROM jon@ghidora;
```

**Important**

Revoking the `EVENT` privilege from a user does not delete or disable any events that may have been created by that user.

An event is not migrated or dropped as a result of renaming or dropping the user who created it.

Suppose that the user `jon@ghidora` has been granted the `EVENT` and `INSERT` privileges on the `myschema` schema. This user then creates the following event:

```sql
CREATE EVENT e_insert
  ON SCHEDULE EVERY 7 SECOND
  DO
    INSERT INTO myschema.mytable;
```

After this event has been created, `root` revokes the `EVENT` privilege for `jon@ghidora`. However, `e_insert` continues to execute, inserting a new row into `mytable` each seven seconds. The same would be true if `root` had issued either of these statements:

- DROP USER `jon@ghidora`;
- RENAME USER `jon@ghidora` TO `someotherguy@ghidora`;

You can verify that this is true by examining the `mysql.event` table (discussed later in this section) or the `INFORMATION_SCHEMA.EVENTS` table (see Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”) before and after issuing a `DROP USER` or `RENAME USER` statement.

Event definitions are stored in the `mysql.event` table. To drop an event created by another user account, the MySQL `root` user (or another user with the necessary privileges) can delete rows from this table. For example, to remove the event `e_insert` shown previously, `root` can use the following statement:

```sql
DELETE FROM mysql.event
  WHERE db = 'myschema'
    AND name = 'e_insert';
```

It is very important to match the event name and database schema name when deleting rows from the `mysql.event` table. This is because different events of the same name can exist in different schemas.

Users’ `EVENT` privileges are stored in the `Event_priv` columns of the `mysql.user` and `mysql.db` tables. In both cases, this column holds one of the values ‘Y’ or ‘N’. ‘N’ is the default. `mysql.user.Event_priv` is set to ‘Y’ for a given user only if that user has the global `EVENT` privilege (that is, if the privilege was bestowed using `GRANT EVENT ON *.*`). For a schema-level `EVENT` privilege, `GRANT` creates a row in `mysql.db` and sets that row’s `Db` column to the name of the schema, the `User` column to the name of the user, and the `Event_priv` column to ‘Y’. There should never be any need to manipulate these tables directly, since the `GRANT EVENT` and `REVOKE EVENT` statements perform the required operations on them.
Five status variables provide counts of event-related operations (but not of statements executed by events; see Section 20.8, “Restrictions on Stored Programs”). These are:

- **Com_create_event**: The number of `CREATE EVENT` statements executed since the last server restart.
- **Com_alter_event**: The number of `ALTER EVENT` statements executed since the last server restart.
- **Com_drop_event**: The number of `DROP EVENT` statements executed since the last server restart.
- **Com_show_create_event**: The number of `SHOW CREATE EVENT` statements executed since the last server restart.
- **Com_show_events**: The number of `SHOW EVENTS` statements executed since the last server restart.

You can view current values for all of these at one time by running the statement `SHOW STATUS LIKE '%event%';`.

### 20.5 Using Views

MySQL supports views, including updatable views. Views are stored queries that when invoked produce a result set. A view acts as a virtual table.

To use views if you have upgraded to MySQL 5.5 from an older release that did not support views, you should upgrade your grant tables so that they contain the view-related privileges. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

The following discussion describes the syntax for creating and dropping views, and shows some examples of how to use them.

### Additional Resources

- You may find the [Views User Forum](https://community.mysql.com) of use when working with views.
- For answers to some commonly asked questions regarding views in MySQL, see Section A.6, “MySQL 5.5 FAQ: Views”.
- There are some restrictions on the use of views; see Section 20.9, “Restrictions on Views”.

### 20.5.1 View Syntax

The `CREATE VIEW` statement creates a new view (see Section 13.1.20, “CREATE VIEW Statement”). To alter the definition of a view or drop a view, use `ALTER VIEW` (see Section 13.1.9, “ALTER VIEW Statement”), or `DROP VIEW` (see Section 13.1.31, “DROP VIEW Statement”).

A view can be created from many kinds of `SELECT` statements. It can refer to base tables or other views. It can use joins, `UNION`, and subqueries. The `SELECT` need not even refer to any tables. The following example defines a view that selects two columns from another table, as well as an expression calculated from those columns:

```sql
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50), (5, 60);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
<table>
<thead>
<tr>
<th>qty</th>
<th>price</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>300</td>
</tr>
</tbody>
</table>
+------+-------+-------+
```
20.5.2 View Processing Algorithms

The optional **ALGORITHM** clause for **CREATE VIEW** or **ALTER VIEW** is a MySQL extension to standard SQL. It affects how MySQL processes the view. **ALGORITHM** takes three values: **MERGE**, **TEMPTABLE**, or **UNDEFINED**.

- For **MERGE**, the text of a statement that refers to the view and the view definition are merged such that parts of the view definition replace corresponding parts of the statement.
- For **TEMPTABLE**, the results from the view are retrieved into a temporary table, which then is used to execute the statement.
- For **UNDEFINED**, MySQL chooses which algorithm to use. It prefers **MERGE** over **TEMPTABLE** if possible, because **MERGE** is usually more efficient and because a view cannot be updatable if a temporary table is used.
- If no **ALGORITHM** clause is present, **UNDEFINED** is the default algorithm.

A reason to specify **TEMPTABLE** explicitly is that locks can be released on underlying tables after the temporary table has been created and before it is used to finish processing the statement. This might result in quicker lock release than the **MERGE** algorithm so that other clients that use the view are not blocked as long.

A view algorithm can be **UNDEFINED** for three reasons:

- No **ALGORITHM** clause is present in the **CREATE VIEW** statement.
- The **CREATE VIEW** statement has an explicit **ALGORITHM = UNDEFINED** clause.
- **ALGORITHM = MERGE** is specified for a view that can be processed only with a temporary table. In this case, MySQL generates a warning and sets the algorithm to **UNDEFINED**.

As mentioned earlier, **MERGE** is handled by merging corresponding parts of a view definition into the statement that refers to the view. The following examples briefly illustrate how the **MERGE** algorithm works. The examples assume that there is a view **v_merge** that has this definition:

```sql
CREATE ALGORITHM = MERGE VIEW v_merge (vc1, vc2) AS
SELECT c1, c2 FROM t WHERE c3 > 100;
```

**Example 1:** Suppose that we issue this statement:

```sql
SELECT * FROM v_merge;
```

MySQL handles the statement as follows:

- **v_merge** becomes **t**
- ***** becomes **vc1, vc2**, which corresponds to **c1, c2**
- The view **WHERE** clause is added

The resulting statement to be executed becomes:

```sql
SELECT c1, c2 FROM t WHERE c3 > 100;
```
Example 2: Suppose that we issue this statement:

```
SELECT * FROM v_merge WHERE vc1 < 100;
```

This statement is handled similarly to the previous one, except that `vc1 < 100` becomes `c1 < 100` and the view `WHERE` clause is added to the statement `WHERE` clause using an `AND` connective (and parentheses are added to make sure the parts of the clause are executed with correct precedence). The resulting statement to be executed becomes:

```
SELECT c1, c2 FROM t WHERE (c3 > 100) AND (c1 < 100);
```

Effectively, the statement to be executed has a `WHERE` clause of this form:

```
WHERE (select WHERE) AND (view WHERE)
```

If the `MERGE` algorithm cannot be used, a temporary table must be used instead. `MERGE` cannot be used if the view contains any of the following constructs:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)
- `DISTINCT`
- `GROUP BY`
- `HAVING`
- `LIMIT`
- `UNION` or `UNION ALL`
- Subquery in the select list
- Assignment to user variables
- Refers only to literal values (in this case, there is no underlying table)

### 20.5.3 Updatable and Insertable Views

Some views are updatable and references to them can be used to specify tables to be updated in data change statements. That is, you can use them in statements such as `UPDATE`, `DELETE`, or `INSERT` to update the contents of the underlying table.

For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable. To be more specific, a view is not updatable if it contains any of the following:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)
- `DISTINCT`
- `GROUP BY`
- `HAVING`
- `UNION` or `UNION ALL`
- Subquery in the select list
- Certain joins (see additional join discussion later in this section)
- Reference to nonupdatable view in the `FROM` clause
Updatable and Insertable Views

- Subquery in the \texttt{WHERE} clause that refers to a table in the \texttt{FROM} clause
- Refers only to literal values (in this case, there is no underlying table to update)
- \texttt{ALGORITHM = TEMPTABLE} (use of a temporary table always makes a view nonupdatable)
- Multiple references to any column of a base table

It is sometimes possible for a multiple-table view to be updatable, assuming that it can be processed with the \texttt{MERGE} algorithm. For this to work, the view must use an inner join (not an outer join or a \texttt{UNION}). Also, only a single table in the view definition can be updated, so the \texttt{SET} clause must name only columns from one of the tables in the view. Views that use \texttt{UNION ALL} are not permitted even though they might be theoretically updatable.

With respect to insertability (being updatable with \texttt{INSERT} statements), an updatable view is insertable if it also satisfies these additional requirements for the view columns:

- There must be no duplicate view column names.
- The view must contain all columns in the base table that do not have a default value.
- The view columns must be simple column references. They must not be expressions or composite expressions, such as these:

  \begin{verbatim}
  3.14159
col1 + 3
UPPER(col2)
col3 / col4
(subquery)
  \end{verbatim}

MySQL sets a flag, called the view updatability flag, at \texttt{CREATE VIEW} time. The flag is set to \texttt{YES} (true) if \texttt{UPDATE} and \texttt{DELETE} (and similar operations) are legal for the view. Otherwise, the flag is set to \texttt{NO} (false). The \texttt{IS_UPDATABLE} column in the \texttt{INFORMATION_SCHEMA.VIEWS} table displays the status of this flag. It means that the server always knows whether a view is updatable.

If a view is not updatable, statements such \texttt{UPDATE}, \texttt{DELETE}, and \texttt{INSERT} are illegal and are rejected. (Even if a view is updatable, it might not be possible to insert into it, as described elsewhere in this section.)

The updatability of views may be affected by the value of the \texttt{updatable_views_with_limit} system variable. See Section 5.1.7, “Server System Variables”.

Earlier discussion in this section pointed out that a view is not insertable if not all columns are simple column references (for example, if it contains columns that are expressions or composite expressions). Although such a view is not insertable, it can be updatable if you update only columns that are not expressions. Consider this view:

\begin{verbatim}
CREATE VIEW v AS SELECT col1, 1 AS col2 FROM t;
\end{verbatim}

This view is not insertable because \texttt{col2} is an expression. But it is updatable if the update does not try to update \texttt{col2}. This update is permissible:

\begin{verbatim}
UPDATE v SET col1 = 0;
\end{verbatim}

This update is not permissible because it attempts to update an expression column:

\begin{verbatim}
UPDATE v SET col2 = 0;
\end{verbatim}

For a multiple-table updatable view, \texttt{INSERT} can work if it inserts into a single table. \texttt{DELETE} is not supported.
**20.5.4 The View WITH CHECK OPTION Clause**

The **WITH CHECK OPTION** clause can be given for an updatable view to prevent inserts to rows for which the **WHERE** clause in the **select_statement** is not true. It also prevents updates to rows for which the **WHERE** clause is true but the update would cause it to be not true (in other words, it prevents visible rows from being updated to nonvisible rows).

In a **WITH CHECK OPTION** clause for an updatable view, the **LOCAL** and **CASCADED** keywords determine the scope of check testing when the view is defined in terms of another view. When neither keyword is given, the default is **CASCADED**. The **LOCAL** keyword restricts the **CHECK OPTION** only to the view being defined. **CASCADED** causes the checks for underlying views to be evaluated as well.

Consider the definitions for the following table and set of views:

```
CREATE TABLE t1 (a INT);
CREATE VIEW v1 AS SELECT * FROM t1 WHERE a < 2
  WITH CHECK OPTION;
CREATE VIEW v2 AS SELECT * FROM v1 WHERE a > 0
  WITH LOCAL CHECK OPTION;
CREATE VIEW v3 AS SELECT * FROM v1 WHERE a > 0
  WITH CASCADED CHECK OPTION;
```

Here the **v2** and **v3** views are defined in terms of another view, **v1**. **v2** has a **LOCAL** check option, so inserts are tested only against the **v2** check. **v3** has a **CASCADED** check option, so inserts are tested not only against its own check, but against those of underlying views. The following statements illustrate these differences:

```
mysql> INSERT INTO v2 VALUES (2);
Query OK, 1 row affected (0.00 sec)
mysql> INSERT INTO v3 VALUES (2);
ERROR 1369 (HY000): CHECK OPTION failed 'test.v3'
```

**20.5.5 View Metadata**

Metadata about views can be obtained as follows:

- Query the **VIEWS** table of the **INFORMATION_SCHEMA** database. See Section 21.28, “The **INFORMATION_SCHEMA** VIEWS Table”.
- Use the **SHOW CREATE VIEW** statement. See Section 13.7.5.14, “SHOW CREATE VIEW Statement”.

**20.6 Stored Object Access Control**

Stored programs (procedures, functions, triggers, and events) and views are defined prior to use and, when referenced, execute within a security context that determines their privileges. These privileges are controlled by their **DEFINER** attribute and **SQL SECURITY** characteristic.

- The **DEFINER** Attribute
- The **SQL SECURITY** Characteristic
- Examples
The DEFINER Attribute

All stored object definitions can include a DEFINER attribute that names a MySQL account. If a definition omits the DEFINER attribute, the default definer is the user who creates the object.

MySQL uses the following rules to control which accounts a user can specify in an object DEFINER attribute:

• If you have the SUPER privilege, you can specify any account as the DEFINER value, although a warning is generated if the account does not exist.

• Otherwise, the only permitted account is your own, either specified literally or as CURRENT_USER or CURRENT_USER(). You cannot set the definer to some other account.

Creating a stored object with a nonexistent DEFINER account may have negative consequences:

• For a stored routine, an error occurs at routine execution time if the SQL SECURITY value is DEFINER but the definer account does not exist.

• For a trigger, it is not a good idea for trigger activation to occur until the account actually does exist. Otherwise, the behavior with respect to privilege checking is undefined.

• For an event, an error occurs at event execution time if the account does not exist.

• For a view, an error occurs when the view is referenced if the SQL SECURITY value is DEFINER but the definer account does not exist.

The SQL SECURITY Characteristic

Definitions for stored routines (procedures and functions) and views can include an SQL SECURITY characteristic with a value of DEFINER or INVOKER to specify whether the object executes in definer or invoker context. If a definition omits the SQL SECURITY characteristic, the default is definer context.

Triggers and events have no SQL SECURITY characteristic and always execute in definer context. The server invokes these objects automatically as necessary, so there is no invoking user.

Definer and invoker security contexts differ as follows:

• A stored object that executes in definer security context executes with the privileges of the account named by its DEFINER attribute. These privileges may be entirely different from those of the invoking user. The invoker must have appropriate privileges to reference the object (for example, EXECUTE to call a stored procedure or SELECT to select from a view), but during object execution, the invoker's privileges are ignored and only the DEFINER account privileges matter. If the DEFINER account has few privileges, the object is correspondingly limited in the operations it can perform. If the DEFINER account is highly privileged (such as a root account), the object can perform powerful operations no matter who invokes it.

• A stored routine or view that executes in invoker security context can perform only operations for which the invoker has privileges. The DEFINER attribute has no effect during object execution.

Examples

Consider the following stored procedure, which is declared with SQL SECURITY DEFINER to execute in definer security context:

CREATE DEFINER = 'admin'@'localhost' PROCEDURE p1()
SQL SECURITY DEFINER
BEGIN
    UPDATE t1 SET counter = counter + 1;
END;

Any user who has the `EXECUTE` privilege for `p1` can invoke it with a `CALL` statement. However, when `p1` executes, it does so in definer security context and thus executes with the privileges of `'admin'@'localhost'`, the account named in the `DEFINER` attribute. This account must have the `EXECUTE` privilege for `p1` as well as the `UPDATE` privilege for the table `t1` referenced within the object body. Otherwise, the procedure fails.

Now consider this stored procedure, which is identical to `p1` except that its `SQL SECURITY` characteristic is `INVOKER`:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE p2()
SQL SECURITY INVOKER
BEGIN
    UPDATE t1 SET counter = counter + 1;
END;
```

Unlike `p1`, `p2` executes in invoker security context and thus with the privileges of the invoking user regardless of the `DEFINER` attribute value. `p2` fails if the invoker lacks the `EXECUTE` privilege for `p2` or the `UPDATE` privilege for the table `t1`.

### Risk-Minimization Guidelines

To minimize the risk potential for stored object creation and use, follow these guidelines:

- For a stored routine or view, use `SQL SECURITY INVOKER` in the object definition when possible so that it can be used only by users with permissions appropriate for the operations performed by the object.
- If you create definer-context stored objects while using an account that has the `SUPER` privilege, specify an explicit `DEFINER` attribute that names an account possessing only the privileges required for the operations performed by the object. Specify a highly privileged `DEFINER` account only when absolutely necessary.
- Administrators can prevent users from creating stored objects that specify highly privileged `DEFINER` accounts by not granting them the `SUPER` privilege.
- Definer-context objects should be written keeping in mind that they may be able to access data for which the invoking user has no privileges. In some cases, you can prevent references to these objects by not granting unauthorized users particular privileges:
  - A stored routine cannot be referenced by a user who does not have the `EXECUTE` privilege for it.
  - A view cannot be referenced by a user who does not have the appropriate privilege for it (`SELECT` to select from it, `INSERT` to insert into it, and so forth).
- However, no such control exists for triggers and events because they always execute in definer context. The server invokes these objects automatically as necessary; users do not reference them directly:
  - A trigger is activated by access to the table with which it is associated, even ordinary table accesses by users with no special privileges.
  - An event is executed by the server on a scheduled basis.
- In both cases, if the `DEFINER` account is highly privileged, the object may be able to perform sensitive or dangerous operations. This remains true if the privileges needed to create the object are revoked from...
the account of the user who created it. Administrators should be especially careful about granting users object-creation privileges.

20.7 Stored Program Binary Logging

The binary log contains information about SQL statements that modify database contents. This information is stored in the form of “events” that describe the modifications. (Binary log events differ from scheduled event stored objects.) The binary log has two important purposes:

• For replication, the binary log is used on master replication servers as a record of the statements to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 17.2, “Replication Implementation”.

• Certain data recovery operations require use of the binary log. After a backup file has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events bring databases up to date from the point of the backup. See Section 7.3.2, “Using Backups for Recovery”.

However, if logging occurs at the statement level, there are certain binary logging issues with respect to stored programs (stored procedures and functions, triggers, and events):

• In some cases, a statement might affect different sets of rows on master and slave.

• Replicated statements executed on a slave are processed by the slave SQL thread, which has full privileges. It is possible for a procedure to follow different execution paths on master and slave servers, so a user can write a routine containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges.

• If a stored program that modifies data is nondeterministic, it is not repeatable. This can result in different data on master and slave, or cause restored data to differ from the original data.

This section describes how MySQL handles binary logging for stored programs. It states the current conditions that the implementation places on the use of stored programs, and what you can do to avoid logging problems. It also provides additional information about the reasons for these conditions.

In general, the issues described here result when binary logging occurs at the SQL statement level (statement-based binary logging). If you use row-based binary logging, the log contains changes made to individual rows as a result of executing SQL statements. When routines or triggers execute, row changes are logged, not the statements that make the changes. For stored procedures, this means that the CALL statement is not logged. For stored functions, row changes made within the function are logged, not the function invocation. For triggers, row changes made by the trigger are logged. On the slave side, only the row changes are seen, not the stored program invocation.

Mixed format binary logging (binlog_format=MIXED) uses statement-based binary logging, except for cases where only row-based binary logging is guaranteed to lead to proper results. With mixed format, when a stored function, stored procedure, trigger, event, or prepared statement contains anything that is not safe for statement-based binary logging, the entire statement is marked as unsafe and logged in row format. The statements used to create and drop procedures, functions, triggers, and events are always safe, and are logged in statement format. For more information about row-based, mixed, and statement-based logging, and how safe and unsafe statements are determined, see Section 17.1.2, “Replication Formats”.

Unless noted otherwise, the remarks here assume that binary logging is enabled on the server (see Section 5.4.4, “The Binary Log”.) If the binary log is not enabled, replication is not possible, nor is the binary log available for data recovery.
The conditions on the use of stored functions in MySQL can be summarized as follows. These conditions do not apply to stored procedures or Event Scheduler events and they do not apply unless binary logging is enabled.

• To create or alter a stored function, you must have the **SUPER** privilege, in addition to the **CREATE ROUTINE** or **ALTER ROUTINE** privilege that is normally required. (Depending on the **DEFINER** value in the function definition, **SUPER** might be required regardless of whether binary logging is enabled. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Statements").

• When you create a stored function, you must declare either that it is deterministic or that it does not modify data. Otherwise, it may be unsafe for data recovery or replication.

By default, for a **CREATE FUNCTION** statement to be accepted, at least one of **DETERMINISTIC**, **NO SQL**, or **READS SQL DATA** must be specified explicitly. Otherwise an error occurs:

```
ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL, or READS SQL DATA in its declaration and binary logging is enabled
(you *might* want to use the less safe log_bin_trust_function_creators variable)
```

This function is deterministic (and does not modify data), so it is safe:

```
CREATE FUNCTION f1(i INT)
RETURNS INT
DETERMINISTIC
READS SQL DATA
BEGIN
  RETURN i;
END;
```

This function uses **UUID()**, which is not deterministic, so the function also is not deterministic and is not safe:

```
CREATE FUNCTION f2()
RETURNS CHAR(36) CHARACTER SET utf8
BEGIN
  RETURN UUID();
END;
```

This function modifies data, so it may not be safe:

```
CREATE FUNCTION f3(p_id INT)
RETURNS INT
BEGIN
  UPDATE t SET modtime = NOW() WHERE id = p_id;
  RETURN ROW_COUNT();
END;
```

Assessment of the nature of a function is based on the “honesty” of the creator. MySQL does not check that a function declared **DETERMINISTIC** is free of statements that produce nondeterministic results.

• When you attempt to execute a stored function, if **binlog_format=STATEMENT** is set, the **DETERMINISTIC** keyword must be specified in the function definition. If this is not the case, an error is generated and the function does not run, unless **log_bin_trust_functionCreators=1** is specified to override this check (see below). For recursive function calls, the **DETERMINISTIC** keyword is required on the outermost call only. If row-based or mixed binary logging is in use, the statement is accepted and replicated even if the function was defined without the **DETERMINISTIC** keyword.

• Because MySQL does not check if a function really is deterministic at creation time, the invocation of a stored function with the **DETERMINISTIC** keyword might carry out an action that is unsafe for statement-based logging, or invoke a function or procedure containing unsafe statements. If this occurs
when `binlog_format=STATEMENT` is set, a warning message is issued. If row-based or mixed binary logging is in use, no warning is issued, and the statement is replicated in row-based format.

- To relax the preceding conditions on function creation (that you must have the `SUPER` privilege and that a function must be declared deterministic or to not modify data), set the global `log_bin_trust_function_creators` system variable to 1. By default, this variable has a value of 0, but you can change it like this:

  ```
  mysql> SET GLOBAL log_bin_trust_function_creators = 1;
  ```

  You can also set this variable at server startup.

  If binary logging is not enabled, `log_bin_trust_function_creators` does not apply. `SUPER` is not required for function creation unless, as described previously, the `DEFINER` value in the function definition requires it.

- For information about built-in functions that may be unsafe for replication (and thus cause stored functions that use them to be unsafe as well), see Section 17.4.1, “Replication Features and Issues”.

Triggers are similar to stored functions, so the preceding remarks regarding functions also apply to triggers with the following exception: `CREATE TRIGGER` does not have an optional `DETERMINISTIC` characteristic, so triggers are assumed to be always deterministic. However, this assumption might be invalid in some cases. For example, the `UUID()` function is nondeterministic (and does not replicate). Be careful about using such functions in triggers.

Triggers can update tables, so error messages similar to those for stored functions occur with `CREATE TRIGGER` if you do not have the required privileges. On the slave side, the slave uses the trigger `DEFINER` attribute to determine which user is considered to be the creator of the trigger.

The rest of this section provides additional detail about the logging implementation and its implications. You need not read it unless you are interested in the background on the rationale for the current logging-related conditions on stored routine use. This discussion applies only for statement-based logging, and not for row-based logging, with the exception of the first item: `CREATE` and `DROP` statements are logged as statements regardless of the logging mode.

- The server writes `CREATE EVENT`, `CREATE PROCEDURE`, `CREATE FUNCTION`, `ALTER EVENT`, `ALTER PROCEDURE`, `ALTER FUNCTION`, `DROP EVENT`, `DROP PROCEDURE`, and `DROP FUNCTION` statements to the binary log.

- A stored function invocation is logged as a `SELECT` statement if the function changes data and occurs within a statement that would not otherwise be logged. This prevents nonreplication of data changes that result from use of stored functions in nonlogged statements. For example, `SELECT` statements are not written to the binary log, but a `SELECT` might invoke a stored function that makes changes. To handle this, a `SELECT func_name()` statement is written to the binary log when the given function makes a change. Suppose that the following statements are executed on the master:

  ```
  CREATE FUNCTION f1(a INT) RETURNS INT
  BEGIN
      IF (a < 3) THEN
          INSERT INTO t2 VALUES (a);
      END IF;
      RETURN 0;
  END;

  CREATE TABLE t1 (a INT);
  INSERT INTO t1 VALUES (1),(2),(3);
  SELECT f1(a) FROM t1;
  ```
Stored Program Binary Logging

When the `SELECT` statement executes, the function `f1()` is invoked three times. Two of those invocations insert a row, and MySQL logs a `SELECT` statement for each of them. That is, MySQL writes the following statements to the binary log:

```sql
SELECT f1(1);
SELECT f1(2);
```

The server also logs a `SELECT` statement for a stored function invocation when the function invokes a stored procedure that causes an error. In this case, the server writes the `SELECT` statement to the log along with the expected error code. On the slave, if the same error occurs, that is the expected result and replication continues. Otherwise, replication stops.

- Logging stored function invocations rather than the statements executed by a function has a security implication for replication, which arises from two factors:
  - It is possible for a function to follow different execution paths on master and slave servers.
  - Statements executed on a slave are processed by the slave SQL thread which has full privileges.

The implication is that although a user must have the `CREATE ROUTINE` privilege to create a function, the user can write a function containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges. For example, if the master and slave servers have server ID values of 1 and 2, respectively, a user on the master server could create and invoke an unsafe function `unsafe_func()` as follows:

```sql
mysql> delimiter //
mysql> CREATE FUNCTION unsafe_func () RETURNS INT
    -> BEGIN
    -> IF @@server_id=2 THEN dangerous_statement; END IF;
    -> RETURN 1;
    -> END;
    -> //
mysql> delimiter ;
mysql> INSERT INTO t VALUES(unsafe_func());
```

The `CREATE FUNCTION` and `INSERT` statements are written to the binary log, so the slave will execute them. Because the slave SQL thread has full privileges, it will execute the dangerous statement. Thus, the function invocation has different effects on the master and slave and is not replication-safe.

To guard against this danger for servers that have binary logging enabled, stored function creators must have the `SUPER` privilege, in addition to the usual `CREATE ROUTINE` privilege that is required. Similarly, to use `ALTER FUNCTION`, you must have the `SUPER` privilege in addition to the `ALTER ROUTINE` privilege. Without the `SUPER` privilege, an error will occur:

```
ERROR 1419 (HY000): You do not have the SUPER privilege and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)
```

If you do not want to require function creators to have the `SUPER` privilege (for example, if all users with the `CREATE ROUTINE` privilege on your system are experienced application developers), set the global `log_bin_trust_function_creators` system variable to 1. You can also set this variable at server startup. If binary logging is not enabled, `log_bin_trust_function_creators` does not apply. `SUPER` is not required for function creation unless, as described previously, the `DEFINER` value in the function definition requires it.
• If a function that performs updates is nondeterministic, it is not repeatable. This can have two undesirable effects:

• It will make a slave different from the master.

• Restored data will be different from the original data.

To deal with these problems, MySQL enforces the following requirement: On a master server, creation and alteration of a function is refused unless you declare the function to be deterministic or to not modify data. Two sets of function characteristics apply here:

• The DETERMINISTIC and NOT DETERMINISTIC characteristics indicate whether a function always produces the same result for given inputs. The default is NOT DETERMINISTIC if neither characteristic is given. To declare that a function is deterministic, you must specify DETERMINISTIC explicitly.

• The CONTAINS SQL, NO SQL, READS SQL DATA, and MODIFIES SQL DATA characteristics provide information about whether the function reads or writes data. Either NO SQL or READS SQL DATA indicates that a function does not change data, but you must specify one of these explicitly because the default is CONTAINS SQL if no characteristic is given.

By default, for a CREATE FUNCTION statement to be accepted, at least one of DETERMINISTIC, NO SQL, or READS SQL DATA must be specified explicitly. Otherwise an error occurs:

```
ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL, or READS SQL DATA in its declaration and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)
```

If you set log_bin_trust_function_creators to 1, the requirement that functions be deterministic or not modify data is dropped.

• Stored procedure calls are logged at the statement level rather than at the CALL level. That is, the server does not log the CALL statement, it logs those statements within the procedure that actually execute. As a result, the same changes that occur on the master will be observed on slave servers. This prevents problems that could result from a procedure having different execution paths on different machines.

In general, statements executed within a stored procedure are written to the binary log using the same rules that would apply were the statements to be executed in standalone fashion. Some special care is taken when logging procedure statements because statement execution within procedures is not quite the same as in nonprocedure context:

• A statement to be logged might contain references to local procedure variables. These variables do not exist outside of stored procedure context, so a statement that refers to such a variable cannot be logged literally. Instead, each reference to a local variable is replaced by this construct for logging purposes:

```
NAME_CONST(var_name, var_value)
```

var_name is the local variable name, and var_value is a constant indicating the value that the variable has at the time the statement is logged. NAME_CONST() has a value of var_value, and a “name” of var_name. Thus, if you invoke this function directly, you get a result like this:

```
mysql> SELECT NAME_CONST('myname', 14);
+--------+
| myname |
+--------+
|     14 |
```
NAME_CONST() enables a logged standalone statement to be executed on a slave with the same effect as the original statement that was executed on the master within a stored procedure.

The use of NAME_CONST() can result in a problem for CREATE TABLE ... SELECT statements when the source column expressions refer to local variables. Converting these references to NAME_CONST() expressions can result in column names that are different on the master and slave servers, or names that are too long to be legal column identifiers. A workaround is to supply aliases for columns that refer to local variables. Consider this statement when `myvar` has a value of 1:

```
CREATE TABLE t1 SELECT myvar;
```

That will be rewritten as follows:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1);
```

To ensure that the master and slave tables have the same column names, write the statement like this:

```
CREATE TABLE t1 SELECT myvar AS myvar;
```

The rewritten statement becomes:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1) AS myvar;
```

- A statement to be logged might contain references to user-defined variables. To handle this, MySQL writes a `SET` statement to the binary log to make sure that the variable exists on the slave with the same value as on the master. For example, if a statement refers to a variable `@my_var`, that statement will be preceded in the binary log by the following statement, where `value` is the value of `@my_var` on the master:

  ```
  SET @my_var = value;
  ```

- Procedure calls can occur within a committed or rolled-back transaction. Transactional context is accounted for so that the transactional aspects of procedure execution are replicated correctly. That is, the server logs those statements within the procedure that actually execute and modify data, and also logs `BEGIN`, `COMMIT`, and `ROLLBACK` statements as necessary. For example, if a procedure updates only transactional tables and is executed within a transaction that is rolled back, those updates are not logged. If the procedure occurs within a committed transaction, `BEGIN` and `COMMIT` statements are logged with the updates. For a procedure that executes within a rolled-back transaction, its statements are logged using the same rules that would apply if the statements were executed in standalone fashion:

  - Updates to transactional tables are not logged.
  - Updates to nontransactional tables are logged because rollback does not cancel them.
  - Updates to a mix of transactional and nontransactional tables are logged surrounded by `BEGIN` and `ROLLBACK` so that slaves will make the same changes and rollbacks as on the master.

- A stored procedure call is not written to the binary log at the statement level if the procedure is invoked from within a stored function. In that case, the only thing logged is the statement that invokes the function (if it occurs within a statement that is logged) or a `DO` statement (if it occurs within a statement that is not logged). For this reason, care should be exercised in the use of stored functions that invoke a procedure, even if the procedure is otherwise safe in itself.
20.8 Restrictions on Stored Programs

These restrictions apply to the features described in Chapter 20, Stored Objects.

Some of the restrictions noted here apply to all stored routines; that is, both to stored procedures and stored functions. There are also some restrictions specific to stored functions but not to stored procedures.

The restrictions for stored functions also apply to triggers. There are also some restrictions specific to triggers.

The restrictions for stored procedures also apply to the DO clause of Event Scheduler event definitions. There are also some restrictions specific to events.

SQL Statements Not Permitted in Stored Routines

Stored routines cannot contain arbitrary SQL statements. The following statements are not permitted:

- The locking statements LOCK TABLES and UNLOCK TABLES.
- ALTER VIEW.
- LOAD DATA and LOAD TABLE.
- SQL prepared statements (PREPARE, EXECUTE, DEALLOCATE PREPARE) can be used in stored procedures, but not stored functions or triggers. Thus, stored functions and triggers cannot use dynamic SQL (where you construct statements as strings and then execute them).
- Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. For a list of statements supported as prepared statements, see Section 13.5, “Prepared Statements”. Exceptions are SIGNAL and RESIGNAL, which are not permissible as prepared statements but are permitted in stored programs.
- Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement scope is the current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, SELECT ... INTO local_var cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, “PREPARE Statement”.
- Inserts cannot be delayed. INSERT DELAYED syntax is accepted, but the statement is handled as a normal INSERT.
- Within all stored programs (stored procedures and functions, triggers, and events), the parser treats BEGIN [WORK] as the beginning of a BEGIN ... END block. To begin a transaction in this context, use START TRANSACTION instead.

Restrictions for Stored Functions

The following additional statements or operations are not permitted within stored functions. They are permitted within stored procedures, except stored procedures that are invoked from within a stored function or trigger. For example, if you use FLUSH in a stored procedure, that stored procedure cannot be called from a stored function or trigger.

- Statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.
Restrictions for Triggers

- Statements that return a result set. This includes `SELECT` statements that do not have an `INTO var_list` clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. A function can process a result set either with `SELECT ... INTO var_list` or by using a cursor and `FETCH` statements. See Section 13.2.9.1, “SELECT ... INTO Statement”, and Section 13.6.6, “Cursors”.

- `FLUSH` statements.

- Stored functions cannot be used recursively.

- A stored function or trigger cannot modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.

- If you refer to a temporary table multiple times in a stored function under different aliases, a `Can't reopen table: 'tbl_name'` error occurs, even if the references occur in different statements within the function.

- `HANDLER ... READ` statements that invoke stored functions can cause replication errors. As of MySQL 5.5.7, such statements are disallowed.

Restrictions for Triggers

For triggers, the following additional restrictions apply:

- Triggers are not activated by foreign key actions.

- When using row-based replication, triggers on the slave are not activated by statements originating on the master. The triggers on the slave are activated when using statement-based replication. For more information, see Section 17.4.1.35, “Replication and Triggers”.

- The `RETURN` statement is not permitted in triggers, which cannot return a value. To exit a trigger immediately, use the `LEAVE` statement.

- Triggers are not permitted on tables in the `mysql` database. Nor are they permitted on `INFORMATION_SCHEMA` or `performance_schema` tables. Those tables are actually views and triggers are not permitted on views.

- The trigger cache does not detect when metadata of the underlying objects has changed. If a trigger uses a table and the table has changed since the trigger was loaded into the cache, the trigger operates using the outdated metadata.

Name Conflicts within Stored Routines

The same identifier might be used for a routine parameter, a local variable, and a table column. Also, the same local variable name can be used in nested blocks. For example:

```sql
CREATE PROCEDURE p (i INT)
BEGIN
    DECLARE i INT DEFAULT 0;
    SELECT i FROM t;
    BEGIN
        DECLARE i INT DEFAULT 1;
        SELECT i FROM t;
    END;
END;
```

In such cases, the identifier is ambiguous and the following precedence rules apply:

- A local variable takes precedence over a routine parameter or table column.
• A routine parameter takes precedence over a table column.

• A local variable in an inner block takes precedence over a local variable in an outer block.

The behavior that variables take precedence over table columns is nonstandard.

Replication Considerations

Use of stored routines can cause replication problems. This issue is discussed further in Section 20.7, “Stored Program Binary Logging”.

The `--replicate-wild-do-table=db_name.tbl_name` option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

Debugging Considerations

There are no stored routine debugging facilities.

Unsupported Syntax from the SQL:2003 Standard

The MySQL stored routine syntax is based on the SQL:2003 standard. The following items from that standard are not currently supported:

• `UNDO` handlers

• `FOR` loops

Stored Routine Concurrency Considerations

To prevent problems of interaction between sessions, when a client issues a statement, the server uses a snapshot of routines and triggers available for execution of the statement. That is, the server calculates a list of procedures, functions, and triggers that may be used during execution of the statement, loads them, and then proceeds to execute the statement. While the statement executes, it does not see changes to routines performed by other sessions.

For maximum concurrency, stored functions should minimize their side-effects; in particular, updating a table within a stored function can reduce concurrent operations on that table. A stored function acquires table locks before executing, to avoid inconsistency in the binary log due to mismatch of the order in which statements execute and when they appear in the log. When statement-based binary logging is used, statements that invoke a function are recorded rather than the statements executed within the function. Consequently, stored functions that update the same underlying tables do not execute in parallel. In contrast, stored procedures do not acquire table-level locks. All statements executed within stored procedures are written to the binary log, even for statement-based binary logging. See Section 20.7, “Stored Program Binary Logging”.

Event Scheduler Restrictions

The following limitations are specific to the Event Scheduler:

• Event names are handled in case-insensitive fashion. For example, you cannot have two events in the same database with the names `anEvent` and `AnEvent`.

• An event may not be created, altered, or dropped from within a stored program, if the event name is specified by means of a variable. An event also may not create, alter, or drop stored routines or triggers.

• DDL statements on events are prohibited while a `LOCK TABLES` statement is in effect.
Restrictions on Views

• Event timings using the intervals YEAR, QUARTER, MONTH, and YEAR_MONTH are resolved in months; those using any other interval are resolved in seconds. There is no way to cause events scheduled to occur at the same second to execute in a given order. In addition—due to rounding, the nature of threaded applications, and the fact that a nonzero length of time is required to create events and to signal their execution—events may be delayed by as much as 1 or 2 seconds. However, the time shown in the INFORMATION_SCHEMA.EVENTS table's LAST_EXECUTED column or the mysql.event table's last_executed column is always accurate to within one second of the actual event execution time. (See also Bug #16522.)

• Each execution of the statements contained in the body of an event takes place in a new connection; thus, these statements has no effect in a given user session on the server's statement counts such as Com_select and Com_insert that are displayed by SHOW STATUS. However, such counts are updated in the global scope. (Bug #16422)

• Events do not support times later than the end of the Unix Epoch; this is approximately the beginning of the year 2038. Such dates are specifically not permitted by the Event Scheduler. (Bug #16396)

• References to stored functions, user-defined functions, and tables in the ON SCHEDULE clauses of CREATE EVENT and ALTER EVENT statements are not supported. These sorts of references are not permitted. (See Bug #22830 for more information.)

Stored routines and triggers in NDB Cluster. Stored procedures, stored functions, and triggers are all supported by tables using the NDB storage engine; however, it is important to keep in mind that they do not propagate automatically between MySQL Servers acting as Cluster SQL nodes. This is because of the following:

• Stored routine definitions are kept in tables in the mysql system database using the MyISAM storage engine, and so do not participate in clustering.

• The .TRN and .TRG files containing trigger definitions are not read by the NDB storage engine, and are not copied between Cluster nodes.

Any stored routine or trigger that interacts with NDB Cluster tables must be re-created by running the appropriate CREATE PROCEDURE, CREATE FUNCTION, or CREATE TRIGGER statements on each MySQL Server that participates in the cluster where you wish to use the stored routine or trigger. Similarly, any changes to existing stored routines or triggers must be carried out explicitly on all Cluster SQL nodes, using the appropriate ALTER or DROP statements on each MySQL Server accessing the cluster.

Warning

Do not attempt to work around the issue described in the first item mentioned previously by converting any mysql database tables to use the NDB storage engine. Altering the system tables in the mysql database is not supported and is very likely to produce undesirable results.

20.9 Restrictions on Views

The maximum number of tables that can be referenced in the definition of a view is 61.

View processing is not optimized:

• It is not possible to create an index on a view.

• Indexes can be used for views processed using the merge algorithm. However, a view that is processed with the temptable algorithm is unable to take advantage of indexes on its underlying tables (although indexes can be used during generation of the temporary tables).
Restrictions on Views

Subqueries cannot be used in the `FROM` clause of a view.

There is a general principle that you cannot modify a table and select from the same table in a subquery. See Section 13.2.10.12, "Restrictions on Subqueries".

The same principle also applies if you select from a view that selects from the table, if the view selects from the table in a subquery and the view is evaluated using the merge algorithm. Example:

```sql
CREATE VIEW v1 AS
SELECT * FROM t2 WHERE EXISTS (SELECT 1 FROM t1 WHERE t1.a = t2.a);
UPDATE t1, v2 SET t1.a = 1 WHERE t1.b = v2.b;
```

If the view is evaluated using a temporary table, you can select from the view in the subquery and still modify that table in the outer query. In this case the view will be stored in a temporary table and thus you are not really selecting from the table in a subquery and modifying it "at the same time." (This is another reason you might wish to force MySQL to use the temptable algorithm by specifying `ALGORITHM = TEMPTABLE` in the view definition.)

You can use `DROP TABLE` or `ALTER TABLE` to drop or alter a table that is used in a view definition. No warning results from the `DROP` or `ALTER` operation, even though this invalidates the view. Instead, an error occurs later, when the view is used. `CHECK TABLE` can be used to check for views that have been invalidated by `DROP` or `ALTER` operations.

A view definition is “frozen” by certain statements. If a statement prepared by `PREPARE` refers to a view, the view definition seen each time the statement is executed later will be the definition of the view at the time it was prepared. This is true even if the view definition is changed after the statement is prepared and before it is executed. In the following example, the result returned by the `EXECUTE` statement is a random number, not the current date and time:

```sql
CREATE VIEW v AS SELECT RAND();
PREPARE s FROM 'SELECT * FROM v';
ALTER VIEW v AS SELECT NOW();
EXECUTE s;
```

With regard to view updatability, the overall goal for views is that if any view is theoretically updatable, it should be updatable in practice. MySQL as quickly as possible. Many theoretically updatable views can be updated now, but limitations still exist. For details, see Section 20.5.3, "Updatable and Insertable Views".

There exists a shortcoming with the current implementation of views. If a user is granted the basic privileges necessary to create a view (the `CREATE VIEW` and `SELECT` privileges), that user will be unable to call `SHOW CREATE VIEW` on that object unless the user is also granted the `SHOW VIEW` privilege.

That shortcoming can lead to problems backing up a database with `mysqldump`, which may fail due to insufficient privileges. This problem is described in Bug #22062.

The workaround to the problem is for the administrator to manually grant the `SHOW VIEW` privilege to users who are granted `CREATE VIEW`, since MySQL doesn't grant it implicitly when views are created.

Views do not have indexes, so index hints do not apply. Use of index hints when selecting from a view is not permitted.

`SHOW CREATE VIEW` displays view definitions using an `AS alias_name` clause for each column. If a column is created from an expression, the default alias is the expression text, which can be quite long. Aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters). As a result, views created from the output of `SHOW CREATE VIEW` fail if any column alias exceeds 64 characters. This can cause problems in the following circumstances for views with too-long aliases:
Restrictions on Views

- View definitions fail to replicate to newer slaves that enforce the column-length restriction.

- Dump files created with `mysqldump` cannot be loaded into servers that enforce the column-length restriction.

A workaround for either problem is to modify each problematic view definition to use aliases that provide shorter column names. Then the view will replicate properly, and can be dumped and reloaded without causing an error. To modify the definition, drop and create the view again with `DROP VIEW` and `CREATE VIEW`, or replace the definition with `CREATE OR REPLACE VIEW`.

For problems that occur when reloading view definitions in dump files, another workaround is to edit the dump file to modify its `CREATE VIEW` statements. However, this does not change the original view definitions, which may cause problems for subsequent dump operations.
Table of Contents

21.1 Introduction ............................................................................................................. 2692
21.2 The INFORMATION_SCHEMA CHARACTER_SETS Table ..................................... 2695
21.3 The INFORMATION_SCHEMA COLLATIONS Table ................................................... 2695
21.4 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table ... 2696
21.5 The INFORMATION_SCHEMA COLUMNS Table ......................................................... 2696
21.6 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table .................................... 2699
21.7 The INFORMATION_SCHEMA ENGINES Table ......................................................... 2699
21.8 The INFORMATION_SCHEMA EVENTS Table ......................................................... 2700
21.9 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables .......... 2704
21.10 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables ... 2704
21.11 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table .................................... 2705
21.12 The INFORMATION_SCHEMA PARAMETERS Table ................................................. 2706
21.13 The INFORMATION_SCHEMA PARTITIONS Table ................................................... 2707
21.14 The INFORMATION_SCHEMA PLUGINS Table ........................................................ 2711
21.15 The INFORMATION_SCHEMA PROCESSLIST Table .............................................. 2712
21.16 The INFORMATION_SCHEMA PROFILING Table ................................................... 2713
21.17 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table ...................... 2714
21.18 The INFORMATION_SCHEMA ROUTINES Table .................................................... 2715
21.19 The INFORMATION_SCHEMA SCHEMATA Table .................................................. 2718
21.20 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table ................................... 2719
21.21 The INFORMATION_SCHEMA STATISTICS Table ................................................... 2719
21.22 The INFORMATION_SCHEMA TABLES Table ....................................................... 2721
21.23 The INFORMATION_SCHEMA TABLESPACES Table ................................................ 2725
21.24 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table .................................... 2726
21.25 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table ..................................... 2726
21.26 The INFORMATION_SCHEMA TRIGGERS Table .................................................... 2727
21.27 The INFORMATION_SCHEMA USER_PRIVILEGES Table ....................................... 2729
21.28 The INFORMATION_SCHEMA VIEWS Table .......................................................... 2729
21.29 INFORMATION_SCHEMA InnoDB Tables .............................................................. 2731
  21.29.1 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table ................................. 2731
  21.29.2 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table .................... 2734
  21.29.3 The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table .................... 2737
  21.29.4 The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables ...... 2741
  21.29.5 The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables .................................................................................................................. 2742
21.29.6 The INFORMATION_SCHEMA INNODB_LOCKS Table .......................................... 2743
21.29.7 The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table ............................... 2745
21.29.8 The INFORMATION_SCHEMA INNODB_TRX Table ............................................. 2746
21.30 INFORMATION_SCHEMA NDB Cluster Tables ....................................................... 2749
  21.30.1 The INFORMATION_SCHEMA FILES Table ..................................................... 2749
  21.30.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table .......... 2755
21.31 INFORMATION_SCHEMA Thread Pool Tables .......................................................... 2756
  21.31.1 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table ......................... 2756
  21.31.2 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table ....................... 2758
  21.31.3 The INFORMATION_SCHEMA TP_THREAD_STATE Table .................................... 2760
21.32 Extensions to SHOW Statements ............................................................................ 2761
INFORMATION_SCHEMA provides access to database metadata, information about the MySQL server such as the name of a database or table, the data type of a column, or access privileges. Other terms that are sometimes used for this information are data dictionary and system catalog.

21.1 Introduction

INFORMATION_SCHEMA provides access to database metadata, information about the MySQL server such as the name of a database or table, the data type of a column, or access privileges. Other terms that are sometimes used for this information are data dictionary and system catalog.

- INFORMATION_SCHEMA Usage Notes
- Character Set Considerations
- INFORMATION_SCHEMA as Alternative to SHOW Statements
- INFORMATION_SCHEMA and Privileges
- Performance Considerations
- Standards Considerations
- Conventions in the INFORMATION_SCHEMA Reference Sections
- Related Information

INFORMATION_SCHEMA Usage Notes

INFORMATION_SCHEMA is a database within each MySQL instance, the place that stores information about all the other databases that the MySQL server maintains. The INFORMATION_SCHEMA database contains several read-only tables. They are actually views, not base tables, so there are no files associated with them, and you cannot set triggers on them. Also, there is no database directory with that name.

Although you can select INFORMATION_SCHEMA as the default database with a USE statement, you can only read the contents of tables, not perform INSERT, UPDATE, or DELETE operations on them.

Here is an example of a statement that retrieves information from INFORMATION_SCHEMA:

```sql
mysql> SELECT table_name, table_type, engine
FROM information_schema.tables
WHERE table_schema = 'db5'
ORDER BY table_name;
```

<table>
<thead>
<tr>
<th>table_name</th>
<th>table_type</th>
<th>engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>fk</td>
<td>BASE TABLE</td>
<td>InnoDB</td>
</tr>
<tr>
<td>fk2</td>
<td>BASE TABLE</td>
<td>InnoDB</td>
</tr>
<tr>
<td>goto</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>into</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>k</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>kurs</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>loop</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>pk</td>
<td>BASE TABLE</td>
<td>InnoDB</td>
</tr>
<tr>
<td>t</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>t2</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>t3</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>t7</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>tables</td>
<td>BASE TABLE</td>
<td>MyISAM</td>
</tr>
<tr>
<td>v</td>
<td>VIEW</td>
<td>NULL</td>
</tr>
<tr>
<td>v2</td>
<td>VIEW</td>
<td>NULL</td>
</tr>
<tr>
<td>v3</td>
<td>VIEW</td>
<td>NULL</td>
</tr>
<tr>
<td>v56</td>
<td>VIEW</td>
<td>NULL</td>
</tr>
</tbody>
</table>
Character Set Considerations

The definition for character columns (for example, `TABLES.TABLE_NAME`) is generally `VARCHAR(N) CHARACTER SET utf8` where \( N \) is at least 64. MySQL uses the default collation for this character set (`utf8_general_ci`) for all searches, sorts, comparisons, and other string operations on such columns.

Because some MySQL objects are represented as files, searches in `INFORMATION_SCHEMA` string columns can be affected by file system case sensitivity. For more information, see Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

INFORMATION_SCHEMA as Alternative to SHOW Statements

The `SELECT ... FROM INFORMATION_SCHEMA` statement is intended as a more consistent way to provide access to the information provided by the various `SHOW` statements that MySQL supports (`SHOW DATABASES`, `SHOW TABLES`, and so forth). Using `SELECT` has these advantages, compared to `SHOW`:

- It conforms to Codd’s rules, because all access is done on tables.
- You can use the familiar syntax of the `SELECT` statement, and only need to learn some table and column names.
- The implementor need not worry about adding keywords.
- You can filter, sort, concatenate, and transform the results from `INFORMATION_SCHEMA` queries into whatever format your application needs, such as a data structure or a text representation to parse.
- This technique is more interoperable with other database systems. For example, Oracle Database users are familiar with querying tables in the Oracle data dictionary.

Because `SHOW` is familiar and widely used, the `SHOW` statements remain as an alternative. In fact, along with the implementation of `INFORMATION_SCHEMA`, there are enhancements to `SHOW` as described in Section 21.32, “Extensions to SHOW Statements”.

INFORMATION_SCHEMA and Privileges

Each MySQL user has the right to access these tables, but can see only the rows in the tables that correspond to objects for which the user has the proper access privileges. In some cases (for example, the `ROUTINE_DEFINITION` column in the `INFORMATION_SCHEMA ROUTINES` table), users who have insufficient privileges see `NULL`. These restrictions do not apply for InnoDB tables; you can see them with only the `PROCESS` privilege.

The same privileges apply to selecting information from `INFORMATION_SCHEMA` and viewing the same information through `SHOW` statements. In either case, you must have some privilege on an object to see information about it.

Performance Considerations

`INFORMATION_SCHEMA` queries that search for information from more than one database might take a long time and impact performance. To check the efficiency of a query, you can use `EXPLAIN`. For information about using `EXPLAIN` output to tune `INFORMATION_SCHEMA` queries, see Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”.
Standards Considerations

The implementation for the INFORMATION_SCHEMA table structures in MySQL follows the ANSI/ISO SQL:2003 standard Part 11 Schemata. Our intent is approximate compliance with SQL:2003 core feature F021 Basic information schema.

Users of SQL Server 2000 (which also follows the standard) may notice a strong similarity. However, MySQL has omitted many columns that are not relevant for our implementation, and added columns that are MySQL-specific. One such added column is the ENGINE column in the INFORMATION_SCHEMA TABLES table.

Although other DBMSs use a variety of names, like syscat or system, the standard name is INFORMATION_SCHEMA.

To avoid using any name that is reserved in the standard or in DB2, SQL Server, or Oracle, we changed the names of some columns marked “MySQL extension”. (For example, we changed COLLATION to TABLE_COLLATION in the TABLES table.) See the list of reserved words near the end of this article: https://web.archive.org/web/20070428032454/http://www.dbazine.com/db2/db2-disarticles/gulutzan5.

Conventions in the INFORMATION_SCHEMA Reference Sections

The following sections describe each of the tables and columns in INFORMATION_SCHEMA. For each column, there are three pieces of information:

- “INFORMATION_SCHEMA Name” indicates the name for the column in the INFORMATION_SCHEMA table. This corresponds to the standard SQL name unless the “Remarks” field says “MySQL extension.”
- “SHOW Name” indicates the equivalent field name in the closest SHOW statement, if there is one.
- “Remarks” provides additional information where applicable. If this field is NULL, it means that the value of the column is always NULL. If this field says “MySQL extension,” the column is a MySQL extension to standard SQL.

Many sections indicate what SHOW statement is equivalent to a SELECT that retrieves information from INFORMATION_SCHEMA. For SHOW statements that display information for the default database if you omit a FROM db_name clause, you can often select information for the default database by adding an AND TABLE_SCHEMA = SCHEMA() condition to the WHERE clause of a query that retrieves information from an INFORMATION_SCHEMA table.

Related Information

These sections discuss additional INFORMATION_SCHEMA-related topics:

- information about INFORMATION_SCHEMA tables specific to the InnoDB storage engine: Section 21.29, “INFORMATION_SCHEMA InnoDB Tables”
- information about INFORMATION_SCHEMA tables specific to the NDB storage engine (NDB Cluster): Section 21.30, “INFORMATION_SCHEMA NDB Cluster Tables”
- information about INFORMATION_SCHEMA tables specific to the thread pool plugin: Section 21.31, “INFORMATION_SCHEMA Thread Pool Tables”
- Answers to questions that are often asked concerning the INFORMATION_SCHEMA database: Section A.7, “MySQL 5.5 FAQ: INFORMATION_SCHEMA”
- INFORMATION_SCHEMA queries and the optimizer: Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
21.2 The INFORMATION_SCHEMA CHARACTER_SETS Table

The CHARACTER_SETS table provides information about available character sets.

The CHARACTER_SETS table has these columns:

- CHARACTER_SET_NAME
  The character set name.
- DEFAULT_COLLATE_NAME
  The default collation for the character set.
- DESCRIPTION
  A description of the character set.
- MAXLEN
  The maximum number of bytes required to store one character.

Notes

Character set information is also available from the SHOW CHARACTER SET statement. See Section 13.7.5.4, “SHOW CHARACTER SET Statement”. The following statements are equivalent:

```sql
SELECT * FROM INFORMATION_SCHEMA.CHARACTER_SETS
    [WHERE CHARACTER_SET_NAME LIKE 'wild']
SHOW CHARACTER SET
    [LIKE 'wild']
```

21.3 The INFORMATION_SCHEMA COLLATIONS Table

The COLLATIONS table provides information about collations for each character set.

The COLLATIONS table has these columns:

- COLLATION_NAME
  The collation name.
- CHARACTER_SET_NAME
  The name of the character set with which the collation is associated.
- ID
  The collation ID.
- IS_DEFAULT
  Whether the collation is the default for its character set.
- IS_COMPILED

Notes

Whether the character set is compiled into the server.

- **SORTLEN**
  
  This is related to the amount of memory required to sort strings expressed in the character set.

Notes

Collation information is also available from the `SHOW COLLATION` statement. See Section 13.7.5.5, "SHOW COLLATION Statement". The following statements are equivalent:

```sql
SELECT COLLATION_NAME FROM INFORMATION_SCHEMA.COLLATIONS
  [WHERE COLLATION_NAME LIKE 'wild']
SHOW COLLATION
  [LIKE 'wild']
```

21.4 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table

The `COLLATION_CHARACTER_SET_APPLICABILITY` table indicates what character set is applicable for what collation.

The `COLLATION_CHARACTER_SET_APPLICABILITY` table has these columns:

- **COLLATION_NAME**
  
  The collation name.

- **CHARACTER_SET_NAME**
  
  The name of the character set with which the collation is associated.

Notes

The `COLLATION_CHARACTER_SET_APPLICABILITY` columns are equivalent to the first two columns displayed by the `SHOW COLLATION` statement.

21.5 The INFORMATION_SCHEMA COLUMNS Table

The `COLUMNS` table provides information about columns in tables.

The `COLUMNS` table has these columns:

- **TABLE_CATALOG**
  
  The name of the catalog to which the table containing the column belongs. This value is always `def`.

- **TABLE_SCHEMA**
  
  The name of the schema (database) to which the table containing the column belongs.

- **TABLE_NAME**
  
  The name of the table containing the column.

- **COLUMN_NAME**
The INFORMATION_SCHEMA COLUMNS Table

The name of the column.

- **ORDINAL_POSITION**
  
The position of the column within the table. **ORDINAL_POSITION** is necessary because you might want to say ORDER BY ORDINAL_POSITION. Unlike **SHOW COLUMNS, SELECT** from the COLUMNS table does not have automatic ordering.

- **COLUMN_DEFAULT**
  
The default value for the column. This is **NULL** if the column has an explicit default of **NULL**, or if the column definition includes no **DEFAULT** clause.

- **IS_NULLABLE**
  
The column nullability. The value is **YES** if **NULL** values can be stored in the column, **NO** if not.

- **DATA_TYPE**
  
The column data type.

  The **DATA_TYPE** value is the type name only with no other information. The **COLUMN_TYPE** value contains the type name and possibly other information such as the precision or length.

- **CHARACTER_MAXIMUM_LENGTH**
  
  For string columns, the maximum length in characters.

- **CHARACTER_OCTET_LENGTH**
  
  For string columns, the maximum length in bytes.

- **NUMERIC_PRECISION**
  
  For numeric columns, the numeric precision.

- **NUMERIC_SCALE**
  
  For numeric columns, the numeric scale.

- **CHARACTER_SET_NAME**
  
  For character string columns, the character set name.

- **COLLATION_NAME**
  
  For character string columns, the collation name.

- **COLUMN_TYPE**
  
The column data type.

  The **DATA_TYPE** value is the type name only with no other information. The **COLUMN_TYPE** value contains the type name and possibly other information such as the precision or length.

- **COLUMN_KEY**
  
  Whether the column is indexed:
• If \textit{COLUMN\_KEY} is empty, the column either is not indexed or is indexed only as a secondary column in a multiple-column, nonunique index.

• If \textit{COLUMN\_KEY} is \texttt{PRI}, the column is a \texttt{PRIMARY\_KEY} or is one of the columns in a multiple-column \texttt{PRIMARY\_KEY}.

• If \textit{COLUMN\_KEY} is \texttt{UNI}, the column is the first column of a \texttt{UNIQUE} index. (A \texttt{UNIQUE} index permits multiple \texttt{NULL} values, but you can tell whether the column permits \texttt{NULL} by checking the \texttt{Null} column.)

• If \textit{COLUMN\_KEY} is \texttt{MUL}, the column is the first column of a nonunique index in which multiple occurrences of a given value are permitted within the column.

If more than one of the \textit{COLUMN\_KEY} values applies to a given column of a table, \textit{COLUMN\_KEY} displays the one with the highest priority, in the order \texttt{PRI}, \texttt{UNI}, \texttt{MUL}.

A \texttt{UNIQUE} index may be displayed as \texttt{PRI} if it cannot contain \texttt{NULL} values and there is no \texttt{PRIMARY KEY} in the table. A \texttt{UNIQUE} index may display as \texttt{MUL} if several columns form a composite \texttt{UNIQUE} index; although the combination of the columns is unique, each column can still hold multiple occurrences of a given value.

• \texttt{EXTRA}

Any additional information that is available about a given column. The value is nonempty in these cases: \texttt{auto\_increment} for columns that have the \texttt{AUTO\_INCREMENT} attribute; \texttt{on\_update CURRENT\_TIMESTAMP} for \texttt{TIMESTAMP} columns that have the \texttt{ON\_UPDATE CURRENT\_TIMESTAMP} attribute.

• \texttt{PRIVILEGES}

The privileges you have for the column.

• \texttt{COLUMN\_COMMENT}

Any comment included in the column definition.

Notes

• In \texttt{SHOW COLUMNS}, the \texttt{Type} display includes values from several different \texttt{COLUMNS} columns.

• \texttt{CHARACTER\_OCTET\_LENGTH} should be the same as \texttt{CHARACTER\_MAXIMUM\_LENGTH}, except for multibyte character sets.

• \texttt{CHARACTER\_SET\_NAME} can be derived from \texttt{COLLATION\_NAME}. For example, if you say \texttt{SHOW FULL COLUMNS FROM t}, and you see in the \texttt{COLLATION\_NAME} column a value of \texttt{latin1\_swedish\_ci}, the character set is what is before the first underscore: \texttt{latin1}.

Column information is also available from the \texttt{SHOW COLUMNS} statement. See Section 13.7.5.6, “SHOW COLUMNS Statement”. The following statements are nearly equivalent:

```sql
SELECT COLUMN_NAME, DATA_TYPE, IS_NULLABLE, COLUMN_DEFAULT
FROM INFORMATION_SCHEMA.COLUMNS
WHERE table_name = 'tbl_name'
[AND table_schema = 'db_name']
[AND column_name LIKE 'wild']
SHOW COLUMNS
FROM tbl_name
```
21.6 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table

The COLUMN_PRIVILEGES table provides information about column privileges. It takes its values from the mysql.columns_priv system table.

The COLUMN_PRIVILEGES table has these columns:

- **GRANTEE**
  The name of the account to which the privilege is granted, in 'user_name'@'host_name' format.

- **TABLE_CATALOG**
  The name of the catalog to which the table containing the column belongs. This value is always def.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the table containing the column belongs.

- **TABLE_NAME**
  The name of the table containing the column.

- **COLUMN_NAME**
  The name of the column.

- **PRIVILEGE_TYPE**
  The privilege granted. The value can be any privilege that can be granted at the column level; see Section 13.7.1.3, “GRANT Statement”. Each row lists a single privilege, so there is one row per column privilege held by the grantee.

  In the output from SHOW FULL COLUMNS, the privileges are all in one column and in lowercase, for example, select, insert, update, references. In COLUMN_PRIVILEGES, there is one privilege per row, in uppercase.

- **IS_GRANTABLE**
  YES if the user has the GRANT OPTION privilege, NO otherwise. The output does not list GRANT OPTION as a separate row with PRIVILEGE_TYPE='GRANT OPTION'.

Notes

- The COLUMN_PRIVILEGES table is a nonstandard INFORMATION_SCHEMA table.

The following statements are not equivalent:

```sql
SELECT ... FROM INFORMATION_SCHEMA.COLUMN_PRIVILEGES
SHOW GRANTS ...
```

21.7 The INFORMATION_SCHEMA ENGINES Table

The ENGINES table provides information about storage engines. This is particularly useful for checking whether a storage engine is supported, or to see what the default engine is.
The **ENGINES** table has these columns:

- **ENGINE**
  - The name of the storage engine.

- **SUPPORT**
  - The server's level of support for the storage engine, as shown in the following table.

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>The engine is supported and is active</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>Like YES, plus this is the default engine</td>
</tr>
<tr>
<td>NO</td>
<td>The engine is not supported</td>
</tr>
<tr>
<td>DISABLED</td>
<td>The engine is supported but has been disabled</td>
</tr>
</tbody>
</table>

A value of **NO** means that the server was compiled without support for the engine, so it cannot be enabled at runtime.

A value of **DISABLED** occurs either because the server was started with an option that disables the engine, or because not all options required to enable it were given. In the latter case, the error log should contain a reason indicating why the option is disabled. See Section 5.4.2, “The Error Log”.

You might also see **DISABLED** for a storage engine if the server was compiled to support it, but was started with a `--skip-engine_name` option. For the **NDB** storage engine, **DISABLED** means the server was compiled with support for NDB Cluster, but was not started with the `--ndbcluster` option.

All MySQL servers support **MyISAM** tables. It is not possible to disable **MyISAM**.

- **COMMENT**
  - A brief description of the storage engine.

- **TRANSACTIONS**
  - Whether the storage engine supports transactions.

- **XA**
  - Whether the storage engine supports XA transactions.

- **SAVEPOINTS**
  - Whether the storage engine supports savepoints.

### Notes

- The **ENGINES** table is a nonstandard **INFORMATION_SCHEMA** table.

Storage engine information is also available from the **SHOW ENGINES** statement. See Section 13.7.5.17, “SHOW ENGINES Statement”. The following statements are equivalent:

```sql
SELECT * FROM INFORMATION_SCHEMA.ENGINES
SHOW ENGINES
```

**21.8 The INFORMATION_SCHEMA EVENTS Table**
The `EVENTS` table provides information about Event Manager events, which are discussed in Section 20.4, “Using the Event Scheduler”.

The `EVENTS` table has these columns:

- **EVENT_CATALOG**
  The name of the catalog to which the event belongs. This value is always `def`.

- **EVENT_SCHEMA**
  The name of the schema (database) to which the event belongs.

- **EVENT_NAME**
  The name of the event.

- **DEFINER**
  The account of the user who created the event, in `user_name'@'host_name'` format.

- **TIME_ZONE**
  The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is `SYSTEM`.

- **EVENT_BODY**
  The language used for the statements in the event's `DO` clause. The value is always `SQL`.

- **EVENT_DEFINITION**
  The text of the SQL statement making up the event's `DO` clause; in other words, the statement executed by this event.

- **EVENT_TYPE**
  The event repetition type, either `ONE TIME` (transient) or `RECURRING` (repeating).

- **EXECUTE_AT**
  For a one-time event, this is the `DATETIME` value specified in the `AT` clause of the `CREATE EVENT` statement used to create the event, or of the last `ALTER EVENT` statement that modified the event. The value shown in this column reflects the addition or subtraction of any `INTERVAL` value included in the event's `AT` clause. For example, if an event is created using `ON SCHEDULE AT CURRENT_TIMESTAMP + '1:6' DAY_HOUR`, and the event was created at 2018-02-09 14:05:30, the value shown in this column would be `2018-02-10 20:05:30`. If the event's timing is determined by an `EVERY` clause instead of an `AT` clause (that is, if the event is recurring), the value of this column is `NULL`.

- **INTERVAL_VALUE**
  For a recurring event, the number of intervals to wait between event executions. For a transient event, the value is always `NULL`.

- **INTERVAL_FIELD**
  The time units used for the interval which a recurring event waits before repeating. For a transient event, the value is always `NULL`.2701
The INFORMATION_SCHEMA EVENTS Table

- **SQL_MODE**
  The SQL mode in effect when the event was created or altered, and under which the event executes. For the permitted values, see Section 5.1.10, “Server SQL Modes”.

- **STARTS**
  The start date and time for a recurring event. This is displayed as a DATETIME value, and is NULL if no start date and time are defined for the event. For a transient event, this column is always NULL. For a recurring event whose definition includes a STARTS clause, this column contains the corresponding DATETIME value. As with the EXECUTE_AT column, this value resolves any expressions used. If there is no STARTS clause affecting the timing of the event, this column is NULL.

- **ENDS**
  For a recurring event whose definition includes an ENDS clause, this column contains the corresponding DATETIME value. As with the EXECUTE_AT column, this value resolves any expressions used. If there is no ENDS clause affecting the timing of the event, this column is NULL.

- **STATUS**
  The event status. One of ENABLED, DISABLED, or SLAVESIDE_DISABLED. SLAVESIDE_DISABLED indicates that the creation of the event occurred on another MySQL server acting as a replication master and replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave. For more information, see Section 17.4.1.15, “Replication of Invoked Features”.

- **ON_COMPLETION**
  One of the two values PRESERVE or NOT PRESERVE.

- **CREATED**
  The date and time when the event was created. This is a TIMESTAMP value.

- **LAST_ALTERED**
  The date and time when the event was last modified. This is a TIMESTAMP value. If the event has not been modified since its creation, this value is the same as the CREATED value.

- **LAST_EXECUTED**
  The date and time when the event last executed. This is a DATETIME value. If the event has never executed, this column is NULL. LAST_EXECUTED indicates when the event started. As a result, the ENDS column is never less than LAST_EXECUTED.

- **EVENT_COMMENT**
  The text of the comment, if the event has one. If not, this value is empty.

- **ORIGINATOR**
  The server ID of the MySQL server on which the event was created; used in replication. The default value is 0.

- **CHARACTER_SET_CLIENT**
The session value of the `character_set_client` system variable when the event was created.

- **COLLATION_CONNECTION**
  The session value of the `collation_connection` system variable when the event was created.

- **DATABASE_COLLATION**
  The collation of the database with which the event is associated.

**Notes**

- The `EVENTS` table is a nonstandard `INFORMATION_SCHEMA` table.

- Times in the `EVENTS` table are displayed using the event time zone, the current session time zone, or UTC, as described in Section 20.4.4, “Event Metadata”.

- For more information about `SLAVESIDE_DISABLED` and the `ORIGINATOR` column, see Section 17.4.1.15, “Replication of Invoked Features”.

**Example**

Suppose that the user 'jon'@'ghidora' creates an event named `e_daily`, and then modifies it a few minutes later using an `ALTER EVENT` statement, as shown here:

```sql
DELIMITER |

CREATE EVENT e_daily
ON SCHEDULE
  EVERY 1 DAY
COMMENT 'Saves total number of sessions then clears the table each day'
BEGIN
  INSERT INTO site_activity.totals (time, total)
  SELECT CURRENT_TIMESTAMP, COUNT(*)
  FROM site_activity.sessions;
  DELETE FROM site_activity.sessions;
END |

DELIMITER ;

ALTER EVENT e_daily
ENABLE;
```

(Note that comments can span multiple lines.)

This user can then run the following `SELECT` statement, and obtain the output shown:

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
WHERE EVENT_NAME = 'e_daily'
AND EVENT_SCHEMA = 'myschema'\G
*************************** 1. row ***************************
EVENT_CATALOG: def
EVENT_SCHEMA: myschema
EVENT_NAME: e_daily
DEFINER: jon@ghidora
TIME_ZONE: SYSTEM
EVENT_BODY: SQL
EVENT_DEFINITION: BEGIN
  INSERT INTO site_activity.totals (time, total)
  SELECT CURRENT_TIMESTAMP, COUNT(*)
  FROM site_activity.sessions;
```
The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables

-- Event information is also available from the SHOW EVENTS statement. See Section 13.7.5.19, “SHOW EVENTS Statement”. The following statements are equivalent:

-\n
SHOW EVENTS [FROM 'db_name'] [LIKE 'wild']

21.9 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables

The GLOBAL_STATUS and SESSION_STATUS tables provide information about server status variables. Their contents correspond to the information produced by the SHOW GLOBAL STATUS and SHOW SESSION STATUS statements (see Section 13.7.5.36, “SHOW STATUS Statement”).

Notes

- The VARIABLE_VALUE column for each of these tables is defined as VARCHAR(1024).

21.10 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables

The GLOBAL_VARIABLES and SESSION_VARIABLES tables provide information about server status variables. Their contents correspond to the information produced by the SHOW GLOBAL VARIABLES and SHOW SESSION VARIABLES statements (see Section 13.7.5.40, “SHOW VARIABLES Statement”).

Notes

- The VARIABLE_VALUE column for each of these tables is defined as VARCHAR(1024). For variables with very long values that are not completely displayed, use SELECT as a workaround. For example:

```
SELECT @@GLOBAL.innodb_data_file_path;
```
21.11 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table

The INFORMATION_SCHEMA KEY_COLUMN_USAGE table describes which key columns have constraints. The KEY_COLUMN_USAGE table has these columns:

- **CONSTRAINT_CATALOG**
  The name of the catalog to which the constraint belongs. This value is always def.

- **CONSTRAINT_SCHEMA**
  The name of the schema (database) to which the constraint belongs.

- **CONSTRAINT_NAME**
  The name of the constraint.

- **TABLE_CATALOG**
  The name of the catalog to which the table belongs. This value is always def.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the table belongs.

- **TABLE_NAME**
  The name of the table that has the constraint.

- **COLUMN_NAME**
  The name of the column that has the constraint.

  If the constraint is a foreign key, then this is the column of the foreign key, not the column that the foreign key references.

- **ORDINAL_POSITION**
  The column's position within the constraint, not the column's position within the table. Column positions are numbered beginning with 1.

- **POSITION_IN_UNIQUE_CONSTRAINT**
  NULL for unique and primary-key constraints. For foreign-key constraints, this column is the ordinal position in key of the table that is being referenced.

- **REFERENCED_TABLE_SCHEMA**
  The name of the schema (database) referenced by the constraint.

- **REFERENCED_TABLE_NAME**
  The name of the table referenced by the constraint.

- **REFERENCED_COLUMN_NAME**
  The name of the column referenced by the constraint.

Suppose that there are two tables name \( t_1 \) and \( t_3 \) that have the following definitions:
21.12 The INFORMATION_SCHEMA PARAMETERS Table

The PARAMETERS table provides information about parameters for stored routines (stored procedures and stored functions), and about return values for stored functions. The PARAMETERS table does not include built-in SQL functions or user-defined functions (UDFs). Parameter information is similar to the contents of the param_list column in the mysql.proc table.

The PARAMETERS table has these columns:

- **SPECIFIC_CATALOG**
  The name of the catalog to which the routine containing the parameter belongs. This value is always def.

- **SPECIFIC_SCHEMA**
  The name of the schema (database) to which the routine containing the parameter belongs.

- **SPECIFIC_NAME**
  The name of the routine containing the parameter.

- **ORDINAL_POSITION**
  For successive parameters of a stored procedure or function, the ORDINAL_POSITION values are 1, 2, 3, and so forth. For a stored function, there is also a row that applies to the function return value (as described by the RETURNS clause). The return value is not a true parameter, so the row that describes it has these unique characteristics:
    - The ORDINAL_POSITION value is 0.
    - The PARAMETER_NAME and PARAMETER_MODE values are NULL because the return value has no name and the mode does not apply.

- **PARAMETER_MODE**
The mode of the parameter. This value is one of **IN**, **OUT**, or **INOUT**. For a stored function return value, this value is **NULL**.

- **PARAMETER_NAME**
  The name of the parameter. For a stored function return value, this value is **NULL**.

- **DATA_TYPE**
  The parameter data type.

  The **DATA_TYPE** value is the type name only with no other information. The **DTD_IDENTIFIER** value contains the type name and possibly other information such as the precision or length.

- **CHARACTER_MAXIMUM_LENGTH**
  For string parameters, the maximum length in characters.

- **CHARACTER_OCTET_LENGTH**
  For string parameters, the maximum length in bytes.

- **NUMERIC_PRECISION**
  For numeric parameters, the numeric precision.

- **NUMERIC_SCALE**
  For numeric parameters, the numeric scale.

- **CHARACTER_SET_NAME**
  For character string parameters, the character set name.

- **COLLATION_NAME**
  For character string parameters, the collation name.

- **DTD_IDENTIFIER**
  The parameter data type.

  The **DATA_TYPE** value is the type name only with no other information. The **DTD_IDENTIFIER** value contains the type name and possibly other information such as the precision or length.

- **ROUTINE_TYPE**
  **PROCEDURE** for stored procedures, **FUNCTION** for stored functions.

## 21.13 The INFORMATION_SCHEMA PARTITIONS Table

The **PARTITIONS** table provides information about table partitions. Each row in this table corresponds to an individual partition or subpartition of a partitioned table. For more information about partitioning tables, see Chapter 19, *Partitioning*.

The **PARTITIONS** table has these columns:

- **TABLE_CATALOG**
The name of the catalog to which the table belongs. This value is always def.

- **TABLE_SCHEMA**
  The name of the database to which the table belongs.

- **TABLE_NAME**
  The name of the table containing the partition.

- **PARTITION_NAME**
  The name of the partition.

- **SUBPARTITION_NAME**
  If the `PARTITIONS` table row represents a subpartition, the name of subpartition; otherwise NULL.

- **PARTITION_ORDINAL_POSITION**
  All partitions are indexed in the same order as they are defined, with 1 being the number assigned to the first partition. The indexing can change as partitions are added, dropped, and reorganized; the number shown is this column reflects the current order, taking into account any indexing changes.

- **SUBPARTITION_ORDINAL_POSITION**
  Subpartitions within a given partition are also indexed and reindexed in the same manner as partitions are indexed within a table.

- **PARTITION_METHOD**
  One of the values RANGE, LIST, HASH, LINEAR HASH, KEY, or LINEAR KEY; that is, one of the available partitioning types as discussed in Section 19.2, “Partitioning Types”.

- **SUBPARTITION_METHOD**
  One of the values HASH, LINEAR HASH, KEY, or LINEAR KEY; that is, one of the available subpartitioning types as discussed in Section 19.2.6, “Subpartitioning”.

- **PARTITION_EXPRESSION**
  The expression for the partitioning function used in the `CREATE TABLE` or `ALTER TABLE` statement that created the table’s current partitioning scheme.

For example, consider a partitioned table created in the `test` database using this statement:

```sql
CREATE TABLE tp (
  c1 INT,
  c2 INT,
  c3 VARCHAR(25)
) PARTITION BY HASH(c1 + c2) PARTITIONS 4;
```

The `PARTITION_EXPRESSION` column in a `PARTITIONS` table row for a partition from this table displays `c1 + c2`, as shown here:

```sql
SELECT DISTINCT PARTITION_EXPRESSION FROM INFORMATION_SCHEMA.PARTITIONS
```
The INFORMATION_SCHEMA PARTITIONS Table

```
WHERE TABLE_NAME='tp' AND TABLE_SCHEMA='test';
+----------------------+
| PARTITION_EXPRESSION |
| c1 + c2             |
+----------------------+
```

• **SUBPARTITION_EXPRESSION**

This works in the same fashion for the subpartitioning expression that defines the subpartitioning for a table as **PARTITION_EXPRESSION** does for the partitioning expression used to define a table’s partitioning.

If the table has no subpartitions, this column is **NULL**.

• **PARTITION_DESCRIPTION**

This column is used for RANGE and LIST partitions. For a **RANGE** partition, it contains the value set in the partition’s **VALUES LESS THAN** clause, which can be either an integer or **MAXVALUE**. For a **LIST** partition, this column contains the values defined in the partition’s **VALUES IN** clause, which is a list of comma-separated integer values.

For partitions whose **PARTITION_METHOD** is other than **RANGE** or **LIST**, this column is always **NULL**.

• **TABLE_ROWS**

The number of table rows in the partition.

For partitioned InnoDB tables, the row count given in the **TABLE_ROWS** column is only an estimated value used in SQL optimization, and may not always be exact.

For **NDB** tables, you can also obtain this information using the `ndb_desc` utility.

• **AVG_ROW_LENGTH**

The average length of the rows stored in this partition or subpartition, in bytes. This is the same as **DATA_LENGTH** divided by **TABLE_ROWS**.

For **NDB** tables, you can also obtain this information using the `ndb_desc` utility.

• **DATA_LENGTH**

The total length of all rows stored in this partition or subpartition, in bytes; that is, the total number of bytes stored in the partition or subpartition.

For **NDB** tables, you can also obtain this information using the `ndb_desc` utility.

• **MAX_DATA_LENGTH**

The maximum number of bytes that can be stored in this partition or subpartition.

For **NDB** tables, you can also obtain this information using the `ndb_desc` utility.

• **INDEX_LENGTH**

The length of the index file for this partition or subpartition, in bytes.

For partitions of **NDB** tables, whether the tables use implicit or explicit partitioning, the **INDEX_LENGTH** column value is always 0. However, you can obtain equivalent information using the `ndb_desc` utility.
Notes

• **DATA_FREE**
The number of bytes allocated to the partition or subpartition but not used.
For **NDB** tables, you can also obtain this information using the *ndb_desc* utility.

• **CREATE_TIME**
The time that the partition or subpartition was created.
Prior to MySQL 5.5.44, for partitioned **InnoDB** tables, this column was always **NULL**. The correct creation time is shown in MySQL 5.5.44 and later. (Bug #17299181, Bug #69990)

• **UPDATE_TIME**
The time that the partition or subpartition was last modified.
For partitioned **InnoDB** tables, the value is always **NULL**.

• **CHECK_TIME**
The last time that the table to which this partition or subpartition belongs was checked.
For partitioned **InnoDB** tables, this column is always **NULL**.

• **CHECKSUM**
The checksum value, if any; otherwise **NULL**.

• **PARTITION_COMMENT**
The text of the comment, if the partition has one. If not, this value is empty.
In MySQL 5.5, the display width of this column is 80 characters, and partition comments which exceed this length are truncated to fit. This issue is fixed in MySQL 5.6. (Bug #11748924, Bug #37728)

• **NODEGROUP**
This is the nodegroup to which the partition belongs. This is relevant only to NDB Cluster tables; otherwise, the value is always **0**.

• **TABLESPACE_NAME**
The name of the tablespace to which the partition belongs. The value is always **DEFAULT**, unless the table uses the **NDB** storage engine (see the *Notes* at the end of this section).

**Notes**

• The **PARTITIONS** table is a nonstandard **INFORMATION_SCHEMA** table.

• A table using any storage engine other than **NDB** and which is not partitioned has one row in the **PARTITIONS** table. However, the values of the **PARTITION_NAME**, **SUBPARTITION_NAME**, **PARTITION_ORDINAL_POSITION**, **SUBPARTITION_ORDINAL_POSITION**, **PARTITION_METHOD**, **SUBPARTITION_METHOD**, **PARTITION_EXPRESSION**, **SUBPARTITION_EXPRESSION**, and **PARTITION_DESCRIPTION** columns are all **NULL**. Also, the **PARTITION_COMMENT** column in this case is blank.

• An **NDB** table which is not explicitly partitioned has one row in the **PARTITIONS** table for each data node in the NDB cluster. For each such row:
The INFORMATION_SCHEMA PLUGINS Table

- The `SUBPARTITION_NAME`, `SUBPARTITION_ORDINAL_POSITION`, `SUBPARTITION_METHOD`, `PARTITION_EXPRESSION`, `SUBPARTITION_EXPRESSION`, `CREATE_TIME`, `UPDATE_TIME`, `CHECK_TIME`, `CHECKSUM`, and `TABLESPACE_NAME` columns are all `NULL`.

- The `PARTITION_METHOD` is always `KEY`.

- The `NODEGROUP` column is `default`.

- The `PARTITION_EXPRESSION` and `PARTITION_COMMENT` columns are empty.

21.14 The INFORMATION_SCHEMA PLUGINS Table

The `PLUGINS` table provides information about server plugins.

The `PLUGINS` table has these columns:

- **PLUGIN_NAME**
  - The name used to refer to the plugin in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`.

- **PLUGIN_VERSION**
  - The version from the plugin's general type descriptor.

- **PLUGIN_STATUS**
  - The plugin status, one of `ACTIVE`, `INACTIVE`, `DISABLED`, or `DELETED`.

- **PLUGIN_TYPE**
  - The type of plugin, such as `STORAGE ENGINE`, `INFORMATION_SCHEMA`, or `AUTHENTICATION`.

- **PLUGIN_TYPE_VERSION**
  - The version from the plugin's type-specific descriptor.

- **PLUGIN_LIBRARY**
  - The name of the plugin shared library file. This is the name used to refer to the plugin file in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`. This file is located in the directory named by the `plugin_dir` system variable. If the library name is `NULL`, the plugin is compiled in and cannot be uninstalled with `UNINSTALL PLUGIN`.

- **PLUGIN_LIBRARY_VERSION**
  - The plugin API interface version.

- **PLUGIN_AUTHOR**
  - The plugin author.

- **PLUGIN_DESCRIPTION**
  - A short description of the plugin.

- **PLUGIN_LICENSE**
  - The plugin license.
How the plugin is licensed (for example, GPL).

• **LOAD_OPTION**

   How the plugin was loaded. The value is OFF, ON, FORCE, or FORCE_PLUS_PERMANENT. See Section 5.5.1, “Installing and Uninstalling Plugins”.

---

### Notes

- The **PLUGINS** table is a nonstandard **INFORMATION_SCHEMA** table.
- For plugins installed with **INSTALL PLUGIN**, the **PLUGIN_NAME** and **PLUGIN_LIBRARY** values are also registered in the **mysql.plugin** table.
- For information about plugin data structures that form the basis of the information in the **PLUGINS** table, see Section 24.2, “The MySQL Plugin API”.

Plugin information is also available from the **SHOW PLUGINS** statement. See Section 13.7.5.26, “SHOW PLUGINS Statement”. These statements are equivalent:

```sql
SELECT
    PLUGIN_NAME, PLUGIN_STATUS, PLUGIN_TYPE,
    PLUGIN_LIBRARY, PLUGIN_LICENSE
FROM INFORMATION_SCHEMA.PLUGINS;
SHOW PLUGINS;
```

### 21.15 The INFORMATION_SCHEMA PROCESSLIST Table

The **PROCESSLIST** table provides information about which threads are running.

The **PROCESSLIST** table has these columns:

- **ID**

  The connection identifier. This is the same type of value displayed in the **Id** column of the **SHOW PROCESSLIST** statement and returned by the **CONNECTION_ID()** function.

- **USER**

  The MySQL user who issued the statement. A value of **system user** refers to a nonclient thread spawned by the server to handle tasks internally. This could be the I/O or SQL thread used on replication slaves or a delayed-row handler. For **system user**, there is no host specified in the **Host** column. **unauthenticated user** refers to a thread that has become associated with a client connection but for which authentication of the client user has not yet been done. **event_scheduler** refers to the thread that monitors scheduled events (see Section 20.4, “Using the Event Scheduler”).

- **HOST**

  The host name of the client issuing the statement (except for **system user**, for which there is no host). The host name for TCP/IP connections is reported in **host_name:client_port** format to make it easier to determine which client is doing what.

- **DB**

  The default database, if one is selected; otherwise **NULL**.

- **COMMAND**

```sql
2712
```
The type of command the thread is executing. For descriptions for thread commands, see Section 8.14, “Examining Thread Information”. The value of this column corresponds to the \texttt{COM\_xxx} commands of the client/server protocol and \texttt{Com\_xxx} status variables. See Section 5.1.9, “Server Status Variables”.

• \textbf{TIME}

The time in seconds that the thread has been in its current state. For a slave SQL thread, the value is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. See Section 17.2.1, “Replication Implementation Details”.

• \textbf{STATE}

An action, event, or state that indicates what the thread is doing. Descriptions for \texttt{STATE} values can be found at Section 8.14, “Examining Thread Information”.

Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

For the \texttt{SHOW PROCESSLIST} statement, the value of \texttt{STATE} is \texttt{NULL}.

• \textbf{INFO}

The statement the thread is executing, or \texttt{NULL} if it is not executing any statement. The statement might be the one sent to the server, or an innermost statement if the statement executes other statements. For example, if a \texttt{CALL} statement executes a stored procedure that is executing a \texttt{SELECT} statement, the \texttt{INFO} value shows the \texttt{SELECT} statement.

Notes

• The \texttt{PROCESSLIST} table is a nonstandard \texttt{INFORMATION\_SCHEMA} table.

• Like the output from the \texttt{SHOW PROCESSLIST} statement, the \texttt{PROCESSLIST} table shows information only about your own threads, unless you have the \texttt{PROCESS} privilege, in which case you will see information about other threads, too. As an anonymous user, you cannot see any rows at all.

• If an SQL statement refers to the \texttt{PROCESSLIST} table, MySQL populates the entire table once, when statement execution begins, so there is read consistency during the statement. There is no read consistency for a multi-statement transaction.

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.PROCESSLIST
SHOW FULL PROCESSLIST
```

21.16 The \texttt{INFORMATION\_SCHEMA PROFILING} Table

The \texttt{PROFILING} table provides statement profiling information. Its contents correspond to the information produced by the \texttt{SHOW PROFILE} and \texttt{SHOW PROFILES} statements (see Section 13.7.5.31, “SHOW PROFILE Statement”). The table is empty unless the \texttt{profiling} session variable is set to 1.

The \texttt{PROFILING} table has these columns:

• \textbf{QUERY\_ID}

A numeric statement identifier.
• **SEQ**
  A sequence number indicating the display order for rows with the same `QUERY_ID` value.

• **STATE**
  The profiling state to which the row measurements apply.

• **DURATION**
  How long statement execution remained in the given state, in seconds.

• **CPU_USER, CPU_SYSTEM**
  User and system CPU use, in seconds.

• **CONTEXT_VOLUNTARY, CONTEXT_INVOLUNTARY**
  How many voluntary and involuntary context switches occurred.

• **BLOCK_OPS_IN, BLOCK_OPS_OUT**
  The number of block input and output operations.

• **MESSAGES_SENT, MESSAGES_RECEIVED**
  The number of communication messages sent and received.

• **PAGE_FAULTS_MAJOR, PAGE_FAULTS_MINOR**
  The number of major and minor page faults.

• **SWAPS**
  How many swaps occurred.

• **SOURCE_FUNCTION, SOURCE_FILE, and SOURCE_LINE**
  Information indicating where in the source code the profiled state executes.

**Notes**

The **PROFILING** table is a nonstandard **INFORMATION_SCHEMA** table.

Profiling information is also available from the **SHOW PROFILE** and **SHOW PROFILES** statements. See Section 13.7.5.31, “SHOW PROFILE Statement”. For example, the following queries are equivalent:

```sql
SHOW PROFILE FOR QUERY 2;
```

```sql
SELECT STATE, FORMAT(DURATION, 6) AS DURATION
FROM INFORMATION_SCHEMA.PROFILING
WHERE QUERY_ID = 2 ORDER BY SEQ;
```

### 21.17 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table

The **REFERENTIAL_CONSTRAINTS** table provides information about foreign keys.
The `REFERENTIAL_CONSTRAINTS` table has these columns:

- **CONSTRAINT_CATALOG**
  The name of the catalog to which the constraint belongs. This value is always `def`.

- **CONSTRAINT_SCHEMA**
  The name of the schema (database) to which the constraint belongs.

- **CONSTRAINT_NAME**
  The name of the constraint.

- **UNIQUE_CONSTRAINT_CATALOG**
  The name of the catalog containing the unique constraint that the constraint references. This value is always `def`.

- **UNIQUE_CONSTRAINT_SCHEMA**
  The name of the schema (database) containing the unique constraint that the constraint references.

- **UNIQUE_CONSTRAINT_NAME**
  The name of the unique constraint that the constraint references.

- **MATCH_OPTION**
  The value of the constraint `MATCH` attribute. The only valid value at this time is `NONE`.

- **UPDATE_RULE**
  The value of the constraint `ON UPDATE` attribute. The possible values are `CASCADE`, `SET NULL`, `SET DEFAULT`, `RESTRICT`, `NO ACTION`.

- **DELETE_RULE**
  The value of the constraint `ON DELETE` attribute. The possible values are `CASCADE`, `SET NULL`, `SET DEFAULT`, `RESTRICT`, `NO ACTION`.

- **TABLE_NAME**
  The name of the table. This value is the same as in the `TABLE_CONSTRAINTS` table.

- **REFERENCED_TABLE_NAME**
  The name of the table referenced by the constraint.

### 21.18 The INFORMATION_SCHEMA ROUTINES Table

The `ROUTINES` table provides information about stored routines (stored procedures and stored functions). The `ROUTINES` table does not include built-in SQL functions or user-defined functions (UDFs).

The column named “`mysql.proc Name`” indicates the `mysql.proc` table column that corresponds to the `INFORMATION_SCHEMA ROUTINES` table column, if any.

The `ROUTINES` table has these columns:
The INFORMATION_SCHEMA ROUTINES Table

- **SPECIFIC_NAME**
  The name of the routine.

- **ROUTINE_CATALOG**
  The name of the catalog to which the routine belongs. This value is always `def`.

- **ROUTINE_SCHEMA**
  The name of the schema (database) to which the routine belongs.

- **ROUTINE_NAME**
  The name of the routine.

- **ROUTINE_TYPE**
  `PROCEDURE` for stored procedures, `FUNCTION` for stored functions.

- **DATA_TYPE**
  If the routine is a stored function, the return value data type. If the routine is a stored procedure, this value is empty.

  The `DATA_TYPE` value is the type name only with no other information. The `DTD_IDENTIFIER` value contains the type name and possibly other information such as the precision or length.

- **CHARACTER_MAXIMUM_LENGTH**
  For stored function string return values, the maximum length in characters. If the routine is a stored procedure, this value is `NULL`.

- **CHARACTER_OCTET_LENGTH**
  For stored function string return values, the maximum length in bytes. If the routine is a stored procedure, this value is `NULL`.

- **NUMERIC_PRECISION**
  For stored function numeric return values, the numeric precision. If the routine is a stored procedure, this value is `NULL`.

- **NUMERIC_SCALE**
  For stored function numeric return values, the numeric scale. If the routine is a stored procedure, this value is `NULL`.

- **CHARACTER_SET_NAME**
  For stored function character string return values, the character set name. If the routine is a stored procedure, this value is `NULL`.

- **COLLATION_NAME**
  For stored function character string return values, the collation name. If the routine is a stored procedure, this value is `NULL`.

- **DTD_IDENTIFIER**
The INFORMATION_SCHEMA ROUTINES Table

If the routine is a stored function, the return value data type. If the routine is a stored procedure, this value is empty.

The **DATA_TYPE** value is the type name only with no other information. The **DTD_IDENTIFIER** value contains the type name and possibly other information such as the precision or length.

- **ROUTINE_BODY**
  The language used for the routine definition. This value is always **SQL**.

- **ROUTINE_DEFINITION**
  The text of the SQL statement executed by the routine.

- **EXTERNAL_NAME**
  This value is always **NULL**.

- **EXTERNAL_LANGUAGE**
  The language of the stored routine. MySQL calculates **EXTERNAL_LANGUAGE** thus:
  - If `mysql.proc.language='SQL'`, **EXTERNAL_LANGUAGE** is **NULL**
  - Otherwise, **EXTERNAL_LANGUAGE** is what is in `mysql.proc.language`. However, we do not have external languages yet, so it is always **NULL**.

- **PARAMETER_STYLE**
  This value is always **SQL**.

- **IS_DETERMINISTIC**
  **YES** or **NO**, depending on whether the routine is defined with the **DETERMINISTIC** characteristic.

- **SQL_DATA_ACCESS**
  The data access characteristic for the routine. The value is one of **CONTAINS SQL**, **NO SQL**, **READS SQL DATA**, or **MODIFIES SQL DATA**.

- **SQL_PATH**
  This value is always **NULL**.

- **SECURITY_TYPE**
  The routine **SQL SECURITY** characteristic. The value is one of **DEFINER** or **INVOKER**.

- **CREATED**
  The date and time when the routine was created. This is a **TIMESTAMP** value.

- **LAST_ALTERED**
  The date and time when the routine was last modified. This is a **TIMESTAMP** value. If the routine has not been modified since its creation, this value is the same as the **CREATED** value.

- **SQL_MODE**
The SQL mode in effect when the routine was created or altered, and under which the routine executes. For the permitted values, see Section 5.1.10, “Server SQL Modes”.

- **ROUTINE_COMMENT**
  The text of the comment, if the routine has one. If not, this value is empty.

- **DEFINER**
  The account of the user who created the routine, in 'user_name'@'host_name' format.

- **CHARACTER_SET_CLIENT**
  The session value of the character_set_client system variable when the routine was created.

- **COLLATION_CONNECTION**
  The session value of the collation_connection system variable when the routine was created.

- **DATABASE_COLLATION**
  The collation of the database with which the routine is associated.

Notes

- Information about stored function return values is also available in the PARAMETERS table. The return value row for a stored function can be identified as the row that has an ORDINAL_POSITION value of 0.

21.19 The INFORMATION_SCHEMA SCHEMATA Table

A schema is a database, so the SCHEMATA table provides information about databases.

The SCHEMATA table has these columns:

- **CATALOG_NAME**
  The name of the catalog to which the schema belongs. This value is always def.

- **SCHEMA_NAME**
  The name of the schema.

- **DEFAULT_CHARACTER_SET_NAME**
  The schema default character set.

- **DEFAULT_COLLATION_NAME**
  The schema default collation.

- **SQL_PATH**
  This value is always NULL.

Schema names are also available from the SHOW DATABASES statement. See Section 13.7.5.15, “SHOW DATABASES Statement”. The following statements are equivalent:

```
SELECT SCHEMA_NAME AS 'Database'
```
FROM INFORMATION_SCHEMA.SCHEMATA
[WHERE SCHEMA_NAME LIKE 'wild']
SHOW DATABASES
[LIKE 'wild']

You see only those databases for which you have some kind of privilege, unless you have the global SHOW DATABASES privilege.

Caution
Because a global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with SHOW DATABASES or by examining the INFORMATION_SCHEMA SCHEMATA table.

21.20 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table

The SCHEMA_PRIVILEGES table provides information about schema (database) privileges. It takes its values from the mysql.db system table.

The SCHEMA_PRIVILEGES table has these columns:

• GRANTEE
  The name of the account to which the privilege is granted, in 'user_name'@'host_name' format.

• TABLE_CATALOG
  The name of the catalog to which the schema belongs. This value is always def.

• TABLE_SCHEMA
  The name of the schema.

• PRIVILEGE_TYPE
  The privilege granted. The value can be any privilege that can be granted at the schema level; see Section 13.7.1.3, “GRANT Statement”. Each row lists a single privilege, so there is one row per schema privilege held by the grantee.

• IS_GRANTABLE
  YES if the user has the GRANT OPTION privilege, NO otherwise. The output does not list GRANT OPTION as a separate row with PRIVILEGE_TYPE='GRANT OPTION'.

Notes

• The SCHEMA_PRIVILEGES table is a nonstandard INFORMATION_SCHEMA table.

The following statements are not equivalent:

SELECT ... FROM INFORMATION_SCHEMA.SCHEMA_PRIVILEGES
SHOW GRANTS ...

21.21 The INFORMATION_SCHEMA STATISTICS Table

The STATISTICS table provides information about table indexes.
The **STATISTICS** table has these columns:

- **TABLE_CATALOG**
  The name of the catalog to which the table containing the index belongs. This value is always **def**.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the table containing the index belongs.

- **TABLE_NAME**
  The name of the table containing the index.

- **NON_UNIQUE**
  0 if the index cannot contain duplicates, 1 if it can.

- **INDEX_SCHEMA**
  The name of the schema (database) to which the index belongs.

- **INDEX_NAME**
  The name of the index. If the index is the primary key, the name is always **PRIMARY**.

- **SEQ_IN_INDEX**
  The column sequence number in the index, starting with 1.

- **COLUMN_NAME**
  The column name. See also the description for the **EXPRESSION** column.

- **COLLATION**
  How the column is sorted in the index. This can have values **A** (ascending), **D** (descending), or **NULL** (not sorted).

- **CARDINALITY**
  An estimate of the number of unique values in the index. To update this number, run **ANALYZE TABLE** or (for **MyISAM** tables) **myisamchk -a**.

  **CARDINALITY** is counted based on statistics stored as integers, so the value is not necessarily exact even for small tables. The higher the cardinality, the greater the chance that MySQL uses the index when doing joins.

- **SUB_PART**
  The index prefix. That is, the number of indexed characters if the column is only partly indexed, **NULL** if the entire column is indexed.

**Note**

Prefix **limits** are measured in bytes. However, prefix **lengths** for index specifications in **CREATE TABLE**, **ALTER TABLE**, and **CREATE INDEX** statements are interpreted as number of characters for nonbinary string types (**CHAR**, **VARCHAR**, **TEXT**) and number of bytes for binary string types (**BINARY**, **VARBINARY**, **LONGVARBINARY**).
VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

For additional information about index prefixes, see Section 8.3.4, “Column Indexes”, and Section 13.1.13, “CREATE INDEX Statement”.

• PACKED
  Indicates how the key is packed. NULL if it is not.

• NULLABLE
  Contains YES if the column may contain NULL values and '' if not.

• INDEX_TYPE
  The index method used (BTREE, FULLTEXT, HASH, RTREE).

• COMMENT
  Information about the index not described in its own column, such as disabled if the index is disabled.

• INDEX_COMMENT
  Any comment provided for the index with a COMMENT attribute when the index was created.

Notes

• There is no standard INFORMATION_SCHEMA table for indexes. The MySQL column list is similar to what SQL Server 2000 returns for sp_statistics, except that QUALIFIER and OWNER are replaced with CATALOG and SCHEMA, respectively.

Information about table indexes is also available from the SHOW_INDEX statement. See Section 13.7.5.23, “SHOW INDEX Statement”. The following statements are equivalent:

  ```sql
  SELECT * FROM INFORMATION_SCHEMA.STATISTICS
  WHERE table_name = 'tbl_name'
  AND table_schema = 'db_name'
  
  SHOW INDEX
  FROM tbl_name
  FROM db_name
  ```

21.22 The INFORMATION_SCHEMA TABLES Table

The TABLES table provides information about tables in databases.

The TABLES table has these columns:

• TABLE_CATALOG
  The name of the catalog to which the table belongs. This value is always def.

• TABLE_SCHEMA
  The name of the schema (database) to which the table belongs.

• TABLE_NAME
  The name of the table.
The INFORMATION_SCHEMA TABLES Table

- **TABLE_TYPE**

  BASE TABLE for a table, VIEW for a view, or SYSTEM VIEW for an INFORMATION_SCHEMA table.

  The TABLES table does not list TEMPORARY tables.

- **ENGINE**


  For partitioned tables, ENGINE shows the name of the storage engine used by all partitions.

- **VERSION**

  The version number of the table's .frm file.

- **ROW_FORMAT**

  The row-storage format (Fixed, Dynamic, Compressed, Redundant, Compact). For MyISAM tables, Dynamic corresponds to what myisamchk -dvv reports as Packed. InnoDB table format is either Redundant or Compact when using the Antelope file format, or Compressed or Dynamic when using the Barracuda file format.

- **TABLE_ROWS**

  The number of rows. Some storage engines, such as MyISAM, store the exact count. For other storage engines, such as InnoDB, this value is an approximation, and may vary from the actual value by as much as 40% to 50%. In such cases, use SELECT COUNT(*) to obtain an accurate count.

  TABLE_ROWS is NULL for INFORMATION_SCHEMA tables.

  For InnoDB tables, the row count is only a rough estimate used in SQL optimization. (This is also true if the InnoDB table is partitioned.)

- **AVG_ROW_LENGTH**

  The average row length.

  Refer to the notes at the end of this section for related information.

- **DATA_LENGTH**

  For MyISAM, DATA_LENGTH is the length of the data file, in bytes.

  For InnoDB, DATA_LENGTH is the approximate amount of space allocated for the clustered index, in bytes. Specifically, it is the clustered index size, in pages, multiplied by the InnoDB page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- **MAX_DATA_LENGTH**

  For MyISAM, MAX_DATA_LENGTH is maximum length of the data file. This is the total number of bytes of data that can be stored in the table, given the data pointer size used.

  Unused for InnoDB.

  Refer to the notes at the end of this section for information regarding other storage engines.
The INFORMATION_SCHEMA TABLES Table

- **INDEX_LENGTH**
  
  For **MyISAM**, `INDEX_LENGTH` is the length of the index file, in bytes.
  
  For **InnoDB**, `INDEX_LENGTH` is the approximate amount of space allocated for non-clustered indexes, in bytes. Specifically, it is the sum of non-clustered index sizes, in pages, multiplied by the **InnoDB** page size.
  
  Refer to the notes at the end of this section for information regarding other storage engines.

- **DATA_FREE**
  
  The number of allocated but unused bytes.
  
  **InnoDB** tables report the free space of the tablespace to which the table belongs. For a table located in the shared tablespace, this is the free space of the shared tablespace. If you are using multiple tablespaces and the table has its own tablespace, the free space is for only that table. Free space means the number of bytes in completely free extents minus a safety margin. Even if free space displays as 0, it may be possible to insert rows as long as new extents need not be allocated.
  
  For **NDB Cluster**, `DATA_FREE` shows the space allocated on disk for, but not used by, a Disk Data table or fragment on disk. (In-memory data resource usage is reported by the `DATA_LENGTH` column.)
  
  For partitioned tables, this value is only an estimate and may not be absolutely correct. A more accurate method of obtaining this information in such cases is to query the **INFORMATION_SCHEMA** PARTITIONS table, as shown in this example:

  ```sql
  SELECT SUM(DATA_FREE)
  FROM INFORMATION_SCHEMA.PARTITIONS
  WHERE TABLE_SCHEMA = 'mydb'
  AND TABLE_NAME = 'mytable';
  ```
  
  For more information, see [Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”](#).

- **AUTO_INCREMENT**
  
  The next `AUTO_INCREMENT` value.

- **CREATE_TIME**
  
  When the table was created.
  
  Prior to MySQL 5.5.44, for partitioned **InnoDB** tables, the `CREATE_TIME` column shows **NULL**. This column shows the correct table creation time for such tables in MySQL 5.5.44 and later. (Bug #17299181, Bug #69990)

- **UPDATE_TIME**
  
  When the data file was last updated. For some storage engines, this value is **NULL**. For example, **InnoDB** stores multiple tables in its **system tablespace** and the data file timestamp does not apply. Even with **file-per-table** mode with each **InnoDB** table in a separate `.ibd` file, **change buffering** can delay the write to the data file, so the file modification time is different from the time of the last insert, update, or delete. For **MyISAM**, the data file timestamp is used; however, on Windows the timestamp is not updated by updates, so the value is inaccurate.
  
  For partitioned **InnoDB** tables, `UPDATE_TIME` is always **NULL**.

- **CHECK_TIME**
When the table was last checked. Not all storage engines update this time, in which case, the value is always \texttt{NULL}.

For partitioned InnoDB tables, \texttt{CHECK_TIME} is always \texttt{NULL}.

- **TABLE_COLLATION**

  The table default collation. The output does not explicitly list the table default character set, but the collation name begins with the character set name.

- **CHECKSUM**

  The live checksum value, if any.

- **CREATE_OPTIONS**

  Extra options used with \texttt{CREATE TABLE}. The original options from when \texttt{CREATE TABLE} was executed are retained and the options reported here may differ from the active table settings and options.

  \texttt{CREATE_OPTIONS} shows \texttt{partitioned} if the table is partitioned.

- **TABLE_COMMENT**

  The comment used when creating the table (or information as to why MySQL could not access the table information).

Notes

- For NDB tables, the output of this statement shows appropriate values for the \texttt{AVG_ROW_LENGTH} and \texttt{DATA_LENGTH} columns, with the exception that \texttt{BLOB} columns are not taken into account.

- For NDB tables, \texttt{DATA_LENGTH} includes data stored in main memory only; the \texttt{MAX_DATA_LENGTH} and \texttt{DATA_FREE} columns apply to Disk Data.

- For NDB Cluster Disk Data tables, \texttt{MAX_DATA_LENGTH} shows the space allocated for the disk part of a Disk Data table or fragment. (In-memory data resource usage is reported by the \texttt{DATA_LENGTH} column.)

- For MEMORY tables, the \texttt{DATA_LENGTH}, \texttt{MAX_DATA_LENGTH}, and \texttt{INDEX_LENGTH} values approximate the actual amount of allocated memory. The allocation algorithm reserves memory in large amounts to reduce the number of allocation operations.

- For views, all \texttt{TABLES} columns are \texttt{NULL} except that \texttt{TABLE_NAME} indicates the view name and \texttt{TABLE_COMMENT} says \texttt{VIEW}.

Table information is also available from the \texttt{SHOW TABLE STATUS} and \texttt{SHOW TABLES} statements. See Section 13.7.5.37, “SHOW TABLE STATUS Statement”, and Section 13.7.5.38, “SHOW TABLES Statement”. The following statements are equivalent:

```sql
SELECT
  TABLE_NAME, ENGINE, VERSION, ROW_FORMAT, TABLE_ROWS, AVG_ROW_LENGTH,
  DATA_LENGTH, MAX_DATA_LENGTH, INDEX_LENGTH, DATA_FREE, AUTO_INCREMENT,
  CREATE_TIME, UPDATE_TIME, CHECK_TIME, TABLE_COLLATION, CHECKSUM,
  CREATE_OPTIONS, TABLE_COMMENT
FROM INFORMATION_SCHEMA.TABLES
WHERE table_schema = \textquote{db_name}
[AND table_name LIKE \textquote{wild}]"
The INFORMATION_SCHEMA TABLESPACES Table

The following statements are equivalent:

```sql
SELECT
    TABLE_NAME, TABLE_TYPE
FROM INFORMATION_SCHEMA.TABLES
WHERE table_schema = 'db_name'
[AND table_name LIKE 'wild']
```

```sql
SHOW FULL TABLES
FROM 'db_name'
[LIKE 'wild']
```

### 21.23 The INFORMATION_SCHEMA TABLESPACES Table

The TABLESPACES table provides information about active MySQL Cluster tablespaces.

The TABLESPACES table has these columns:

- **TABLESPACE_NAME**
  The name of the tablespace.

- **ENGINE**
  The name of the storage engine that uses the tablespace.

- **TABLESPACE_TYPE**
  The tablespace type.

- **LOGFILE_GROUP_NAME**
  The name of the logfile group assigned to the tablespace.

- **EXTENT_SIZE**
  The size in bytes of the extents used by files that belong to the tablespace.

- **AUTOEXTEND_SIZE**
  Unused.

- **MAXIMUM_SIZE**
  Unused.

- **NODEGROUP_ID**
  Unused.

- **TABLESPACE_COMMENT**
  Unused.

**Notes**

- The TABLESPACES table is a nonstandard INFORMATION_SCHEMA table.
- The TABLESPACES table does not provide information about InnoDB tablespaces.
21.24 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table

The `TABLE_CONSTRAINTS` table describes which tables have constraints.

The `TABLE_CONSTRAINTS` table has these columns:

- **CONSTRAINT_CATALOG**
  The name of the catalog to which the constraint belongs. This value is always `def`.

- **CONSTRAINT_SCHEMA**
  The name of the schema (database) to which the constraint belongs.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the table belongs.

- **TABLE_NAME**
  The name of the table.

- **CONSTRAINT_TYPE**
  The type of constraint. The value can be `UNIQUE`, `PRIMARY KEY`, `FOREIGN KEY`, or `CHECK`. This is a `CHAR` (not `ENUM`) column. The `CHECK` value is not available until MySQL supports `CHECK`.

  The `UNIQUE` and `PRIMARY KEY` information is about the same as what you get from the `Key_name` column in the output from `SHOW INDEX` when the `Non_unique` column is `0`.

21.25 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table

The `TABLE_PRIVILEGES` table provides information about table privileges. It takes its values from the `mysql.tables_priv` system table.

The `TABLE_PRIVILEGES` table has these columns:

- **GRANTEE**
  The name of the account to which the privilege is granted, in `'user_name'@'host_name'` format.

- **TABLE_CATALOG**
  The name of the catalog to which the table belongs. This value is always `def`.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the table belongs.

- **TABLE_NAME**
  The name of the table.

- **PRIVILEGE_TYPE**
  The privilege granted. The value can be any privilege that can be granted at the table level; see Section 13.7.1.3, “GRANT Statement”. Each row lists a single privilege, so there is one row per table privilege held by the grantee.
• **IS_GRANTABLE**

  **YES** if the user has the **GRANT OPTION** privilege, **NO** otherwise. The output does not list **GRANT OPTION** as a separate row with **PRIVILEGE_TYPE='GRANT OPTION'**.

Notes

• The **TABLE_PRIVILEGES** table is a nonstandard **INFORMATION_SCHEMA** table.

The following statements are not equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.TABLE_PRIVILEGES
SHOW GRANTS ...
```

### 21.26 The **INFORMATION_SCHEMA TRIGGERS** Table

The **TRIGGERS** table provides information about triggers. To see information about a table’s triggers, you must have the **TRIGGER** privilege for the table.

The **TRIGGERS** table has these columns:

• **TRIGGER_CATALOG**

  The name of the catalog to which the trigger belongs. This value is always def.

• **TRIGGER_SCHEMA**

  The name of the schema (database) to which the trigger belongs.

• **TRIGGER_NAME**

  The name of the trigger.

• **EVENT_MANIPULATION**

  The trigger event. This is the type of operation on the associated table for which the trigger activates. The value is **INSERT** (a row was inserted), **DELETE** (a row was deleted), or **UPDATE** (a row was modified).

• **EVENT_OBJECT_CATALOG**, **EVENT_OBJECT_SCHEMA**, and **EVENT_OBJECT_TABLE**

  As noted in Section 20.3, "Using Triggers", every trigger is associated with exactly one table. These columns indicate the catalog and schema (database) in which this table occurs, and the table name, respectively. The **EVENT_OBJECT_CATALOG** value is always def.

• **ACTION_ORDER**

  The ordinal position of the trigger’s action within the list of all similar triggers on the same table. This value is always 0 because it is not possible to have more than one trigger with the same **EVENT_MANIPULATION** and **ACTION_TIMING** on the same table.

• **ACTION_CONDITION**

  This value is always NULL.

• **ACTION_STATEMENT**
The trigger body; that is, the statement executed when the trigger activates. This text uses UTF-8 encoding.

- **ACTION_ORIENTATION**
  This value is always `ROW`.

- **ACTION_TIMING**
  Whether the trigger activates before or after the triggering event. The value is `BEFORE` or `AFTER`.

- **ACTION_REFERENCE_OLD_TABLE**
  This value is always `NULL`.

- **ACTION_REFERENCE_NEW_TABLE**
  This value is always `NULL`.

- **ACTION_REFERENCE_OLD_ROW** and **ACTION_REFERENCE_NEW_ROW**
  The old and new column identifiers, respectively. The `ACTION_REFERENCE_OLD_ROW` value is always `OLD` and the `ACTION_REFERENCE_NEW_ROW` value is always `NEW`.

- **CREATED**
  This value is always `NULL`.

- **SQL_MODE**
  The SQL mode in effect when the trigger was created, and under which the trigger executes. For the permitted values, see Section 5.1.10, “Server SQL Modes”.

- **DEFINER**
  The account of the user who created the trigger, in `'user_name'@'host_name'` format.

- **CHARACTER_SET_CLIENT**
  The session value of the `character_set_client` system variable when the trigger was created.

- **COLLATION_CONNECTION**
  The session value of the `collation_connection` system variable when the trigger was created.

- **DATABASE_COLLATION**
  The collation of the database with which the trigger is associated.

**Example**

The following example uses the `ins_sum` trigger defined in Section 20.3, “Using Triggers”:

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.TRIGGERS
WHERE TRIGGER_SCHEMA='test' AND TRIGGER_NAME='ins_sum'\G
*************************** 1. row ***************************
TRIGGER_CATALOG: def
TRIGGER_SCHEMA: test
TRIGGER_NAME: ins_sum
```
The INFORMATION_SCHEMA USER_PRIVILEGES Table

The USER_PRIVILEGES table provides information about global privileges. It takes its values from the mysql.user system table.

The USER_PRIVILEGES table has these columns:

- **GRANTEE**
  
  The name of the account to which the privilege is granted, in 'user_name'@'host_name' format.

- **TABLE_CATALOG**
  
  The name of the catalog. This value is always def.

- **PRIVILEGE_TYPE**
  
  The privilege granted. The value can be any privilege that can be granted at the global level; see Section 13.7.1.3, “GRANT Statement”. Each row lists a single privilege, so there is one row per global privilege held by the grantee.

- **IS_GRANTABLE**
  
  YES if the user has the GRANT OPTION privilege, NO otherwise. The output does not list GRANT OPTION as a separate row with PRIVILEGE_TYPE='GRANT OPTION'.

Notes

- The USER_PRIVILEGES table is a nonstandard INFORMATION_SCHEMA table.

The following statements are not equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.USER_PRIVILEGES
SHOW GRANTS ...
```
The VIEWS table provides information about views in databases. You must have the SHOW VIEW privilege to access this table.

The VIEWS table has these columns:

- **TABLE_CATALOG**
  The name of the catalog to which the view belongs. This value is always def.

- **TABLE_SCHEMA**
  The name of the schema (database) to which the view belongs.

- **TABLE_NAME**
  The name of the view.

- **VIEW_DEFINITION**
  The SELECT statement that provides the definition of the view. This column has most of what you see in the Create Table column that SHOW CREATE VIEW produces. Skip the words before SELECT and skip the words WITH CHECK OPTION. Suppose that the original statement was:

  ```
  CREATE VIEW v AS
  SELECT s2,s1 FROM t
  WHERE s1 > 5
  ORDER BY s1
  WITH CHECK OPTION;
  ```

  Then the view definition looks like this:

  ```
  SELECT s2,s1 FROM t WHERE s1 > 5 ORDER BY s1
  ```

- **CHECK_OPTION**
  The value of the CHECK_OPTION attribute. The value is one of NONE, CASCADE, or LOCAL.

- **IS_UPDATABLE**
  MySQL sets a flag, called the view updatability flag, at CREATE VIEW time. The flag is set to YES (true) if UPDATE and DELETE (and similar operations) are legal for the view. Otherwise, the flag is set to NO (false). The IS_UPDATABLE column in the VIEWS table displays the status of this flag. If means that the server always knows whether a view is updatable.

  If a view is not updatable, statements such UPDATE, DELETE, and INSERT are illegal and are rejected. (Even if a view is updatable, it might not be possible to insert into it; for details, refer to Section 20.5.3, “Updatable and Insertable Views”.)

- **DEFINER**
  The account of the user who created the view, in 'user_name'@'host_name' format.

- **SECURITY_TYPE**
  The view SQL SECURITY characteristic. The value is one of DEFINER or INVOKER.

- **CHARACTER_SET_CLIENT**
  The session value of the character_set_client system variable when the view was created.
MySQL permits different `sql_mode` settings to tell the server the type of SQL syntax to support. For example, you might use the `ANSI` SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (`||`), in your queries. If you then create a view that concatenates items, you might worry that changing the `sql_mode` setting to a value different from `ANSI` could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a ` CONCAT()` function:

```
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)
mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT VIEW_DEFINITION FROM INFORMATION_SCHEMA.VIEWS
    WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v';
+----------------------------------+
<table>
<thead>
<tr>
<th>VIEW_DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>select concat('a','b') AS 'col1'</td>
</tr>
</tbody>
</table>
+----------------------------------+
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of `sql_mode` do not affect the results from the view. However, an additional consequence is that comments prior to `SELECT` are stripped from the definition by the server.

### 21.29 INFORMATION_SCHEMA InnoDB Tables

This section provides table definitions for `InnoDB INFORMATION_SCHEMA` tables. For related information and examples, see Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”.

`InnoDB INFORMATION_SCHEMA` tables can be used to monitor ongoing InnoDB activity, to detect inefficiencies before they turn into issues, or to troubleshoot performance and capacity issues. As your database becomes bigger and busier, running up against the limits of your hardware capacity, you monitor and tune these aspects to keep the database running smoothly.

#### 21.29.1 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table

The `INNODB_BUFFER_PAGE` table provides information about each `page` in the InnoDB buffer pool.

For related usage information and examples, see Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”.

**Warning**

Querying the `INNODB_BUFFER_PAGE` table can affect performance. Do not query this table on a production system unless you are aware of the performance impact and have determined it to be acceptable. To avoid impacting performance on a production system, reproduce the issue you want to investigate and query buffer pool statistics on a test instance.

The `INNODB_BUFFER_PAGE` table has these columns:
The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table

- **POOL_ID**
  The buffer pool ID. This is an identifier to distinguish between multiple buffer pool instances.

- **BLOCK_ID**
  The buffer pool block ID.

- **SPACE**
  The tablespace ID.

- **PAGE_NUMBER**
  The page number.

- **PAGE_TYPE**
  The page type. The following table shows the permitted values.

  **Table 21.1 INNODB_BUFFER_PAGE.PAGE_TYPE Values**

<table>
<thead>
<tr>
<th>Page Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALLOCATED</td>
<td>Freshly allocated page</td>
</tr>
<tr>
<td>BLOB</td>
<td>Uncompressed BLOB page</td>
</tr>
<tr>
<td>COMPRESSED_BLOB2</td>
<td>Subsequent comp BLOB page</td>
</tr>
<tr>
<td>COMPRESSED_BLOB</td>
<td>First compressed BLOB page</td>
</tr>
<tr>
<td>EXTENT_DESCRIPTOR</td>
<td>Extent descriptor page</td>
</tr>
<tr>
<td>FILE_SPACE_HEADER</td>
<td>File space header</td>
</tr>
<tr>
<td>IBUF_BITMAP</td>
<td>Insert buffer bitmap</td>
</tr>
<tr>
<td>IBUF_FREE_LIST</td>
<td>Insert buffer free list</td>
</tr>
<tr>
<td>IBUF_INDEX</td>
<td>Insert buffer index</td>
</tr>
<tr>
<td>INDEX</td>
<td>B-tree node</td>
</tr>
<tr>
<td>INODE</td>
<td>Index node</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>System page</td>
</tr>
<tr>
<td>TRX_SYSTEM</td>
<td>Transaction system data</td>
</tr>
<tr>
<td>UNDO_LOG</td>
<td>Undo log page</td>
</tr>
<tr>
<td>UNKNOWN</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

- **FLUSH_TYPE**
  The flush type.

- **FIX_COUNT**
  The number of threads using this block within the buffer pool. When zero, the block is eligible to be evicted.

- **IS_HASHED**
  Whether a hash index has been built on this page.
The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table

- **NEWEST_MODIFICATION**
  The Log Sequence Number of the youngest modification.

- **OLDEST_MODIFICATION**
  The Log Sequence Number of the oldest modification.

- **ACCESS_TIME**
  An abstract number used to judge the first access time of the page.

- **TABLE_NAME**
  The name of the table the page belongs to. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **INDEX_NAME**
  The name of the index the page belongs to. This can be the name of a clustered index or a secondary index. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **NUMBER_RECORDS**
  The number of records within the page.

- **DATA_SIZE**
  The sum of the sizes of the records. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **COMPRESSED_SIZE**
  The compressed page size. `NULL` for pages that are not compressed.

- **PAGE_STATE**
  The page state. The following table shows the permitted values.

  Table 21.2 INNODB_BUFFER_PAGE.PAGE_STATE Values

<table>
<thead>
<tr>
<th>Page State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FILE_PAGE</td>
<td>A buffered file page</td>
</tr>
<tr>
<td>MEMORY</td>
<td>Contains a main memory object</td>
</tr>
<tr>
<td>NOT_USED</td>
<td>In the free list</td>
</tr>
<tr>
<td>NULL</td>
<td>Clean compressed pages, compressed pages in the flush list, pages used as</td>
</tr>
<tr>
<td></td>
<td>buffer pool watch sentinels</td>
</tr>
<tr>
<td>READY_FOR_USE</td>
<td>A free page</td>
</tr>
<tr>
<td>REMOVE_HASH</td>
<td>Hash index should be removed before placing in the free list</td>
</tr>
</tbody>
</table>

- **IO_FIX**
  Whether any I/O is pending for this page: **IO_NONE** = no pending I/O, **IO_READ** = read pending, **IO_WRITE** = write pending.

- **IS_OLD**
Whether the block is in the sublist of old blocks in the LRU list.

- **FREE_PAGE_CLOCK**

The value of the `freed_page_clock` counter when the block was the last placed at the head of the LRU list. The `freed_page_clock` counter tracks the number of blocks removed from the end of the LRU list.

### Example

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE WHERE BLOCK_ID=9
```

<table>
<thead>
<tr>
<th>POOL_ID: 0</th>
<th>BLOCK_ID: 9</th>
<th>SPACE: 0</th>
<th>PAGE_NUMBER: 8019</th>
<th>PAGE_TYPE: INDEX</th>
<th>FLUSH_TYPE: 2</th>
<th>FIX_COUNT: 0</th>
<th>IS_HASHED: YES</th>
<th>NEWEST_MODIFICATION: 226918754</th>
<th>OLDEST_MODIFICATION: 0</th>
</tr>
</thead>
</table>
```

### Notes

- This table is useful primarily for expert-level performance monitoring, or when developing performance-related extensions for MySQL.

- You must have the `PROCESS` privilege to query this table.

- Use the `INFORMATION_SCHEMA COLUMNS` table or the `SHOW COLUMNS` statement to view additional information about the columns of this table, including data types and default values.

- When tables, table rows, partitions, or indexes are deleted, associated pages remain in the buffer pool until space is required for other data. The `INNODB_BUFFER_PAGE` table reports information about these pages until they are evicted from the buffer pool. For more information about how the InnoDB manages buffer pool data, see Section 14.8.1, "Buffer Pool".

### 21.29.2 The INFORMATION_SCHEMA INNODB BUFFER PAGE LRU Table

The `INNODB_BUFFER_PAGE_LRU` table provides information about the pages in the InnoDB buffer pool; in particular, how they are ordered in the LRU list that determines which pages to evict from the buffer pool when it becomes full.

The `INNODB_BUFFER_PAGE_LRU` table has the same columns as the `INNODB_BUFFER_PAGE` table, except that the `INNODB_BUFFER_PAGE_LRU` table has `LRU_POSITION` and `COMPRESSED` columns instead of `BLOCK_ID` and `PAGE_STATE` columns.

For related usage information and examples, see Section 14.18.3, "InnoDB INFORMATION_SCHEMA Buffer Pool Tables".
Warning

Querying the `INNODB_BUFFER_PAGE_LRU` table can affect performance. Do not query this table on a production system unless you are aware of the performance impact and have determined it to be acceptable. To avoid impacting performance on a production system, reproduce the issue you want to investigate and query buffer pool statistics on a test instance.

The `INNODB_BUFFER_PAGE_LRU` table has these columns:

- **POOL_ID**
  The buffer pool ID. This is an identifier to distinguish between multiple buffer pool instances.

- **LRU_POSITION**
  The position of the page in the LRU list.

- **SPACE**
  The tablespace ID.

- **PAGE_NUMBER**
  The page number.

- **PAGE_TYPE**
  The page type. The following table shows the permitted values.

<table>
<thead>
<tr>
<th>Page Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALLOCATED</td>
<td>Freshly allocated page</td>
</tr>
<tr>
<td>BLOB</td>
<td>Uncompressed BLOB page</td>
</tr>
<tr>
<td>COMPRESSED_BLOB2</td>
<td>Subsequent comp BLOB page</td>
</tr>
<tr>
<td>COMPRESSED_BLOB</td>
<td>First compressed BLOB page</td>
</tr>
<tr>
<td>EXTENT_DESCRIPTOR</td>
<td>Extent descriptor page</td>
</tr>
<tr>
<td>FILE_SPACE_HEADER</td>
<td>File space header</td>
</tr>
<tr>
<td>IBUF_BITMAP</td>
<td>Insert buffer bitmap</td>
</tr>
<tr>
<td>IBUF_FREE_LIST</td>
<td>Insert buffer free list</td>
</tr>
<tr>
<td>IBUF_INDEX</td>
<td>Insert buffer index</td>
</tr>
<tr>
<td>INDEX</td>
<td>B-tree node</td>
</tr>
<tr>
<td>INODE</td>
<td>Index node</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>System page</td>
</tr>
<tr>
<td>TRX_SYSTEM</td>
<td>Transaction system data</td>
</tr>
<tr>
<td>UNDO_LOG</td>
<td>Undo log page</td>
</tr>
<tr>
<td>UNKNOWN</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

- **FLUSH_TYPE**
The flush type.

- **FIX_COUNT**
  The number of threads using this block within the buffer pool. When zero, the block is eligible to be evicted.

- **IS_HASHED**
  Whether a hash index has been built on this page.

- **NEWEST_MODIFICATION**
  The Log Sequence Number of the youngest modification.

- **OLDEST_MODIFICATION**
  The Log Sequence Number of the oldest modification.

- **ACCESS_TIME**
  An abstract number used to judge the first access time of the page.

- **TABLE_NAME**
  The name of the table the page belongs to. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **INDEX_NAME**
  The name of the index the page belongs to. This can be the name of a clustered index or a secondary index. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **NUMBER_RECORDS**
  The number of records within the page.

- **DATA_SIZE**
  The sum of the sizes of the records. This column is applicable only to pages with a `PAGE_TYPE` value of `INDEX`.

- **COMPRESSED_SIZE**
  The compressed page size. `NULL` for pages that are not compressed.

- **COMPRESSED**
  Whether the page is compressed.

- **IO_FIX**
  Whether any I/O is pending for this page: `IO_NONE` = no pending I/O, `IO_READ` = read pending, `IO_WRITE` = write pending.

- **IS_OLD**
  Whether the block is in the sublist of old blocks in the LRU list.
The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table

- **FREE_PAGE_CLOCK**

  The value of the `freed_page_clock` counter when the block was the last placed at the head of the LRU list. The `freed_page_clock` counter tracks the number of blocks removed from the end of the LRU list.

**Example**

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE_LRU LIMIT 1\G
*************************** 1. row ***************************
POOL_ID: 0
LRU_POSITION: 0
SPACE: 0
PAGE_NUMBER: 7485
PAGE_TYPE: INDEX
FLUSH_TYPE: 2
FIX_COUNT: 0
IS_HASHED: YES
NEWEST_MODIFICATION: 216319316
OLDEST_MODIFICATION: 0
ACCESS_TIME: 3376846384
TABLE_NAME: employees/salaries
INDEX_NAME: emp_no
NUMBER_RECORDS: 1300
DATA_SIZE: 15600
COMPRESSED_SIZE: 0
COMPRESSED: NO
IO_FIX: IO_NONE
IS_OLD: YES
FREE_PAGE_CLOCK: 0
```

**Notes**

- This table is useful primarily for expert-level performance monitoring, or when developing performance-related extensions for MySQL.
- You must have the `PROCESS` privilege to query this table.
- Use the `INFORMATION_SCHEMA_COLUMNS` table or the `SHOW COLUMNS` statement to view additional information about the columns of this table, including data types and default values.
- Querying this table can require MySQL to allocate a large block of contiguous memory, more than 64 bytes times the number of active pages in the buffer pool. This allocation could potentially cause an out-of-memory error, especially for systems with multi-gigabyte buffer pools.
- Querying this table requires MySQL to lock the data structure representing the buffer pool while traversing the LRU list, which can reduce concurrency, especially for systems with multi-gigabyte buffer pools.
- When tables, table rows, partitions, or indexes are deleted, associated pages remain in the buffer pool until space is required for other data. The `INNODB_BUFFER_PAGE_LRU` table reports information about these pages until they are evicted from the buffer pool. For more information about how the InnoDB manages buffer pool data, see Section 14.8.1, “Buffer Pool”.

### 21.29.3 The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table

The `INNODB_BUFFER_POOL_STATS` table provides much of the same buffer pool information provided in `SHOW ENGINE INNODB STATUS` output. Much of the same information may also be obtained using InnoDB buffer pool server status variables.
The idea of making pages in the buffer pool “young” or “not young” refers to transferring them between the sublists at the head and tail of the buffer pool data structure. Pages made “young” take longer to age out of the buffer pool, while pages made “not young” are moved much closer to the point of eviction.

For related usage information and examples, see Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”.

The `INNODB_BUFFER_POOL_STATS` table has these columns:

- **POOL_ID**
  
  The buffer pool ID. This is an identifier to distinguish between multiple buffer pool instances.

- **POOL_SIZE**
  
  The InnoDB buffer pool size in pages.

- **FREE BUFFERS**
  
  The number of free pages in the InnoDB buffer pool.

- **DATABASE_PAGES**
  
  The number of pages in the InnoDB buffer pool containing data. This number includes both dirty and clean pages.

- **OLD_DATABASE_PAGES**
  
  The number of pages in the old buffer pool sublist.

- **MODIFIED_DATABASE_PAGES**
  
  The number of modified (dirty) database pages.

- **PENDING_DECOMPRESS**
  
  The number of pages pending decompression.

- **PENDING_READS**
  
  The number of pending reads.

- **PENDING_FLUSH_LRU**
  
  The number of pages pending flush in the LRU.

- **PENDING_FLUSH_LIST**
  
  The number of pages pending flush in the flush list.

- **PAGES_MADE_YOUNG**
  
  The number of pages made young.

- **PAGES_NOT_MADE_YOUNG**
  
  The number of pages not made young.

- **PAGES_MADE_YOUNG_RATE**
The number of pages made young per second (pages made young since the last printout / time elapsed).

• **PAGES_MADE_NOT_YOUNG_RATE**
  The number of pages not made per second (pages not made young since the last printout / time elapsed).

• **NUMBER_PAGES_READ**
  The number of pages read.

• **NUMBER_PAGES_CREATED**
  The number of pages created.

• **NUMBER_PAGES_WRITTEN**
  The number of pages written.

• **PAGES_READ_RATE**
  The number of pages read per second (pages read since the last printout / time elapsed).

• **PAGES_CREATE_RATE**
  The number of pages created per second (pages created since the last printout / time elapsed).

• **PAGES_WRITTEN_RATE**
  The number of pages written per second (pages written since the last printout / time elapsed).

• **NUMBER_PAGES_GET**
  The number of logical read requests.

• **HIT_RATE**
  The buffer pool hit rate.

• **YOUNG_MAKE_PER_THOUSAND_GETS**
  The number of pages made young per thousand gets.

• **NOT_YOUNG_MAKE_PER_THOUSAND_GETS**
  The number of pages not made young per thousand gets.

• **NUMBER_PAGES_READ_AHEAD**
  The number of pages read ahead.

• **NUMBER_READ_AHEAD_EVICTED**
  The number of pages read into the InnoDB buffer pool by the read-ahead background thread that were subsequently evicted without having been accessed by queries.

• **READ_AHEAD_RATE**
  The read-ahead rate per second (pages read ahead since the last printout / time elapsed).
The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table

- **READ_AHEAD_EVICTED_RATE**
  The number of read-ahead pages evicted without access per second (read-ahead pages not accessed since the last printout / time elapsed).

- **LRU_IO_TOTAL**
  Total LRU I/O.

- **LRU_IO_CURRENT**
  LRU I/O for the current interval.

- **UNCOMPRESS_TOTAL**
  The total number of pages decompressed.

- **UNCOMPRESS_CURRENT**
  The number of pages decompressed in the current interval.

**Example**

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_POOL_STATS;
*************************** 1. row ***************************
POOL_ID: 0
POOL_SIZE: 8192
FREE_BUFFERS: 0
DATABASE_PAGES: 8014
OLD_DATABASE_PAGES: 2938
MODIFIED_DATABASE_PAGES: 0
PENDING_DECOMPRESS: 0
PENDING_READS: 0
PENDING_FLUSH_LRU: 0
PENDING_FLUSH_LIST: 0
PAGES_MADE_YOUNG: 7380
PAGES_NOT_MADE_YOUNG: 0
PAGES_MADE_YOUNG_RATE: 0
PAGES_MADE_NOT_YOUNG_RATE: 0
NUMBER_PAGES_READ: 2723
NUMBER_PAGES_CREATED: 12657
NUMBER_PAGES_WRITTEN: 16181
PAGES_READ_RATE: 0
PAGES_CREATE_RATE: 0
PAGES_WRITTEN_RATE: 0
NUMBER_PAGES_GET: 28952710
HIT_RATE: 1000
YOUNG_MAKE_PER_THOUSAND_GETS: 0
NOT_YOUNG_MAKE_PER_THOUSAND_GETS: 0
NUMBER_PAGES_READ_AHEAD: 2469
NUMBER_READ_AHEAD_EVICTED: 0
READ_AHEAD_RATE: 0
READ_AHEAD_EVICTED_RATE: 0
LRU_IO_TOTAL: 0
LRU_IO_CURRENT: 0
UNCOMPRESS_TOTAL: 0
UNCOMPRESS_CURRENT: 0
```

**Notes**

- This table is useful primarily for expert-level performance monitoring, or when developing performance-related extensions for MySQL.

- You must have the **PROCESS** privilege to query this table.
• Use the INFORMATION_SCHEMA COLUMNS table or the SHOW COLUMNS statement to view additional information about the columns of this table, including data types and default values.

21.29.4 The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables

The INNODB_CMP and INNODB_CMP_RESET tables provide status information on operations related to compressed InnoDB tables.

The INNODB_CMP and INNODB_CMP_RESET tables have these columns:

• PAGE_SIZE
  The compressed page size in bytes.

• COMPRESS_OPS
  The number of times a B-tree page of size PAGE_SIZE has been compressed. Pages are compressed whenever an empty page is created or the space for the uncompressed modification log runs out.

• COMPRESS_OPS_OK
  The number of times a B-tree page of size PAGE_SIZE has been successfully compressed. This count should never exceed COMPRESS_OPS.

• COMPRESS_TIME
  The total time in seconds used for attempts to compress B-tree pages of size PAGE_SIZE.

• UNCOMPRESS_OPS
  The number of times a B-tree page of size PAGE_SIZE has been uncompressed. B-tree pages are uncompressed whenever compression fails or at first access when the uncompressed page does not exist in the buffer pool.

• UNCOMPRESS_TIME
  The total time in seconds used for uncompressing B-tree pages of the size PAGE_SIZE.

Example

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_CMP;
+----------------+-------+--------+--------+---------+----------------+
| page_size      | 1024  | compress_ops | 0      | compress_ops_ok | 0        |
| compress_time  | 0     | 0        | 0      | 0       | 0        |
| uncompress_time| 0     | 0        | 0      | 0       | 0        |
+----------------+-------+--------+--------+---------+----------------+
| page_size      | 2048  | 0      | 0      | 0       | 0        |
| compress_time  | 0     | 0      | 0      | 0       | 0        |
| uncompress_time| 0     | 0      | 0      | 0       | 0        |
+----------------+-------+--------+--------+---------+----------------+
| page_size      | 4096  | 0      | 0      | 0       | 0        |
| compress_time  | 0     | 0      | 0      | 0       | 0        |
| uncompress_time| 0     | 0      | 0      | 0       | 0        |
+----------------+-------+--------+--------+---------+----------------+
```
The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables

```
compress_time: 0
uncompress_ops: 0
uncompress_time: 0
*************************** 4. row ***************************
  page_size: 8192
  compress_ops: 199755
  compress_ops_ok: 112015
  compress_time: 83
  uncompress_ops: 74253
  uncompress_time: 13
*************************** 5. row ***************************
  page_size: 16384
  compress_ops: 0
  compress_ops_ok: 0
  compress_time: 0
  uncompress_ops: 0
  uncompress_time: 0
```

Notes

- Use these tables to measure the effectiveness of InnoDB table compression in your database.
- You must have the PROCESS privilege to query this table.
- Use the INFORMATION_SCHEMA COLUMNS table or the SHOW COLUMNS statement to view additional information about the columns of this table, including data types and default values.
- For usage information, see Section 14.18.1.3, “Using the Compression Information Schema Tables”.

21.29.5 The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables

The INNODB_CMPMEM and INNODB_CMPMEM_RESET tables provide status information on compressed pages within the InnoDB buffer pool.

The INNODB_CMPMEM and INNODB_CMPMEM_RESET tables have these columns:

- **PAGE_SIZE**
  
  The block size in bytes. Each record of this table describes blocks of this size.

- **BUFFER_POOL_INSTANCE**
  
  A unique identifier for the buffer pool instance.

- **PAGES_USED**
  
  The number of blocks of size PAGE_SIZE that are currently in use.

- **PAGES_FREE**
  
  The number of blocks of size PAGE_SIZE that are currently available for allocation. This column shows the external fragmentation in the memory pool. Ideally, these numbers should be at most 1.

- **RELOCATION_OPS**
  
  The number of times a block of size PAGE_SIZE has been relocated. The buddy system can relocate the allocated “buddy neighbor” of a freed block when it tries to form a bigger freed block. Reading from the INNODB_CMPMEM_RESET table resets this count.
• **RELOCATION_TIME**

The total time in microseconds used for relocating blocks of size \texttt{PAGE_SIZE}. Reading from the table \texttt{INNODB_CMPMEM_RESET} resets this count.

**Example**

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_CMPMEM\G
*************************** 1. row ***************************
  page_size: 1024
  buffer_pool_instance: 0
  pages_used: 0
  pages_free: 0
  relocation_ops: 0
  relocation_time: 0
*************************** 2. row ***************************
  page_size: 2048
  buffer_pool_instance: 0
  pages_used: 0
  pages_free: 0
  relocation_ops: 0
  relocation_time: 0
*************************** 3. row ***************************
  page_size: 4096
  buffer_pool_instance: 0
  pages_used: 0
  pages_free: 0
  relocation_ops: 0
  relocation_time: 0
*************************** 4. row ***************************
  page_size: 8192
  buffer_pool_instance: 0
  pages_used: 9043
  pages_free: 1
  relocation_ops: 2457
  relocation_time: 0
*************************** 5. row ***************************
  page_size: 16384
  buffer_pool_instance: 0
  pages_used: 0
  pages_free: 0
  relocation_ops: 0
  relocation_time: 0
```

**Notes**

• Use these tables to measure the effectiveness of \texttt{InnoDB} table compression in your database.

• You must have the \texttt{PROCESS} privilege to query this table.

• Use the \texttt{INFORMATION_SCHEMA_COLUMNS} table or the \texttt{SHOW COLUMNS} statement to view additional information about the columns of this table, including data types and default values.

• For usage information, see Section 14.18.1.3, “Using the Compression Information Schema Tables”.

**21.29.6 The INFORMATION_SCHEMA INNODB_LOCKS Table**

The \texttt{INNODB_LOCKS} table provides information about each lock that an \texttt{InnoDB} transaction has requested but not yet acquired, and each lock that a transaction holds that is blocking another transaction.

The \texttt{INNODB_LOCKS} table has these columns:

• **LOCK_ID**
The INFORMATION_SCHEMA INNODB_LOCKS Table

A unique lock ID number, internal to InnoDB. Treat it as an opaque string. Although LOCK_ID currently contains TRX_ID, the format of the data in LOCK_ID is subject to change at any time. Do not write applications that parse the LOCK_ID value.

- **LOCK_TRX_ID**
  The ID of the transaction holding the lock. To obtain details about the transaction, join this column with the TRX_ID column of the INNODB_TRX table.

- **LOCK_MODE**
  How the lock is requested. Permitted lock mode descriptors are S, X, IS, IX, GAP, AUTO_INC, and UNKNOWN. Lock mode descriptors may be used in combination to identify particular lock modes. For information about InnoDB lock modes, see Section 14.10.1, “InnoDB Locking”.

- **LOCK_TYPE**
  The type of lock. Permitted values are RECORD for a row-level lock, TABLE for a table-level lock.

- **LOCK_TABLE**
  The name of the table that has been locked or contains locked records.

- **LOCK_INDEX**
  The name of the index, if LOCK_TYPE is RECORD; otherwise NULL.

- **LOCK_SPACE**
  The tablespace ID of the locked record, if LOCK_TYPE is RECORD; otherwise NULL.

- **LOCK_PAGE**
  The page number of the locked record, if LOCK_TYPE is RECORD; otherwise NULL.

- **LOCK_REC**
  The heap number of the locked record within the page, if LOCK_TYPE is RECORD; otherwise NULL.

- **LOCK_DATA**
  The data associated with the lock, if any. A value is shown if the LOCK_TYPE is RECORD, otherwise the value is NULL. Primary key values of the locked record are shown for a lock placed on the primary key index. Secondary index values of the locked record are shown for a lock placed on a unique secondary index. Secondary index values are shown with primary key values appended if the secondary index is not unique. If there is no primary key, LOCK_DATA shows either the key values of a selected unique index or the unique InnoDB internal row ID number, according to the rules governing InnoDB clustered index use (see Section 14.9.2.1, “Clustered and Secondary Indexes”). LOCK_DATA reports “supremum pseudo-record” for a lock taken on a supremum pseudo-record. If the page containing the locked record is not in the buffer pool because it was written to disk while the lock was held, InnoDB does not fetch the page from disk. Instead, LOCK_DATA reports NULL.

**Example**

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_LOCKS;
*************************** 1. row ***************************
lock_id: 3723:72:3:2
lock_trx_id: 3723
lock_mode: X
```
The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table

Notes

- Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.

- You must have the PROCESS privilege to query this table.

- Use the INFORMATION_SCHEMA COLUMNS table or the SHOW COLUMNS statement to view additional information about the columns of this table, including data types and default values.

- For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

21.29.7 The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table

The INNODB_LOCK_WAITS table contains one or more rows for each blocked InnoDB transaction, indicating the lock it has requested and any locks that are blocking that request.

The INNODB_LOCK_WAITS table has these columns:

- REQUESTING_TRX_ID
  The ID of the requesting (blocked) transaction.

- REQUESTED_LOCK_ID
  The ID of the lock for which a transaction is waiting. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.

- BLOCKING_TRX_ID
  The ID of the blocking transaction.

- BLOCKING_LOCK_ID
  The ID of a lock held by a transaction blocking another transaction from proceeding. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.

Example

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_LOCK_WAITS\G
*************************** 1. row ***************************
requesting_trx_id: 3B7
```

2745
The INFORMATION_SCHEMA INNODB_TRX Table

21.29.8 The INFORMATION_SCHEMA INNODB_TRX Table

The INNODB_TRX table provides information about every transaction currently executing inside InnoDB, including whether the transaction is waiting for a lock, when the transaction started, and the SQL statement the transaction is executing, if any.

For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

The INNODB_TRX table has these columns:

• **TRX_ID**
  A unique transaction ID number, internal to InnoDB. (Starting in MySQL 5.6, these IDs are not created for transactions that are read only and nonlocking. See Optimizing InnoDB Read-Only Transactions for details.)

• **TRX_WEIGHT**
  The weight of a transaction, reflecting (but not necessarily the exact count of) the number of rows altered and the number of rows locked by the transaction. To resolve a deadlock, InnoDB selects the transaction with the smallest weight as the “victim” to roll back. Transactions that have changed nontransactional tables are considered heavier than others, regardless of the number of altered and locked rows.

• **TRX_STATE**
  The transaction execution state. Permitted values are RUNNING, LOCK WAIT, ROLLING BACK, and COMMITTING.

• **TRX_STARTED**
  The transaction start time.

• **TRX_REQUESTED_LOCK_ID**
  The ID of the lock the transaction is currently waiting for, if TRX_STATE is LOCK WAIT; otherwise NULL. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.

• **TRX_WAIT_STARTED**
  The time when the transaction started waiting on the lock, if TRX_STATE is LOCK WAIT; otherwise NULL.

Notes

• Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.

• You must have the PROCESS privilege to query this table.

• Use the INFORMATION_SCHEMA COLUMNS table or the SHOW COLUMNS statement to view additional information about the columns of this table, including data types and default values.

• For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

requested_lock_id: 3B7:0:306:2
blocking_trx_id: 3B6
blocking_lock_id: 3B6:0:306:2
The INFORMATION_SCHEMA INNODB_TRX Table

- **TRX_MYSQL_THREAD_ID**
  The MySQL thread ID. To obtain details about the thread, join this column with the ID column of the INFORMATION_SCHEMA PROCESSLIST table, but see Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.

- **TRX_QUERY**
  The SQL statement that is being executed by the transaction.

- **TRX_OPERATION_STATE**
  The transaction’s current operation, if any; otherwise NULL.

- **TRX_TABLES_IN_USE**
  The number of InnoDB tables used while processing the current SQL statement of this transaction.

- **TRX_TABLES_LOCKED**
  The number of InnoDB tables that the current SQL statement has row locks on. (Because these are row locks, not table locks, the tables can usually still be read from and written to by multiple transactions, despite some rows being locked.)

- **TRX_LOCK_STRUCTS**
  The number of locks reserved by the transaction.

- **TRX_LOCK_MEMORY_BYTES**
  The total size taken up by the lock structures of this transaction in memory.

- **TRX_ROWS_LOCKED**
  The approximate number of rows locked by this transaction. The value might include delete-marked rows that are physically present but not visible to the transaction.

- **TRX_ROWS_MODIFIED**
  The number of modified and inserted rows in this transaction.

- **TRX_CONCURRENCY_TICKETS**
  A value indicating how much work the current transaction can do before being swapped out, as specified by the innodb_concurrency_tickets system variable.

- **TRX_ISOLATION_LEVEL**
  The isolation level of the current transaction.

- **TRX_UNIQUE_CHECKS**
  Whether unique checks are turned on or off for the current transaction. For example, they might be turned off during a bulk data load.

- **TRX_FOREIGN_KEY_CHECKS**
  Whether foreign key checks are turned on or off for the current transaction. For example, they might be turned off during a bulk data load.
The INFORMATION_SCHEMA INNODB_TRX Table

- **TRX_LAST_FOREIGN_KEY_ERROR**
  The detailed error message for the last foreign key error, if any; otherwise NULL.

- **TRX_ADAPTIVE_HASH_LATCHED**
  Whether the adaptive hash index is locked by the current transaction. (Only a single transaction at a time can modify the adaptive hash index.)

- **TRX_ADAPTIVE_HASH_TIMEOUT**
  Whether to relinquish the search latch immediately for the adaptive hash index, or reserve it across calls from MySQL. When there is no adaptive hash index contention, this value remains zero and statements reserve the latch until they finish. During times of contention, it counts down to zero, and statements release the latch immediately after each row lookup.

**Example**

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_TRX
*************************** 1. row ***************************
  trx_id: 3B7
  trx_state: RUNNING
  trx_started: 2014-11-19 14:33:45
  trx_requested_lock_id: NULL
  trx_wait_started: NULL
  trx_weight: 1
  trx_mysql_thread_id: 2
  trx_query: SELECT * FROM INFORMATION_SCHEMA.INNODB_TRX
  trx_operation_state: NULL
  trx_tables_in_use: 0
  trx_tables_locked: 0
  trx_lock_structs: 1
 trx_lock_memory_bytes: 376
  trx_rows_locked: 0
 trx_rows_modified: 0
  trx_concurrency_tickets: 0
  trx_isolation_level: REPEATABLE READ
  trx_unique_checks: 1
  trx_foreign_key_checks: 1
  trx_last_foreign_key_error: NULL
  trx_adaptive_hash_latched: 0
  trx_adaptive_hash_timeout: 10000
*************************** 2. row ***************************
  trx_id: 3B6
  trx_state: RUNNING
  trx_requested_lock_id: NULL
  trx_wait_started: NULL
  trx_weight: 94055
  trx_mysql_thread_id: 1
  trx_query: DELETE FROM employees.salaries WHERE salary > 75000
  trx_operation_state: updating or deleting
  trx_tables_in_use: 1
  trx_tables_locked: 1
  trx_lock_structs: 841
 trx_lock_memory_bytes: 129464
  trx_rows_locked: 392752
 trx_rows_modified: 93214
  trx_concurrency_tickets: 0
  trx_isolation_level: REPEATABLE READ
  trx_unique_checks: 1
  trx_foreign_key_checks: 1
  trx_last_foreign_key_error: NULL
  trx_adaptive_hash_latched: 0
  trx_adaptive_hash_timeout: 10000
```
Notes

• Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.

• You must have the PROCESS privilege to query this table.

• Use the INFORMATION_SCHEMA COLUMNS table or the SHOW_COLUMNS statement to view additional information about the columns of this table, including data types and default values.

21.30 INFORMATION_SCHEMA NDB Cluster Tables

The following sections provide information about INFORMATION_SCHEMA tables which are specific to NDB Cluster. The FILES table was added in MySQL Server 5.1 as part of NDB Cluster data-on-disk support (it is available in standard MySQL 5.5 but is not used there). The ndb_transid_mysql_connection_map table was added as part of additions made to NDB Cluster’s ndbinfo information database in MySQL NDB Cluster 7.2.2; it is implemented as an INFORMATION_SCHEMA plugin available only in NDB Cluster binaries or source, and does not exist in MySQL Server 5.5.

Additional statistical and other data about NDB Cluster transactions, operations, threads, blocks, and other aspects of performance can be obtained from the tables in the ndbinfo database. Information about these tables, see Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

21.30.1 The INFORMATION_SCHEMA FILES Table

The FILES table provides information about the files in which MySQL NDB Disk Data tables are stored.

The FILES table has these columns:

• FILE_ID
  A file identifier. FILE_ID column values are auto-generated.

• FILE_NAME
  The name of an UNDO log file created by CREATE LOGFILE GROUP or ALTER LOGFILE GROUP, or of a data file created by CREATE TABLESPACE or ALTER TABLESPACE.

• FILE_TYPE
  One of the values UNDO LOG, DATAFILE, or TABLESPACE.

• TABLESPACE_NAME
  The name of the tablespace with which the file is associated.

• TABLE_CATALOG
  This value is always empty.

• TABLE_SCHEMA
  This value is always NULL.

• TABLE_NAME
  The name of the Disk Data table with which the file is associated, if any.
The INFORMATION_SCHEMA FILES Table

- **LOGFILE_GROUP_NAME**
  The name of the log file group to which the log file or data file belongs.

- **LOGFILE_GROUP_NUMBER**
  For an UNDO log file, the auto-generated ID number of the log file group to which the log file belongs.

- **ENGINE**
  For an NDB Cluster Disk Data log file or data file, this value always NDB or NDBCLUSTER.

- **FULLTEXT_KEYS**
  For an NDB Cluster Disk Data log file or data file, this value is always empty.

- **DELETED_ROWS**
  This value is always NULL.

- **UPDATE_COUNT**
  This value is always NULL.

- **FREE_EXTENTS**
  The number of extents which have not yet been used by the file.

- **TOTAL_EXTENTS**
  The total number of extents allocated to the file.

- **EXTENT_SIZE**
  The size of an extent for the file in bytes.

- **INITIAL_SIZE**
  The size of the file in bytes. This is the same value that was used in the INITIAL_SIZE clause of the CREATE LOGFILE GROUP, ALTER LOGFILE GROUP, CREATE TABLESPACE, or ALTER TABLESPACE statement used to create the file.

- **MAXIMUM_SIZE**
  For NDB Cluster Disk Data files, this value is always the same as the INITIAL_SIZE value.

- **AUTOEXTEND_SIZE**
  For NDB Cluster Disk Data files, this value is always empty.

- **CREATION_TIME**
  The date and time when the file was created.

- **LAST_UPDATE_TIME**
  The date and time when the file was last modified.

- **LAST_ACCESS_TIME**
  The date and time when the file was last accessed by the server.
<table>
<thead>
<tr>
<th>Column</th>
<th>Value for NDB Cluster Disk Data files</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECOVER_TIME</td>
<td>always 0</td>
</tr>
<tr>
<td>TRANSACTION_COUNTER</td>
<td>always 0</td>
</tr>
<tr>
<td>VERSION</td>
<td>always NULL</td>
</tr>
<tr>
<td>ROW_FORMAT</td>
<td>always NULL</td>
</tr>
<tr>
<td>TABLE_ROWS</td>
<td>always NULL</td>
</tr>
<tr>
<td>AVG_ROW_LENGTH</td>
<td>always NULL</td>
</tr>
<tr>
<td>DATA_LENGTH</td>
<td>always NULL</td>
</tr>
<tr>
<td>MAX_DATA_LENGTH</td>
<td>always NULL</td>
</tr>
<tr>
<td>INDEX_LENGTH</td>
<td>always NULL</td>
</tr>
<tr>
<td>DATA_FREE</td>
<td>always NULL</td>
</tr>
<tr>
<td>CREATE_TIME</td>
<td>always NULL</td>
</tr>
<tr>
<td>UPDATE_TIME</td>
<td>always NULL</td>
</tr>
<tr>
<td>CHECK_TIME</td>
<td>always NULL</td>
</tr>
<tr>
<td>CHECKSUM</td>
<td>always NULL</td>
</tr>
<tr>
<td>STATUS</td>
<td>always NORMAL</td>
</tr>
<tr>
<td>EXTRA</td>
<td>2751</td>
</tr>
</tbody>
</table>
For NDB Cluster Disk Data files, the **EXTRA** column shows which data node the file belongs to (each data node having its own copy), as well as the size of its undo buffer. Suppose that you use this statement on an NDB Cluster with four data nodes:

```sql
CREATE LOGFILE_GROUP mygroup
    ADD UNDOFILE 'new_undo.dat'
    INITIAL_SIZE 2G
    ENGINE NDB;
```

After running the `CREATE LOGFILE_GROUP` statement successfully, you should see a result similar to the one shown here for this query against the **FILES** table:

```sql
mysql> SELECT LOGFILE_GROUP_NAME, FILE_TYPE, EXTRA
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'new_undo.dat';
```

<table>
<thead>
<tr>
<th>LOGFILE_GROUP_NAME</th>
<th>FILE_TYPE</th>
<th>EXTRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>mygroup</td>
<td>UNDO LOG</td>
<td>CLUSTER_NODE=5;UNDO_BUFFER_SIZE=8388608</td>
</tr>
<tr>
<td>mygroup</td>
<td>UNDO LOG</td>
<td>CLUSTER_NODE=6;UNDO_BUFFER_SIZE=8388608</td>
</tr>
<tr>
<td>mygroup</td>
<td>UNDO LOG</td>
<td>CLUSTER_NODE=7;UNDO_BUFFER_SIZE=8388608</td>
</tr>
<tr>
<td>mygroup</td>
<td>UNDO LOG</td>
<td>CLUSTER_NODE=8;UNDO_BUFFER_SIZE=8388608</td>
</tr>
</tbody>
</table>

**Notes**

- The **FILES** table is a nonstandard **INFORMATION_SCHEMA** table.

**NDB Notes**

- This table provides information about Disk Data files only; you cannot use it for determining disk space allocation or availability for individual NDB tables. However, it is possible to see how much space is allocated for each NDB table having data stored on disk—as well as how much remains available for storage of data on disk for that table—using `ndb_desc`. For more information, see Section 18.4.10, "ndb_desc — Describe NDB Tables".

- The **CREATION_TIME**, **LAST_UPDATE_TIME**, and **LAST_ACCESSED** values are as reported by the operating system, and are not supplied by the NDB storage engine. Where no value is provided by the operating system, these columns display 0000-00-00 00:00:00.

- The difference between the **TOTAL EXTENTS** and **FREE_EXTENTS** columns is the number of extents currently in use by the file:

```sql
SELECT TOTAL_EXTENTS - FREE_EXTENTS AS extents_used
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

To approximate the amount of disk space in use by the file, multiply that difference by the value of the **EXTENT_SIZE** column, which gives the size of an extent for the file in bytes:

```sql
SELECT (TOTAL_EXTENTS - FREE_EXTENTS) * EXTENT_SIZE AS bytes_used
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

Similarly, you can estimate the amount of space that remains available in a given file by multiplying **FREE_EXTENTS** by **EXTENT_SIZE**:

```sql
SELECT FREE_EXTENTS * EXTENT_SIZE AS bytes_free
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```
Important

The byte values produced by the preceding queries are approximations only, and their precision is inversely proportional to the value of `EXTENT_SIZE`. That is, the larger `EXTENT_SIZE` becomes, the less accurate the approximations are.

It is also important to remember that once an extent is used, it cannot be freed again without dropping the data file of which it is a part. This means that deletes from a Disk Data table do not release disk space.

The extent size can be set in a `CREATE TABLESPACE` statement. For more information, see Section 13.1.18, “CREATE TABLESPACE Statement”.

• An additional row is present in the `FILES` table following the creation of a logfile group. This row has NULL for the value of the `FILE_NAME` column. For this row, the value of the `FILE_ID` column is always 0, that of the `FILE_TYPE` column is always `UNDO_LOG`, and that of the `STATUS` column is always `NORMAL`. The value of the `ENGINE` column is always `NDBCLUSTER`.

The `FREE_EXTENTS` column in this row shows the total number of free extents available to all undo files belonging to a given log file group whose name and number are shown in the `LOGFILE_GROUP_NAME` and `LOGFILE_GROUP_NUMBER` columns, respectively.

Suppose there are no existing log file groups on your NDB Cluster, and you create one using the following statement:

```sql
CREATE LOGFILE GROUP lg1
    ADD UNDOFILE 'undofile.dat'
    INITIAL_SIZE = 16M
    UNDO_BUFFER_SIZE = 1M
    ENGINE = NDB;
```

You can now see this NULL row when you query the `FILES` table:

```sql
SELECT DISTINCT
    FILE_NAME AS File,
    FREE_EXTENTS AS Free,
    TOTAL_EXTENTS AS Total,
    EXTENT_SIZE AS Size,
    INITIAL_SIZE AS Initial
FROM INFORMATION_SCHEMA.FILES;
```

<table>
<thead>
<tr>
<th>File</th>
<th>Free</th>
<th>Total</th>
<th>Size</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>undofile.dat</td>
<td>NULL</td>
<td>4194304</td>
<td>4</td>
<td>16777216</td>
</tr>
<tr>
<td>NULL</td>
<td>4184068</td>
<td>NULL</td>
<td>4</td>
<td>NULL</td>
</tr>
</tbody>
</table>

The total number of free extents available for undo logging is always somewhat less than the sum of the `TOTAL_EXTENTS` column values for all undo files in the log file group due to overhead required for maintaining the undo files. This can be seen by adding a second undo file to the log file group, then repeating the previous query against the `FILES` table:

```sql
ALTER LOGFILE GROUP lg1
    ADD UNDOFILE 'undofile02.dat'
    INITIAL_SIZE = 4M
    ENGINE = NDB;
```

```sql
SELECT DISTINCT
    FILE_NAME AS File,
    FREE_EXTENTS AS Free,
FROM INFORMATION_SCHEMA.FILES;
```

You can now see the updated table:
The amount of free space in bytes which is available for undo logging by Disk Data tables using this log file group can be approximated by multiplying the number of free extents by the initial size:

```
mysql> SELECT
    FREE_EXTENTS AS 'Free Extents',
    FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
FROM INFORMATION_SCHEMA.FILES
WHERE LOGFILE_GROUP_NAME = 'lg1'
AND FILE_NAME IS NULL;
```

If you create an NDB Cluster Disk Data table and then insert some rows into it, you can see approximately how much space remains for undo logging afterward, for example:

```
mysql> CREATE TABLESPACE ts1
    ADD DATAFILE 'data1.dat'
    USE LOGFILE GROUP lg1
    INITIAL_SIZE 512M
    ENGINE = NDB;

mysql> CREATE TABLE dd (c1 INT NOT NULL PRIMARY KEY,
    c2 INT, c3 DATE)
    TABLESPACE ts1 STORAGE DISK
    ENGINE = NDB;

mysql> INSERT INTO dd VALUES
    (NULL, 1234567890, '2007-02-02'),
    (NULL, 1126789005, '2007-02-03'),
    (NULL, 1357924680, '2007-02-04'),
    (NULL, 1642097531, '2007-02-05');

mysql> SELECT
    FREE_EXTENTS AS 'Free Extents',
    FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
FROM INFORMATION_SCHEMA.FILES
WHERE LOGFILE_GROUP_NAME = 'lg1'
AND FILE_NAME IS NULL;
```

- An additional row is present in the `FILES` table for any NDB Cluster tablespace, whether or not any data files are associated with the tablespace. This row has NULL for the value of the `FILE_NAME` column. For this row, the value of the `FILE_ID` column is always 0, that of the `FILE_TYPE` column is always 2754.
The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table

TABLESPACE, and that of the STATUS column is always NORMAL. The value of the ENGINE column is always NDBCLUSTER.

• For additional information, and examples of creating and dropping NDB Cluster Disk Data objects, see Section 18.5.12, “NDB Cluster Disk Data Tables”.

21.30.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table

The ndb_transid_mysql_connection_map table provides a mapping between NDB transactions, NDB transaction coordinators, and MySQL Servers attached to an NDB Cluster as API nodes. This information is used when populating the server_operations and server_transactions tables of the ndbinfo NDB Cluster information database.

The ndb_transid_mysql_connection_map table has these columns:

• mysql_connection_id
  The MySQL server connection ID.

• node_id
  The transaction coordinator node ID.

• ndb_transid
  The NDB transaction ID.

Notes

The mysql_connection_id value is the same as the connection or session ID shown in the output of SHOW PROCESSLIST.

There are no SHOW statements associated with this table.

This is a nonstandard table, added in MySQL NDB Cluster 7.2.2. It is implemented as an INFORMATION_SCHEMA plugin; you can verify that it is supported by checking the output of SHOW PLUGINS. If ndb_transid_mysql_connection_map support is enabled, the output from this statement includes a plugin having this name, of type INFORMATION_SCHEMA, and having status ACTIVE, as shown here (using emphasized text):

```
mysql> SHOW PLUGINS;
+----------------------------------+--------+--------------------+---------+---------+
| Name                             | Status | Type               | Library | License |
+----------------------------------+--------+--------------------+---------+---------+
| binlog                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| mysql_native_password            | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| mysql_old_password               | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| CSV                              | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MEMORY                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MRG_MyISAM                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MyISAM                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| PERFORMANCE_SCHEMA               | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| BLACKHOLE                        | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ARCHIVE                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbcluster                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbinfo                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndb_transid_mysql_connection_map | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| InnoDB                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
+----------------------------------+--------+--------------------+---------+---------+
```
The plugin is enabled by default. You can disable it (or force the server not to run unless the plugin starts) by starting the server with the `--ndb-transid-mysql-connection-map` option. If the plugin is disabled, the status is shown by `SHOW PLUGINS` as `DISABLED`. The plugin cannot be enabled or disabled at runtime.

Although the names of this table and its columns are displayed using lowercase, you can use uppercase or lowercase when referring to them in SQL statements.

For this table to be created, the MySQL Server must be a binary supplied with the NDB Cluster distribution, or one built from the NDB Cluster sources with NDB storage engine support enabled. It is not available in the standard MySQL 5.5 Server.

### 21.31 INFORMATION_SCHEMA Thread Pool Tables

The following sections describe the `INFORMATION_SCHEMA` tables associated with the thread pool plugin (see Section 5.5.3, “MySQL Enterprise Thread Pool”). They provide information about thread pool operation:

- **TP_THREAD_GROUP_STATE**: Information about thread pool thread group states
- **TP_THREAD_GROUP_STATS**: Thread group statistics
- **TP_THREAD_STATE**: Information about thread pool thread states

Rows in these tables represent snapshots in time. In the case of **TP_THREAD_STATE**, all rows for a thread group comprise a snapshot in time. Thus, the MySQL server holds the mutex of the thread group while producing the snapshot. But it does not hold mutexes on all thread groups at the same time, to prevent a statement against **TP_THREAD_STATE** from blocking the entire MySQL server.

The thread pool `INFORMATION_SCHEMA` tables are implemented by individual plugins and the decision whether to load one can be made independently of the others (see Section 5.5.3.2, “Thread Pool Installation”). However, the content of all the tables depends on the thread pool plugin being enabled. If a table plugin is enabled but the thread pool plugin is not, the table becomes visible and can be accessed but will be empty.

### 21.31.1 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table

The **TP_THREAD_GROUP_STATE** table has one row per thread group in the thread pool. Each row provides information about the current state of a group.

The **TP_THREAD_GROUP_STATE** table has these columns:

- **TP_GROUP_ID**
  - The thread group ID. This is a unique key within the table.
- **CONSUMER THREADS**

2756
The number of consumer threads. There is at most one thread ready to start executing if the active threads become stalled or blocked.

- **RESERVE_THREADS**

  The number of threads in the reserved state. This means that they will not be started until there is a need to wake a new thread and there is no consumer thread. This is where most threads end up when the thread group has created more threads than needed for normal operation. Often a thread group needs additional threads for a short while and then does not need them again for a while. In this case, they go into the reserved state and remain until needed again. They take up some extra memory resources, but no extra computing resources.

- **CONNECT_THREAD_COUNT**

  The number of threads that are processing or waiting to process connection initialization and authentication. There can be a maximum of four connection threads per thread group; these threads expire after a period of inactivity.

  This column was added in MySQL 5.5.55.

- **CONNECTION_COUNT**

  The number of connections using this thread group.

- **QUEUED_QUERIES**

  The number of statements waiting in the high-priority queue.

- **QUEUED_TRANSACTIONS**

  The number of statements waiting in the low-priority queue. These are the initial statements for transactions that have not started, so they also represent queued transactions.

- **STALL_LIMIT**

  The value of the `thread_pool_stall_limit` system variable for the thread group. This is the same value for all thread groups.

- **PRIO_KICKUP_TIMER**

  The value of the `thread_pool_prio_kickup_timer` system variable for the thread group. This is the same value for all thread groups.

- **ALGORITHM**

  The value of the `thread_pool_algorithm` system variable for the thread group. This is the same value for all thread groups.

- **THREAD_COUNT**

  The number of threads started in the thread pool as part of this thread group.

- **ACTIVE_THREAD_COUNT**

  The number of threads active in executing statements.

- **STALLED_THREAD_COUNT**
The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table

The number of stalled statements in the thread group. A stalled statement could be executing, but from a thread pool perspective it is stalled and making no progress. A long-running statement quickly ends up in this category.

- **WAITING_THREAD_NUMBER**

  If there is a thread handling the polling of statements in the thread group, this specifies the thread number within this thread group. It is possible that this thread could be executing a statement.

- **OLDEST_QUEUED**

  How long in milliseconds the oldest queued statement has been waiting for execution.

- **MAX_THREAD_IDS_IN_GROUP**

  The maximum thread ID of the threads in the group. This is the same as \( \text{MAX(TP_THREAD_NUMBER)} \) for the threads when selected from the TP_THREAD_STATE table. That is, these two queries are equivalent:

  ```sql
  SELECT TP_GROUP_ID, MAX_THREAD_IDS_IN_GROUP
  FROM TP_THREAD_GROUP_STATE;
  
  SELECT TP_GROUP_ID, MAX(TP_THREAD_NUMBER)
  FROM TP_THREAD_STATE GROUP BY TP_GROUP_ID;
  ```

21.31.2 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table

The TP_THREAD_GROUP_STATS table reports statistics per thread group. There is one row per group.

The TP_THREAD_GROUP_STATS table has these columns:

- **TP_GROUP_ID**

  The thread group ID. This is a unique key within the table.

- **CONNECTIONS_STARTED**

  The number of connections started.

- **CONNECTIONS.Closed**

  The number of connections closed.

- **QUERIES_EXECUTED**

  The number of statements executed. This number is incremented when a statement starts executing, not when it finishes.

- **QUERIES_QUEUED**

  The number of statements received that were queued for execution. This does not count statements that the thread group was able to begin executing immediately without queuing, which can happen under the conditions described in Section 5.5.3.3, "Thread Pool Operation".

- **THREADS_STARTED**

  The number of threads started.

- **PRIO_KICKUPS**
The number of statements that have been moved from low-priority queue to high-priority queue based on the value of the `thread_pool_prio_kickup_timer` system variable. If this number increases quickly, consider increasing the value of that variable. A quickly increasing counter means that the priority system is not keeping transactions from starting too early. For InnoDB, this most likely means deteriorating performance due to too many concurrent transactions.

- **STALLED_QUERIES_EXECUTED**
  The number of statements that have become defined as stalled due to executing for longer than the value of the `thread_pool_stall_limit` system variable.

- **BECOME_CONSUMER_THREAD**
  The number of times thread have been assigned the consumer thread role.

- **BECOME_RESERVE_THREAD**
  The number of times threads have been assigned the reserve thread role.

- **BECOME_WAITING_THREAD**
  The number of times threads have been assigned the waiter thread role. When statements are queued, this happens very often, even in normal operation, so rapid increases in this value are normal in the case of a highly loaded system where statements are queued up.

- **WAKE_THREAD_STALL_CHECKER**
  The number of times the stall check thread decided to wake or create a thread to possibly handle some statements or take care of the waiter thread role.

- **SLEEP_WAITS**
  The number of `THD_WAIT_SLEEP` waits. These occur when threads go to sleep; for example, by calling the `SLEEP()` function.

- **DISK_IO_WAITS**
  The number of `THD_WAIT_DISKIO` waits. These occur when threads perform disk I/O that is likely to not hit the file system cache. Such waits occur when the buffer pool reads and writes data to disk, not for normal reads from and writes to files.

- **ROW_LOCK_WAITS**
  The number of `THD_WAIT_ROW_LOCK` waits for release of a row lock by another transaction.

- **GLOBAL_LOCK_WAITS**
  The number of `THD_WAIT_GLOBAL_LOCK` waits for a global lock to be released.

- **META_DATA_LOCK_WAITS**
  The number of `THD_WAIT_META_DATA_LOCK` waits for a metadata lock to be released.

- **TABLE_LOCK_WAITS**
  The number of `THD_WAIT_TABLE_LOCK` waits for a table to be unlocked that the statement needs to access.
The INFORMATION_SCHEMA TP_THREAD_STATE Table

- **USER_LOCK_WAITS**
  The number of `THD_WAIT_USER_LOCK` waits for a special lock constructed by the user thread.

- **BINLOG_WAITS**
  The number of `THD_WAIT_BINLOG_WAITS` waits for the binary log to become free.

- **GROUP_COMMIT_WAITS**
  The number of `THD_WAIT_GROUP_COMMIT` waits. These occur when a group commit must wait for the other parties to complete their part of a transaction.

- **FSYNC_WAITS**
  The number of `THD_WAIT_SYNC` waits for a file sync operation.

### 21.31.3 The INFORMATION_SCHEMA TP_THREAD_STATE Table

The `TP_THREAD_STATE` table has one row per thread created by the thread pool to handle connections. The `TP_THREAD_STATE` table has these columns:

- **TP_GROUP_ID**
  The thread group ID.

- **TP_THREAD_NUMBER**
  The ID of the thread within its thread group. `TP_GROUP_ID` and `TP_THREAD_NUMBER` together provide a unique key within the table.

- **PROCESS_COUNT**
  The 10ms interval in which the statement that uses this thread is currently executing. 0 means no statement is executing, 1 means it is in the first 10ms, and so forth.

- **WAIT_TYPE**
  The type of wait for the thread. `NULL` means the thread is not blocked. Otherwise, the thread is blocked by a call to `thd_wait_begin()` and the value specifies the type of wait. The `xxx_WAIT` columns of the `TP_THREAD_GROUP_STATS` table accumulate counts for each wait type.

The `WAIT_TYPE` value is a string that describes the type of wait, as shown in the following table.

#### Table 21.4 TP_THREAD_STATE Table WAIT_TYPE Values

<table>
<thead>
<tr>
<th>Wait Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>THD_WAIT_SLEEP</code></td>
<td>Waiting for sleep</td>
</tr>
<tr>
<td><code>THD_WAIT_DISKIO</code></td>
<td>Waiting for Disk IO</td>
</tr>
<tr>
<td><code>THD_WAIT_ROW_LOCK</code></td>
<td>Waiting for row lock</td>
</tr>
<tr>
<td><code>THD_WAIT_GLOBAL_LOCK</code></td>
<td>Waiting for global lock</td>
</tr>
<tr>
<td><code>THD_WAIT_META_DATA_LOCK</code></td>
<td>Waiting for metadata lock</td>
</tr>
<tr>
<td><code>THD_WAIT_TABLE_LOCK</code></td>
<td>Waiting for table lock</td>
</tr>
<tr>
<td><code>THD_WAIT_USER_LOCK</code></td>
<td>Waiting for user lock</td>
</tr>
</tbody>
</table>
Extensions to SHOW Statements

<table>
<thead>
<tr>
<th>Wait Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD_WAIT_BINLOG</td>
<td>Waiting for binlog</td>
</tr>
<tr>
<td>THD_WAIT_GROUP_COMMIT</td>
<td>Waiting for group commit</td>
</tr>
<tr>
<td>THD_WAIT_SYNC</td>
<td>Waiting for fsync</td>
</tr>
</tbody>
</table>

21.32 Extensions to SHOW Statements

Some extensions to SHOW statements accompany the implementation of INFORMATION_SCHEMA:

- SHOW can be used to get information about the structure of INFORMATION_SCHEMA itself.
- Several SHOW statements accept a WHERE clause that provides more flexibility in specifying which rows to display.

INFORMATION_SCHEMA is an information database, so its name is included in the output from SHOW DATABASES. Similarly, SHOW TABLES can be used with INFORMATION_SCHEMA to obtain a list of its tables:

```sql
mysql> SHOW TABLES FROM INFORMATION_SCHEMA;
```

<table>
<thead>
<tr>
<th>Tables_in_INFORMATION_SCHEMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHARACTER_SETS</td>
</tr>
<tr>
<td>COLLATIONS</td>
</tr>
<tr>
<td>COLLATION_CHARACTER_SET_APPLICABILITY</td>
</tr>
<tr>
<td>COLUMNS</td>
</tr>
<tr>
<td>COLUMN_PRIVILEGES</td>
</tr>
<tr>
<td>ENGINES</td>
</tr>
<tr>
<td>EVENTS</td>
</tr>
<tr>
<td>FILES</td>
</tr>
<tr>
<td>GLOBAL_STATUS</td>
</tr>
<tr>
<td>GLOBAL_VARIABLES</td>
</tr>
<tr>
<td>KEY_COLUMN_USAGE</td>
</tr>
<tr>
<td>PARTITIONS</td>
</tr>
<tr>
<td>PLUGINS</td>
</tr>
<tr>
<td>PROCESSLIST</td>
</tr>
<tr>
<td>REFERENTIAL_CONSTRAINTS</td>
</tr>
<tr>
<td>ROUTINES</td>
</tr>
<tr>
<td>SCHEMATA</td>
</tr>
<tr>
<td>SCHEMA_PRIVILEGES</td>
</tr>
<tr>
<td>SESSION_STATUS</td>
</tr>
<tr>
<td>SESSION_VARIABLES</td>
</tr>
<tr>
<td>STATISTICS</td>
</tr>
<tr>
<td>TABLES</td>
</tr>
<tr>
<td>TABLE_CONSTRAINTS</td>
</tr>
<tr>
<td>TABLE_PRIVILEGES</td>
</tr>
<tr>
<td>TRIGGERS</td>
</tr>
<tr>
<td>USER_PRIVILEGES</td>
</tr>
<tr>
<td>VIEWS</td>
</tr>
</tbody>
</table>

SHOW COLUMNS and DESCRIBE can display information about the columns in individual INFORMATION_SCHEMA tables.

SHOW statements that accept a LIKE clause to limit the rows displayed also permit a WHERE clause that specifies more general conditions that selected rows must satisfy:
Extensions to SHOW Statements

SHOW FUNCTION STATUS
SHOW INDEX
SHOW OPEN TABLES
SHOW PROCEDURE STATUS
SHOW STATUS
SHOW TABLE STATUS
SHOW TABLES
SHOW TRIGGERS
SHOW VARIABLES

The **WHERE** clause, if present, is evaluated against the column names displayed by the **SHOW** statement. For example, the **SHOW CHARACTER SET** statement produces these output columns:

```sql
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |      2 |
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| cp850    | DOS West European           | cp850_general_ci    |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    |      1 |
| latin1   | cp1252 West European        | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   |      1 |
...```

To use a **WHERE** clause with **SHOW CHARACTER SET**, you would refer to those column names. As an example, the following statement displays information about character sets for which the default collation contains the string 'japanese':

```sql
mysql> SHOW CHARACTER SET WHERE `Default collation` LIKE 'japanese%';
+---------+---------------------------+---------------------+--------+
| Charset | Description               | Default collation   | Maxlen |
| ujis    | EUC-JP Japanese           | ujis_japanese_ci    |      3 |
| sjis    | Shift-JIS Japanese        | sjis_japanese_ci    |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci   |      2 |
| eucjms  | UJIS for Windows Japanese | eucjms_japanese_ci  |      3 |
+---------+---------------------------+---------------------+--------+
```

This statement displays the multibyte character sets:

```sql
mysql> SHOW CHARACTER SET WHERE Maxlen > 1;
+---------+---------------------------+---------------------+--------+
| Charset | Description               | Default collation   | Maxlen |
| big5    | Big5 Traditional Chinese  | big5_chinese_ci     |      2 |
| ujis    | EUC-JP Japanese           | ujis_japanese_ci    |      3 |
| sjis    | Shift-JIS Japanese        | sjis_japanese_ci    |      2 |
| eucjkr  | EUC-KR Korean             | eucjkr_korean_ci    |      2 |
| gb2312  | GB2312 Simplified Chinese | gb2312_chinese_ci   |      2 |
| gbk     | GBK Simplified Chinese    | gbk_chinese_ci      |      2 |
| utf8    | UTF-8 Unicode             | utf8_general_ci     |      3 |
| ucs2    | UCS-2 Unicode             | ucs2_general_ci     |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci   |      2 |
| eucjms  | UJIS for Windows Japanese | eucjms_japanese_ci  |      3 |
+---------+---------------------------+---------------------+--------+
```
The MySQL Performance Schema is a feature for monitoring MySQL Server execution at a low level. The Performance Schema has these characteristics:

- The Performance Schema provides a way to inspect internal execution of the server at runtime. It is implemented using the `PERFORMANCE_SCHEMA` storage engine and the `performance_schema` database. The Performance Schema focuses primarily on performance data. This differs from `INFORMATION_SCHEMA`, which serves for inspection of metadata.

- The Performance Schema monitors server events. An “event” is anything the server does that takes time and has been instrumented so that timing information can be collected. In general, an event could be a function call, a wait for the operating system, a stage of an SQL statement execution such as parsing or sorting, or an entire statement or group of statements. Event collection provides access to information about synchronization calls (such as for mutexes) and file I/O calls for the server and for several storage engines.

- Performance Schema events are distinct from events written to the server's binary log (which describe data modifications) and Event Scheduler events (which are a type of stored program).

- Current events are available, as well as event histories and summaries. This enables you to determine how many times instrumented activities were performed and how much time they took. Event information
is available to show the activities of specific threads, or activity associated with particular objects such as a mutex or file.

- The **PERFORMANCE_SCHEMA** storage engine collects event data using “instrumentation points” in server source code.

- Collected events are stored in tables in the **performance_schema** database. These tables can be queried using `SELECT` statements like other tables.

- Performance Schema configuration can be modified dynamically by updating tables in the **performance_schema** database through SQL statements. Configuration changes affect data collection immediately.

- Tables in the Performance Schema are in-memory tables that use no persistent on-disk storage. The contents are repopulated beginning at server startup and discarded at server shutdown.

- Monitoring is available on all platforms supported by MySQL.

Some limitations might apply: The types of timers might vary per platform. Instruments that apply to storage engines might not be implemented for all storage engines. Instrumentation of each third-party engine is the responsibility of the engine maintainer. See also Section 22.16, “Restrictions on Performance Schema”.

- Data collection is implemented by modifying the server source code to add instrumentation. There are no separate threads associated with the Performance Schema, unlike other features such as replication or the Event Scheduler.

The Performance Schema is intended to provide access to useful information about server execution while having minimal impact on server performance. The implementation follows these design goals:

- Activating the Performance Schema causes no changes in server behavior. For example, it does not cause thread scheduling to change, and it does not cause query execution plans (as shown by `EXPLAIN`) to change.

- No memory allocation is done beyond that which occurs during server startup. By using early allocation of structures with a fixed size, it is never necessary to resize or reallocate them, which is critical for achieving good runtime performance.

- Server monitoring occurs continuously and unobtrusively with very little overhead. Activating the Performance Schema does not make the server unusable.

- The parser is unchanged. There are no new keywords or statements.

- Execution of server code proceeds normally even if the Performance Schema fails internally.

- When there is a choice between performing processing during event collection initially or during event retrieval later, priority is given to making collection faster. This is because collection is ongoing whereas retrieval is on demand and might never happen at all.

- It is easy to add new instrumentation points.

- Instrumentation is versioned. If the instrumentation implementation changes, previously instrumented code will continue to work. This benefits developers of third-party plugins because it is not necessary to upgrade each plugin to stay synchronized with the latest Performance Schema changes.

### 22.1 Performance Schema Quick Start

This section briefly introduces the Performance Schema with examples that show how to use it. For additional examples, see Section 22.15, “Using the Performance Schema to Diagnose Problems”.

2764
For the Performance Schema to be available, support for it must have been configured when
MySQL was built. You can verify whether this is the case by checking the server's help output. If the
Performance Schema is available, the output will mention several variables with names that begin with
\texttt{performance_schema}:

\begin{verbatim}
shell> mysqld --verbose --help
...
--performance_schema
    Enable the performance schema.
--performance_schema_events_waits_history_long_size=#
    Number of rows in events_waits_history_long.
...
\end{verbatim}

If such variables do not appear in the output, your server has not been built to support the Performance
Schema. In this case, see \textit{Section 22.2, “Performance Schema Build Configuration”}.

Assuming that the Performance Schema is available, it is disabled by default. To enable it, start the server
with the \texttt{performance_schema} variable enabled. For example, use these lines in the server
\texttt{my.cnf} file:

\begin{verbatim}
[mysqld]
performance_schema
\end{verbatim}

When the server starts, it sees \texttt{performance_schema} and attempts to initialize the Performance
Schema. To verify successful initialization, use this statement:

\begin{verbatim}
mysql> SHOW VARIABLES LIKE 'performance_schema';
+----------------]+-------|
| Variable_name | Value |
+----------------]+-------|
| performance_schema | ON |
+----------------]+-------|
\end{verbatim}

A value of \texttt{ON} means that the Performance Schema initialized successfully and is ready for use. A value of
\texttt{OFF} means that some error occurred. Check the server error log for information about what went wrong.

The Performance Schema is implemented as a storage engine. If this engine is available (which you
should already have checked earlier), you should see it listed with a \texttt{SUPPORT} value of \texttt{YES} in the output
from the \texttt{INFORMATION_SCHEMA.ENGINES} table or the \texttt{SHOW ENGINES} statement:

\begin{verbatim}
mysql> SELECT * FROM INFORMATION_SCHEMA.ENGINES
WHERE ENGINE='PERFORMANCE_SCHEMA'\G
*************************** 1. row ***************************
| ENGINE: PERFORMANCE_SCHEMA |
| SUPPORT: YES |
| COMMENT: Performance Schema |
| TRANSACTIONS: NO |
| XA: NO |
| SAVEPOINTS: NO |
mysql> SHOW ENGINES\G
...
| Engine: PERFORMANCE_SCHEMA |
| Support: YES |
| Comment: Performance Schema |
| Transactions: NO |
| XA: NO |
| Savepoints: NO |
...
\end{verbatim}

The \texttt{PERFORMANCE_SCHEMA} storage engine operates on tables in the \texttt{performance_schema} database.
You can make \texttt{performance_schema} the default database so that references to its tables need not be
qualified with the database name:
mysql> USE performance_schema;

Performance Schema tables are stored in the performance_schema database. Information about the structure of this database and its tables can be obtained, as for any other database, by selecting from the INFORMATION_SCHEMA database or by using SHOW statements. For example, use either of these statements to see what Performance Schema tables exist:

mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
    WHERE TABLE_SCHEMA = 'performance_schema';

+----------------------------------------------+
| TABLE_NAME                                   |
+----------------------------------------------+
| cond_instances                               |
| events_waits_current                         |
| events_waits_history                         |
| events_waits_history_long                    |
| events_waits_summary_by_instance             |
| events_waits_summary_by_thread_by_event_name |
| events_waits_summary_global_by_event_name    |
| file_instances                               |
| file_summary_by_event_name                   |
| file_summary_by_instance                     |
| mutex_instances                              |
| performance_timers                           |
| rwlock_instances                             |
| setup_consumers                              |
| setup_instruments                            |
| setup_timers                                 |
| threads                                      |
+----------------------------------------------+

mysql> SHOW TABLES FROM performance_schema;

+----------------------------------------------+
| Tables_in_performance_schema                 |
+----------------------------------------------+
| cond_instances                               |
| events_waits_current                         |
| events_waits_history                         |
| ...                                          |

The number of Performance Schema tables increases over time as implementation of additional instrumentation proceeds.

The name of the performance_schema database is lowercase, as are the names of tables within it. Queries should specify the names in lowercase.

To see the structure of individual tables, use SHOW CREATE TABLE:

mysql> SHOW CREATE TABLE performance_schema.setup_consumers\G

*************************** 1. row ***************************
Table: setup_consumers
Create Table: CREATE TABLE `setup_consumers` (  `NAME` varchar(64) NOT NULL,  `ENABLED` enum('YES','NO') NOT NULL  ) ENGINE=PERFORMANCE_SCHEMA DEFAULT CHARSET=utf8

Table structure is also available by selecting from tables such as INFORMATION_SCHEMA.COLUMNS or by using statements such as SHOW COLUMNS.

Tables in the performance_schema database can be grouped according to the type of information in them: Current events, event histories and summaries, object instances, and setup (configuration) information. The following examples illustrate a few uses for these tables. For detailed information about the tables in each group, see Section 22.10, “Performance Schema Table Descriptions”.
To see what the server is doing at the moment, examine the `events_waits_current` table. It contains one row per thread showing each thread’s most recent monitored event:

```sql
mysql> SELECT * FROM performance_schema.events_waits_current\G
*************************** 1. row ***************************
THREAD_ID: 0
EVENT_ID: 5523
EVENT_NAME: wait/synch/mutex/mysys/THR_LOCK::mutex
SOURCE: thr_lock.c:525
TIMER_START: 201660494489586
TIMER_END: 201660494576112
TIMER_WAIT: 86526
SPINS: NULL
OBJECT_SCHEMA: NULL
OBJECT_NAME: NULL
OBJECT_TYPE: NULL
OBJECT_INSTANCE_BEGIN: 142270668
NESTING_EVENT_ID: NULL
OPERATION: lock
NUMBER_OF_BYTES: NULL
FLAGS: 0
```

This event indicates that thread 0 was waiting for 86,526 picoseconds to acquire a lock on `THR_LOCK::mutex`, a mutex in the `mysys` subsystem. The first few columns provide the following information:

- The ID columns indicate which thread the event comes from and the event number.
- `EVENT_NAME` indicates what was instrumented and `SOURCE` indicates which source file contains the instrumented code.
- The timer columns show when the event started and stopped and how long it took. If an event is still in progress, the `TIMER_END` and `TIMER_WAIT` values are `NULL`. Timer values are approximate and expressed in picoseconds. For information about timers and event time collection, see Section 22.4.1, “Performance Schema Event Timing”.

The history tables contain the same kind of rows as the current-events table but have more rows and show what the server has been doing “recently” rather than “currently.” The `events_waits_history` and `events_waits_history_long` tables contain the most recent 10 events per thread and most recent 10,000 events, respectively. For example, to see information for recent events produced by thread 13, do this:

```sql
mysql> SELECT EVENT_ID, EVENT_NAME, TIMER_WAIT FROM performance_schema.events_waits_history
WHERE THREAD_ID = 13
ORDER BY EVENT_ID;
```

```plaintext
+----------+-----------------------------------------+------------+
<table>
<thead>
<tr>
<th>EVENT_ID</th>
<th>EVENT_NAME</th>
<th>TIMER_WAIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>86</td>
<td>wait/synch/mutex/mysys/THR_LOCK::mutex</td>
<td>686322</td>
</tr>
<tr>
<td>87</td>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>320535</td>
</tr>
<tr>
<td>88</td>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>339390</td>
</tr>
<tr>
<td>89</td>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>377100</td>
</tr>
<tr>
<td>90</td>
<td>wait/synch/mutex/sql/LOCK_plugin</td>
<td>614673</td>
</tr>
<tr>
<td>91</td>
<td>wait/synch/mutex/sql/LOCK_open</td>
<td>659925</td>
</tr>
<tr>
<td>92</td>
<td>wait/synch/mutex/sql/THD::LOCK_thd_data</td>
<td>494001</td>
</tr>
<tr>
<td>93</td>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>222489</td>
</tr>
<tr>
<td>94</td>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>214947</td>
</tr>
<tr>
<td>95</td>
<td>wait/synch/mutex/mysys/LOCK_alarm</td>
<td>312993</td>
</tr>
</tbody>
</table>
```

As new events are added to a history table, older events are discarded if the table is full.
Summary tables provide aggregated information for all events over time. The tables in this group summarize event data in different ways. To see which instruments have been executed the most times or have taken the most wait time, sort the `events_waits_summary_global_by_event_name` table on the `COUNT_STAR` or `SUM_TIMER_WAIT` column, which correspond to a `COUNT(*)` or `SUM(TIMER_WAIT)` value, respectively, calculated over all events:

```sql
mysql> SELECT EVENT_NAME, COUNT_STAR
FROM performance_schema.events_waits_summary_global_by_event_name
ORDER BY COUNT_STAR DESC LIMIT 10;
```

<table>
<thead>
<tr>
<th>EVENT_NAME</th>
<th>COUNT_STAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>6419</td>
</tr>
<tr>
<td>wait/io/file/sql/FRM</td>
<td>452</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_plugin</td>
<td>337</td>
</tr>
<tr>
<td>wait/synch/mutex/mysys/THR_LOCK_open</td>
<td>187</td>
</tr>
<tr>
<td>wait/synch/mutex/mysys/LOCK_alarm</td>
<td>147</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/THD::LOCK_thd_data</td>
<td>115</td>
</tr>
<tr>
<td>wait/io/file/mysys/kfile</td>
<td>102</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_global_system_variables</td>
<td>89</td>
</tr>
<tr>
<td>wait/synch/mutex/mysys/THR_LOCK::mutex</td>
<td>89</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_open</td>
<td>88</td>
</tr>
</tbody>
</table>

```sql
mysql> SELECT EVENT_NAME, SUM_TIMER_WAIT
FROM performance_schema.events_waits_summary_global_by_event_name
ORDER BY SUM_TIMER_WAIT DESC LIMIT 10;
```

<table>
<thead>
<tr>
<th>EVENT_NAME</th>
<th>SUM_TIMER_WAIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/io/file/sql/MYSQL_LOG</td>
<td>1599816582</td>
</tr>
<tr>
<td>wait/synch/mutex/mysys/THR_LOCK_malloc</td>
<td>1530083250</td>
</tr>
<tr>
<td>wait/io/file/sql/binlog_index</td>
<td>1385291934</td>
</tr>
<tr>
<td>wait/io/file/sql/FRM</td>
<td>1292823243</td>
</tr>
<tr>
<td>wait/synch/mutex/mysys/kfile</td>
<td>145126935</td>
</tr>
<tr>
<td>wait/io/file/mysys/kfile</td>
<td>104324715</td>
</tr>
<tr>
<td>wait/io/file/sql/casetest</td>
<td>72591750</td>
</tr>
</tbody>
</table>

These results show that the `THR_LOCK_malloc` mutex is “hot,” both in terms of how often it is used and amount of time that threads wait attempting to acquire it.

**Note**

The `THR_LOCK_malloc` mutex is used only in debug builds. In production builds it is not hot because it is nonexistent.

Instance tables document what types of objects are instrumented. An instrumented object, when used by the server, produces an event. These tables provide event names and explanatory notes or status information. For example, the `file_instances` table lists instances of instruments for file I/O operations and their associated files:

```sql
mysql> SELECT *
FROM performance_schema.file_instances\G
```

---

**FILE_NAME:** /opt/mysql-log/60500/binlog.000007
**EVENT_NAME:** wait/io/file/sql/binlog
**OPEN_COUNT:** 0
---

**FILE_NAME:** /opt/mysql/60500/data/mysql/tables_priv.MYI
**EVENT_NAME:** wait/io/file/mysys/kfile
Setup tables are used to configure and display monitoring characteristics. For example, `setup_instruments` lists the set of instruments for which events can be collected and shows which of them are enabled:

```
mysql> SELECT * FROM performance_schema.setup_instruments;
+---------------------------------------------------+---------+-------+
| NAME                                              | ENABLED | TIMED |
+---------------------------------------------------+---------+-------+
| wait/synch/mutex/sql/LOCK_global_read_lock        | YES     | YES   |
| wait/synch/mutex/sql/LOCK_global_system_variables | YES     | YES   |
| wait/synch/mutex/sql/LOCK_lock_db                 | YES     | YES   |
| wait/synch/mutex/sql/LOCK_manager                 | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_grant                  | YES     | YES   |
| wait/synch/rwlock/sql/LOGGER::LOCK_logger         | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_connect       | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_slave         | YES     | YES   |
| wait/io/file/sql/binlog                           | YES     | YES   |
| wait/io/file/sql/binlog_index                      | YES     | YES   |
| wait/io/file/sql/casetest                         | YES     | YES   |
| wait/io/file/sql/dbopt                            | YES     | YES   |
| ...                                                |         |       |
```

To understand how to interpret instrument names, see Section 22.6, “Performance Schema Instrument Naming Conventions”.

To control whether events are collected for an instrument, set its `ENABLED` value to `YES` or `NO`. For example:

```
mysql> UPDATE performance_schema.setup_instruments
       SET ENABLED = 'NO'
       WHERE NAME = 'wait/synch/mutex/sql/LOCK_mysql_create_db';
```

The Performance Schema uses collected events to update tables in the `performance_schema` database, which act as “consumers” of event information. The `setup_consumers` table lists the available consumers and shows which of them are enabled:

```
mysql> SELECT * FROM performance_schema.setup_consumers;
+----------------------------------------------+---------+
| NAME                                         | ENABLED |
+----------------------------------------------+---------+
| events_waits_current                         | YES     |
| events_waits_history                         | YES     |
| events_waits_history_long                    | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name           | YES     |
| events_waits_summary_by_instance             | YES     |
| file_summary_by_event_name                   | YES     |
| file_summary_by_instance                     | YES     |
+----------------------------------------------+---------+
```

To control whether the Performance Schema maintains a consumer as a destination for event information, set its `ENABLED` value.

For more information about the setup tables and how to use them to control event collection, see Section 22.4.2, “Performance Schema Event Filtering”.

2769
There are some miscellaneous tables that do not fall into any of the previous groups. For example, `performance_timers` lists the available event timers and their characteristics. For information about timers, see Section 22.4.1, “Performance Schema Event Timing”.

### 22.2 Performance Schema Build Configuration

For the Performance Schema to be available, it must be configured into the MySQL server at build time. Binary MySQL distributions provided by Oracle Corporation are configured to support the Performance Schema. If you use a binary MySQL distribution from another provider, check with the provider whether the distribution has been appropriately configured.

If you build MySQL from a source distribution, enable the Performance Schema by running `CMake` with the `WITH_PERFSCHEMA_STORAGE_ENGINE` option enabled:

```
shell> cmake . -DWITH_PERFSCHEMA_STORAGE_ENGINE=1
```

Configuring MySQL with the `-DWITHOUT_PERFSCHEMA_STORAGE_ENGINE=1` option prevents inclusion of the Performance Schema, so if you want it included, do not use this option. See Section 2.9.7, “MySQL Source-Configuration Options”.

If you install MySQL over a previous installation that was configured without the Performance Schema (or with an older version of the Performance Schema that has missing or out-of-date tables). One indication of this issue is the presence of messages such as the following in the error log:

```
[ERROR] Native table 'performance_schema'.'events_waits_history'
has the wrong structure
[ERROR] Native table 'performance_schema'.'events_waits_history_long'
has the wrong structure
...'
```

To correct that problem, perform the MySQL upgrade procedure. See Section 2.11, “Upgrading MySQL”.

To verify whether a server was built with Performance Schema support, check its help output. If the Performance Schema is available, the output will mention several variables with names that begin with `performance_schema`:

```
shell> mysql --verbose --help
... --performance_schema
    --performance_schema_events_waits_history_long_size=#
    Number of rows in events_waits_history_long.
...
```

You can also connect to the server and look for a line that names the `PERFORMANCE_SCHEMA` storage engine in the output from `SHOW ENGINES`:

```
mysql> SHOW ENGINES\G
... Engine: PERFORMANCE_SCHEMA
    Support: YES
    Comment: Performance Schema
    Transactions: NO
    XA: NO
    Savepoints: NO
...
```

If the Performance Schema was not configured into the server at build time, no row for `PERFORMANCE_SCHEMA` will appear in the output from `SHOW ENGINES`. You might see `performance_schema` listed in the output from `SHOW DATABASES`, but it will have no tables and you will not be able to use it.
Performance Schema Startup Configuration

A line for `PERFORMANCE_SCHEMA` in the `SHOW ENGINES` output means that the Performance Schema is available, not that it is enabled. To enable it, you must do so at server startup, as described in the next section.

### 22.3 Performance Schema Startup Configuration

To use the MySQL Performance Schema, it must be enabled at server startup to enable event collection to occur.

The Performance Schema is disabled by default. To enable it, start the server with the `performance_schema` variable enabled. For example, use these lines in the server `my.cnf` file:

```
[mysqld]
performance_schema
```

If the server is unable to allocate any internal buffer during Performance Schema initialization, the Performance Schema disables itself and sets `performance_schema` to `OFF`, and the server runs without instrumentation.

The Performance Schema includes several system variables that provide configuration information:

```
mysql> SHOW VARIABLES LIKE 'perf%';
+-----------+---------+
| Variable_name                                     | Value   |
+-----------+---------+
| performance_schema                                | ON      |
| performance_schema_events_waits_history_long_size | 10000   |
| performance_schema_events_waits_history_size      | 10      |
| performance_schema_max_cond_classes               | 80      |
| performance_schema_max_cond_instances             | 1000    |
| performance_schema_max_file_classes               | 50      |
| performance_schema_max_file_handles               | 32768   |
| performance_schema_max_file_instances             | 10000   |
| performance_schema_max_mutex_classes              | 200     |
| performance_schema_max_mutex_instances            | 1000000 |
| performance_schema_max_rwlock_classes             | 30      |
| performance_schema_max_rwlock_instances           | 1000000 |
| performance_schema_max_table_handles              | 100000  |
| performance_schema_max_table_instances            | 50000   |
| performance_schema_max_thread_classes             | 50      |
| performance_schema_max_thread_instances           | 1000    |
```

The `performance_schema` variable is `ON` or `OFF` to indicate whether the Performance Schema is enabled or disabled. The other variables indicate table sizes (number of rows) or memory allocation values.

---

**Note**

With the Performance Schema enabled, the number of Performance Schema instances affects the server memory footprint, perhaps to a large extent. It may be necessary to tune the values of Performance Schema system variables to find the number of instances that balances insufficient instrumentation against excessive memory consumption.

To change the value of Performance Schema system variables, set them at server startup. For example, put the following lines in a `my.cnf` file to change the sizes of the history tables for wait events:

```
[mysqld]
performance_schema
performance_schema_events_waits_history_size=20
```
22.4 Performance Schema Runtime Configuration

Specific Performance Schema features can be enabled at runtime to control which types of event collection occur.

Performance Schema setup tables contain information about monitoring configuration:

```sql
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
    WHERE TABLE_SCHEMA = 'performance_schema'
    AND TABLE_NAME LIKE 'setup%';
```

+-------------------+
| TABLE_NAME        |
+-------------------+
| setup_consumers   |
| setup_instruments |
| setup_timers      |
+-------------------+

You can examine the contents of these tables to obtain information about Performance Schema monitoring characteristics. If you have the `UPDATE` privilege, you can change Performance Schema operation by modifying setup tables to affect how monitoring occurs. For additional details about these tables, see Section 22.10.2, “Performance Schema Setup Tables”.

To see which event timer is selected, query the `setup_timers` tables:

```sql
mysql> SELECT * FROM performance_schema.setup_timers;
```

+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | CYCLE      |
+------+------------+

The `NAME` value indicates the type of instrument to which the timer applies, and `TIMER_NAME` indicates which timer applies to those instruments. The timer applies to instruments where their name begins with a component matching the `NAME` value. There are only “wait” instruments, so this table has only one row and the timer applies to all instruments.

To change the timer, update the `NAME` value. For example, to use the `NANOSECOND` timer:

```sql
mysql> UPDATE performance_schema.setup_timers
    SET TIMER_NAME = 'NANOSECOND'
    WHERE NAME = 'wait';

mysql> SELECT * FROM performance_schema.setup_timers;
```

+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | NANOSECOND |
+------+------------+

For discussion of timers, see Section 22.4.1, “Performance Schema Event Timing”.

The `setup_instruments` and `setup_consumers` tables list the instruments for which events can be collected and the types of consumers for which event information actually is collected, respectively. Section 22.4.2, “Performance Schema Event Filtering”, discusses how you can modify these tables to affect event collection.

If there are Performance Schema configuration changes that must be made at runtime using SQL statements and you would like these changes to take effect each time the server starts, put the statements
in a file and start the server with the \texttt{init}\_file system variable set to name the file. This strategy
can also be useful if you have multiple monitoring configurations, each tailored to produce a different
kind of monitoring, such as casual server health monitoring, incident investigation, application behavior
troubleshooting, and so forth. Put the statements for each monitoring configuration into their own file and
specify the appropriate file as the \texttt{init}\_file value when you start the server.

\section*{22.4.1 Performance Schema Event Timing}

Events are collected by means of instrumentation added to the server source code. Instruments time
events, which is how the Performance Schema provides an idea of how long events take. It is also possible
to configure instruments not to collect timing information. This section discusses the available timers and
their characteristics, and how timing values are represented in events.

\subsection*{Performance Schema Timers}

Two Performance Schema tables provide timer information:

- \texttt{performance}\_timers lists the available timers and their characteristics.
- \texttt{setup}\_timers indicates which timers are used for which instruments.

Each timer row in \texttt{setup}\_timers must refer to one of the timers listed in \texttt{performance}\_timers.

Timers vary in precision and amount of overhead. To see what timers are available and their
characteristics, check the \texttt{performance}\_timers table:

\begin{verbatim}
mysql> SELECT * FROM performance_schema.performance_timers;
+-------------+-----------------+-----------------+----------------|
<table>
<thead>
<tr>
<th>TIMER_NAME</th>
<th>TIMER_FREQUENCY</th>
<th>TIMER_RESOLUTION</th>
<th>TIMER_OVERHEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYCLE</td>
<td>2389029850</td>
<td>1</td>
<td>72</td>
</tr>
<tr>
<td>NANOSECOND</td>
<td>1000000000</td>
<td>1</td>
<td>112</td>
</tr>
<tr>
<td>MICROSECOND</td>
<td>1000000</td>
<td>1</td>
<td>136</td>
</tr>
<tr>
<td>MILLISECOND</td>
<td>1036</td>
<td>1</td>
<td>168</td>
</tr>
<tr>
<td>TICK</td>
<td>105</td>
<td>1</td>
<td>2416</td>
</tr>
</tbody>
</table>
+-------------+-----------------+-----------------+----------------|
\end{verbatim}

If the values associated with a given timer name are \texttt{NULL}, that timer is not supported on your platform.
The rows that do not contain \texttt{NULL} indicate which timers you can use in \texttt{setup}\_timers.

The columns have these meanings:

- The \texttt{TIMER}\_NAME column shows the names of the available timers. \texttt{CYCLE} refers to the timer that is
  based on the CPU (processor) cycle counter. The timers in \texttt{setup}\_timers that you can use are those
  that do not have \texttt{NULL} in the other columns. If the values associated with a given timer name are \texttt{NULL},
  that timer is not supported on your platform.

- \texttt{TIMER}\_FREQUENCY indicates the number of timer units per second. For a cycle timer, the frequency
  is generally related to the CPU speed. The value shown was obtained on a system with a 2.4GHz
  processor. The other timers are based on fixed fractions of seconds. For \texttt{TICK}, the frequency may vary
  by platform (for example, some use 100 ticks/second, others 1000 ticks/second).

- \texttt{TIMER}\_RESOLUTION indicates the number of timer units by which timer values increase at a time. If a
timer has a resolution of 10, its value increases by 10 each time.

- \texttt{TIMER}\_OVERHEAD is the minimal number of cycles of overhead to obtain one timing with the given timer.
The overhead per event is twice the value displayed because the timer is invoked at the beginning and
end of the event.
To see which timer is in effect or to change the timer, access the `setup_timers` table:

```
mysql> SELECT * FROM performance_schema.setup_timers;
+----------+--------------+
| NAME     | TIMER_NAME   |
+----------+--------------+
| wait     | CYCLE        |
+----------+--------------+
mysql> UPDATE performance_schema.setup_timers
           SET TIMER_NAME = 'MICROSECOND'
           WHERE NAME = 'wait';
mysql> SELECT * FROM performance_schema.setup_timers;
+----------+---------------+
| NAME     | TIMER_NAME    |
+----------+---------------+
| wait     | MICROSECOND   |
+----------+---------------+
```

By default, the Performance Schema uses the best timer available for each instrument type, but you can select a different one. Generally the best timer is `CYCLE`, which uses the CPU cycle counter whenever possible to provide high precision and low overhead.

The precision offered by the cycle counter depends on processor speed. If the processor runs at 1 GHz (one billion cycles/second) or higher, the cycle counter delivers sub-nanosecond precision. Using the cycle counter is much cheaper than getting the actual time of day. For example, the standard `gettimeofday()` function can take hundreds of cycles, which is an unacceptable overhead for data gathering that may occur thousands or millions of times per second.

Cycle counters also have disadvantages:

- End users expect to see timings in wall-clock units, such as fractions of a second. Converting from cycles to fractions of seconds can be expensive. For this reason, the conversion is a quick and fairly rough multiplication operation.

- Processor cycle rate might change, such as when a laptop goes into power-saving mode or when a CPU slows down to reduce heat generation. If a processor's cycle rate fluctuates, conversion from cycles to real-time units is subject to error.

- Cycle counters might be unreliable or unavailable depending on the processor or the operating system. For example, on Pentiums, the instruction is `RDTSC` (an assembly-language rather than a C instruction) and it is theoretically possible for the operating system to prevent user-mode programs from using it.

- Some processor details related to out-of-order execution or multiprocessor synchronization might cause the counter to seem fast or slow by up to 1000 cycles.

MySQL works with cycle counters on x86 (Windows, macOS, Linux, Solaris, and other Unix flavors), PowerPC, and IA-64.

**Performance Schema Timer Representation in Events**

Rows in Performance Schema tables that store current events and historical events have three columns to represent timing information: `TIMER_START` and `TIMER_END` indicate when the event started and finished, and `TIMER_WAIT` indicates the event duration.

The `setup_instruments` table has an `ENABLED` column to indicate the instruments for which to collect events. The table also has a `TIMED` column to indicate which instruments are timed. If an instrument is not
enabled, it produces no events. If an enabled instrument is not timed, events produced by the instrument have NULL for the TIMER_START, TIMER_END, and TIMER_WAIT timer values. This in turn causes those values to be ignored when calculating aggregate time values in summary tables (sum, minimum, maximum, and average).

Within events, times are stored in picoseconds (trillionths of a second) to normalize them to a standard unit, regardless of which timer is selected. The timer used for an event is the one in effect when event timing begins. This timer is used to convert start and end values to picoseconds for storage in the event.

Modifications to the setup_timers table affect monitoring immediately. Events already measured are stored using the original timer unit, and events in progress may use the original timer for the begin time and the new timer for the end time. To avoid unpredictable results if you make timer changes, use TRUNCATE TABLE to reset Performance Schema statistics.

The timer baseline (“time zero”) occurs at Performance Schema initialization during server startup. TIMER_START and TIMER_END values in events represent picoseconds since the baseline. TIMER_WAIT values are durations in picoseconds.

Picosecond values in events are approximate. Their accuracy is subject to the usual forms of error associated with conversion from one unit to another. If the CYCLE timer is used and the processor rate varies, there might be drift. For these reasons, it is not reasonable to look at the TIMER_START value for an event as an accurate measure of time elapsed since server startup. On the other hand, it is reasonable to use TIMER_START or TIMER_WAIT values in ORDER BY clauses to order events by start time or duration.

The choice of picoseconds in events rather than a value such as microseconds has a performance basis. One implementation goal was to show results in a uniform time unit, regardless of the timer. In an ideal world this time unit would look like a wall-clock unit and be reasonably precise; in other words, microseconds. But to convert cycles or nanoseconds to microseconds, it would be necessary to perform a division for every instrumentation. Division is expensive on many platforms. Multiplication is not expensive, so that is what is used. Therefore, the time unit is an integer multiple of the highest possible TIMER_FREQUENCY value, using a multiplier large enough to ensure that there is no major precision loss. The result is that the time unit is “picoseconds.” This precision is spurious, but the decision enables overhead to be minimized.

### 22.4.2 Performance Schema Event Filtering

Events are processed in a producer/consumer fashion:

- Instrumented code is the source for events and produces events to be collected. The setup_instruments table lists the instruments for which events can be collected, whether they are enabled, and (for enabled instruments) whether to collect timing information:

```sql
mysql> SELECT * FROM performance_schema.setup_instruments;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/synch/mutex/sql/LOCK_global_read_lock</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_global_system_variables</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_lock_db</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/mutex/sql/LOCK_manager</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/rwlock/sql/LOCK_grant</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/rwlock/sql/LOGGER::LOCK_logger</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/rwlock/sql/LOCK_sys_init_connect</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/synch/rwlock/sql/LOCK_sys_init_slave</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
Performance Schema Event Filtering

| wait/io/file/sql/binlog | YES | YES |
| wait/io/file/sql/binlog_index | YES | YES |
| wait/io/file/sql/casetest | YES | YES |
| wait/io/file/sql/dbopt | YES | YES |

Performance Schema tables are the destinations for events and consume events. The `setup_consumers` table lists the types of consumers to which event information can be sent:

```sql
SELECT * FROM performance_schema.setup_consumers;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>events_waits_current</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_history</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_history_long</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_thread_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>events_waits_summary_by_instance</td>
<td>YES</td>
</tr>
<tr>
<td>file_summary_by_event_name</td>
<td>YES</td>
</tr>
<tr>
<td>file_summary_by_instance</td>
<td>YES</td>
</tr>
</tbody>
</table>

Filtering can be done at different stages of performance monitoring:

- **Pre-filtering.** This is done by modifying Performance Schema configuration so that only certain types of events are collected from producers, and collected events update only certain consumers. To do this, enable or disable instruments or consumers. Pre-filtering is done by the Performance Schema and has a global effect that applies to all users.

  **Reasons to use pre-filtering:**

  - To reduce overhead. Performance Schema overhead should be minimal even with all instruments enabled, but perhaps you want to reduce it further. Or you do not care about timing events and want to disable the timing code to eliminate timing overhead.

  - To avoid filling the current-events or history tables with events in which you have no interest. Pre-filtering leaves more "room" in these tables for instances of rows for enabled instrument types. If you enable only file instruments with pre-filtering, no rows are collected for nonfile instruments. With post-filtering, nonfile events are collected, leaving fewer rows for file events.

  - To avoid maintaining some kinds of event tables. If you disable a consumer, the server does not spend time maintaining destinations for that consumer. For example, if you do not care about event histories, you can disable the history table consumers to improve performance.

- **Post-filtering.** This involves the use of `WHERE` clauses in queries that select information from Performance Schema tables, to specify which of the available events you want to see. Post-filtering is performed on a per-user basis because individual users select which of the available events are of interest.

  **Reasons to use post-filtering:**

  - To avoid making decisions for individual users about which event information is of interest.

  - To use the Performance Schema to investigate a performance issue when the restrictions to impose using pre-filtering are not known in advance.

The following sections provide more detail about pre-filtering and provide guidelines for naming instruments or consumers in filtering operations. For information about writing queries to retrieve information (post-filtering), see Section 22.5, "Performance Schema Queries".
22.4.3 Event Pre-Filtering

Pre-filtering is done by modifying Performance Schema configuration so that only certain types of events are collected from producers, and collected events update only certain consumers. This type of filtering is done by the Performance Schema and has a global effect that applies to all users.

Pre-filtering can be applied to either the producer or consumer stage of event processing:

- To affect pre-filtering at the producer stage, modify the `setup_instruments` table. An instrument can be enabled or disabled by setting its `ENABLED` value to `YES` or `NO`. An instrument can be configured whether to collect timing information by setting its `TIMED` value to `YES` or `NO`.

- To affect pre-filtering at the consumer stage, modify the `setup_consumers` table. A consumer can be enabled or disabled by setting its `ENABLED` value to `YES` or `NO`.

Here are some examples that show the types of pre-filtering operations available:

- Disable all instruments:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = 'NO';
  ```

  Now no events will be collected. This change, like other pre-filtering operations, affects other users as well, even if they want to see event information.

- Disable all file instruments, adding them to the current set of disabled instruments:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = 'NO'
  WHERE NAME LIKE 'wait/io/file/%';
  ```

- Disable only file instruments, enable all other instruments:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = IF(NAME LIKE 'wait/io/file/%', 'NO', 'YES');
  ```

  The preceding queries use the `LIKE` operator and the pattern 'wait/io/file/%' to match all instrument names that begin with 'wait/io/file/'. For additional information about specifying patterns to select instruments, see Section 22.4.4, “Naming Instruments or Consumers for Filtering Operations”.

- Enable all but those instruments in the `mysys` library:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = CASE WHEN NAME LIKE '%/mysys/%' THEN 'YES' ELSE 'NO' END;
  ```

- Disable a specific instrument:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = 'NO'
  WHERE NAME = 'wait/synch/mutex/mysys/TMPDIR_mutex';
  ```

- To toggle the state of an instrument, “flip” its `ENABLED` value:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = IF(ENABLED = 'YES', 'NO', 'YES')
  WHERE NAME = 'wait/synch/mutex/mysys/TMPDIR_mutex';
  ```

- Disable timing for all events:
  
  ```sql
  UPDATE performance_schema.setup_instruments
  ```
Setting the `TIMED` column for instruments affects Performance Schema table contents as described in Section 22.4.1, “Performance Schema Event Timing”.

When you change the monitoring configuration, the Performance Schema does not flush the history tables. Events already collected remain in the current-events and history tables until displaced by newer events. If you disable instruments, you might need to wait a while before events for them are displaced by newer events of interest. Alternatively, use `TRUNCATE TABLE` to empty the history tables.

After making instrumentation changes, you might want to truncate the summary tables to clear aggregate information for previously collected events. The effect of `TRUNCATE TABLE` for summary tables is to reset the summary columns to 0 or `NULL`, not to remove rows.

If you disable a consumer, the server does not spend time maintaining destinations for that consumer. For example, if you do not care about historical event information, disable the history consumers:

```
UPDATE performance_schema.setup_consumers
SET ENABLED = 'NO'
WHERE NAME LIKE '%history%';
```

### 22.4.4 Naming Instruments or Consumers for Filtering Operations

Names given for filtering operations can be as specific or general as required. To indicate a single instrument or consumer, specify its name in full:

```
UPDATE performance_schema.setup_instruments
SET ENABLED = 'NO'
WHERE NAME = 'wait/synch/mutex/myisammrg/MYRG_INFO::mutex';

UPDATE performance_schema.setup_consumers
SET ENABLED = 'NO'
WHERE NAME = 'file_summary_by_instance';
```

To specify a group of instruments or consumers, use a pattern that matches the group members:

```
UPDATE performance_schema.setup_instruments
SET ENABLED = 'NO'
WHERE NAME LIKE 'wait/synch/mutex/%';

UPDATE performance_schema.setup_consumers
SET ENABLED = 'NO'
WHERE NAME LIKE '%history%';
```

If you use a pattern, it should be chosen so that it matches all the items of interest and no others. For example, to select all file I/O instruments, it is better to use a pattern that includes the entire instrument name prefix:

```
... WHERE NAME LIKE 'wait/io/file/%';
```

A pattern of `'/file/'` will match other instruments that have a component of `'/file/'` anywhere in the name. Even less suitable is the pattern `'/file%'` because it will match instruments with `file` anywhere in the name, such as `wait/synch/mutex/sql/LOCK_des_key_file`.

To check which instrument or consumer names a pattern matches, perform a simple test:

```
SELECT NAME FROM performance_schema.setup_instruments
WHERE NAME LIKE 'pattern';
```
SELECT NAME FROM performance_schema.setup_consumers
WHERE NAME LIKE 'pattern';

For information about the types of names that are supported, see Section 22.6, “Performance Schema Instrument Naming Conventions”.

### 22.4.5 Determining What Is Instrumented

It is always possible to determine what instruments the Performance Schema includes by checking the `setup_instruments` table. For example, to see what file-related events are instrumented for the InnoDB storage engine, use this query:

```sql
SELECT * FROM performance_schema.setup_instruments
WHERE NAME LIKE 'wait/io/file/innodb/%';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/io/file/innodb/innodb_data_file</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/io/file/innodb/innodb_log_file</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/io/file/innodb/innodb_temp_file</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

An exhaustive description of precisely what is instrumented is not given in this documentation, for several reasons:

- What is instrumented is the server code. Changes to this code occur often, which also affects the set of instruments.
- It is not practical to list all the instruments because there are hundreds of them.
- As described earlier, it is possible to find out by querying the `setup_instruments` table. This information is always up to date for your version of MySQL, also includes instrumentation for instrumented plugins you might have installed that are not part of the core server, and can be used by automated tools.

### 22.5 Performance Schema Queries

Pre-filtering limits which event information is collected and is independent of any particular user. By contrast, post-filtering is performed by individual users through the use of queries with appropriate `WHERE` clauses that restrict what event information to select from the events available after pre-filtering has been applied.

In Section 22.4.3, “Event Pre-Filtering”, an example showed how to pre-filter for file instruments. If the event tables contain both file and nonfile information, post-filtering is another way to see information only for file events. Add a `WHERE` clause to queries to restrict event selection appropriately:

```sql
mysql> SELECT THREAD_ID, NUMBER_OF_BYTES
               FROM performance_schema.events_waits_history
               WHERE EVENT_NAME LIKE 'wait/io/file/%'
               AND NUMBER_OF_BYTES IS NOT NULL;
```

<table>
<thead>
<tr>
<th>THREAD_ID</th>
<th>NUMBER_OF_BYTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>66</td>
</tr>
<tr>
<td>11</td>
<td>47</td>
</tr>
<tr>
<td>11</td>
<td>139</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>834</td>
</tr>
</tbody>
</table>
22.6 Performance Schema Instrument Naming Conventions

An instrument name consists of a sequence of components separated by ‘/’ characters. Example names:

- `wait/io/file/myisam/log`
- `wait/io/file/mysys/charset`
- `wait/synch/cond/mysys/COND_alarm`
- `wait/synch/cond/sql/BINLOG::update_cond`
- `wait/synch/mutex/mysys/BITMAP_mutex`
- `wait/synch/cond/sql/BINLOG::cond`
- `wait/synch/rwlock/sql/LOCK_delete`
- `wait/synch/rwlock/sql/Query_cache_query::lock`

The instrument name space has a tree-like structure. The components of an instrument name from left to right provide a progression from more general to more specific. The number of components a name has depends on the type of instrument.

The interpretation of a given component in a name depends on the components to the left of it. For example, `myisam` appears in both of the following names, but `myisam` in the first name is related to file I/O, whereas in the second it is related to a synchronization instrument:

- `wait/io/file/myisam/log`
- `wait/synch/cond/myisam/MI_SORT_INFO::cond`

Instrument names consist of a prefix with a structure defined by the Performance Schema implementation and a suffix defined by the developer implementing the instrument code. The top-level component of an instrument prefix indicates the type of instrument. This component also determines which event timer in the `setup_timers` table applies to the instrument. For the prefix part of instrument names, the top level indicates the type of instrument.

The suffix part of instrument names comes from the code for the instruments themselves. Suffixes may include levels such as these:

- A name for the major component (a server module such as `myisam`, `innodb`, `mysys`, or `sql`) or a plugin name.
- The name of a variable in the code, in the form `XXX` (a global variable) or `CCC::MMM` (a member `MMM` in class `CCC`). Examples: `COND_thread_cache`, `THR_LOCK_myisam`, `BINLOG::LOCK_index`.

In MySQL 5.5, there is a single top-level component, `wait`, indicating a wait instrument. The naming tree for wait instruments has this structure:

- `wait/io`
  - An instrumented I/O operation.
- `wait/io/file`
  - An instrumented file I/O operation. For files, the wait is the time waiting for the file operation to complete (for example, a call to `fwrite()`). Due to caching, the physical file I/O on the disk might not happen within this call.
- `wait/synch`
  - An instrumented synchronization object. For synchronization objects, the `TIMER_WAIT` time includes the amount of time blocked while attempting to acquire a lock on the object, if any.
A condition is used by one thread to signal to other threads that something they were waiting for has happened. If a single thread was waiting for a condition, it can wake up and proceed with its execution. If several threads were waiting, they can all wake up and compete for the resource for which they were waiting.

- **wait/synch/mutex**
  
  A mutual exclusion object used to permit access to a resource (such as a section of executable code) while preventing other threads from accessing the resource.

- **wait/synch/rwlock**
  
  A read/write lock object used to lock a specific variable for access while preventing its use by other threads. A shared read lock can be acquired simultaneously by multiple threads. An exclusive write lock can be acquired by only one thread at a time.

### 22.7 Performance Schema Status Monitoring

There are several status variables associated with the Performance Schema:

```
mysql> SHOW STATUS LIKE 'perf%';
+------------------------------------------+-------+
| Variable_name                            | Value |
+------------------------------------------+-------+
| Performance_schema_cond_classes_lost     | 0     |
| Performance_schema_cond_instances_lost   | 0     |
| Performance_schema_file_classes_lost     | 0     |
| Performance_schema_file_handles_lost     | 0     |
| Performance_schema_file_instances_lost   | 0     |
| Performance_schema_locker_lost           | 0     |
| Performance_schema_mutex_classes_lost    | 0     |
| Performance_schema_mutex_instances_lost  | 0     |
| Performance_schema_rwlock_classes_lost   | 0     |
| Performance_schema_rwlock_instances_lost | 0     |
| Performance_schema_table_handles_lost    | 0     |
| Performance_schema_table_instances_lost  | 0     |
| Performance_schema_thread_classes_lost   | 0     |
| Performance_schema_thread_instances_lost | 0     |
+------------------------------------------+-------+
```

The Performance Schema status variables provide information about instrumentation that could not be loaded or created due to memory constraints. Names for these variables have several forms:

- **Performance_schema_xxx_classes_lost** indicates how many instruments of type `xxx` could not be loaded.

- **Performance_schema_xxx_instances_lost** indicates how many instances of object type `xxx` could not be created.

- **Performance_schema_xxx_handles_lost** indicates how many instances of object type `xxx` could not be opened.

- **Performance_schema_locker_lost** indicates how many events are “lost” or not recorded.

For example, if a mutex is instrumented in the server source but the server cannot allocate memory for the instrumentation at runtime, it increments **Performance_schema_mutex_classes_lost**. The mutex still functions as a synchronization object (that is, the server continues to function normally), but performance data for it will not be collected. If the instrument can be allocated, it can be used for initializing instrumented mutex instances. For a singleton mutex such as a global mutex, there will be
only one instance. Other mutexes have an instance per connection, or per page in various caches and data buffers, so the number of instances varies over time. Increasing the maximum number of connections or the maximum size of some buffers will increase the maximum number of instances that might be allocated at once. If the server cannot create a given instrumented mutex instance, it increments `Performance_schema_mutex_instances_lost`.

Suppose that the following conditions hold:

- The server was started with the `--performance_schema_max_mutex_classes=200` option and thus has room for 200 mutex instruments.
- 150 mutex instruments have been loaded already.
- The plugin named `plugin_a` contains 40 mutex instruments.
- The plugin named `plugin_b` contains 20 mutex instruments.

The server allocates mutex instruments for the plugins depending on how many they need and how many are available, as illustrated by the following sequence of statements:

```
INSTALL PLUGIN plugin_a
```

The server now has 150+40 = 190 mutex instruments.

```
UNINSTALL PLUGIN plugin_a;
```

The server still has 190 instruments. All the historical data generated by the plugin code is still available, but new events for the instruments are not collected.

```
INSTALL PLUGIN plugin_a;
```

The server detects that the 40 instruments are already defined, so no new instruments are created, and previously assigned internal memory buffers are reused. The server still has 190 instruments.

```
INSTALL PLUGIN plugin_b;
```

The server has room for 200-190 = 10 instruments (in this case, mutex classes), and sees that the plugin contains 20 new instruments. 10 instruments are loaded, and 10 are discarded or "lost." The `Performance_schema_mutex_classes_lost` indicates the number of instruments (mutex classes) lost:

```
mysql> SHOW STATUS LIKE "perf*mutex_classes_lost";
+---------------------------------------+-------+
| Variable_name                         | Value |
+---------------------------------------+-------+
| Performance_schema_mutex_classes_lost | 10    |
+---------------------------------------+-------+
1 row in set (0.10 sec)
```

The instrumentation still works and collects (partial) data for `plugin_b`.

When the server cannot create a mutex instrument, these results occur:

- No row for the instrument is inserted into the `setup_instruments` table.
- `Performance_schema_mutex_classes_lost` increases by 1.
- `Performance_schema_mutex_instances_lost` does not change. (When the mutex instrument is not created, it cannot be used to create instrumented mutex instances later.)
The pattern just described applies to all types of instruments, not just mutexes.

A value of `Performance_schema_mutex_classes_lost` greater than 0 can happen in two cases:

- To save a few bytes of memory, you start the server with `--performance_schema_max_mutex_classes=N`, where $N$ is less than the default value. The default value is chosen to be sufficient to load all the plugins provided in the MySQL distribution, but this can be reduced if some plugins are never loaded. For example, you might choose not to load some of the storage engines in the distribution.

- You load a third-party plugin that is instrumented for the Performance Schema but do not allow for the plugin's instrumentation memory requirements when you start the server. Because it comes from a third party, the instrument memory consumption of this engine is not accounted for in the default value chosen for `performance_schema_max_mutex_classes`.

If the server has insufficient resources for the plugin's instruments and you do not explicitly allocate more using `--performance_schema_max_mutex_classes=N`, loading the plugin leads to starvation of instruments.

If the value chosen for `performance_schema_max_mutex_classes` is too small, no error is reported in the error log and there is no failure at runtime. However, the content of the tables in the `performance_schema` database will miss events. The `Performance_schema_mutex_classes_lost` status variable is the only visible sign to indicate that some events were dropped internally due to failure to create instruments.

If an instrument is not lost, it is known to the Performance Schema, and is used when instrumenting instances. For example, `wait/synch/mutex/sql/LOCK_delete` is the name of a mutex instrument in the `setup_instruments` table. This single instrument is used when creating a mutex in the code (in `THD::LOCK_delete`) however many instances of the mutex are needed as the server runs. In this case, `LOCK_delete` is a mutex that is per connection (THD), so if a server has 1000 connections, there are 1000 threads, and 1000 instrumented `LOCK_delete` mutex instances (THD::LOCK_delete).

If the server does not have room for all these 1000 instrumented mutexes (instances), some mutexes are created with instrumentation, and some are created without instrumentation. If the server can create only 800 instances, 200 instances are lost. The server continues to run, but increments `Performance_schema_mutex_instances_lost` by 200 to indicate that instances could not be created.

A value of `Performance_schema_mutex_instances_lost` greater than 0 can happen when the code initializes more mutexes at runtime than were allocated for `--performance_schema_max_mutex_instances=N`.

The bottom line is that if `SHOW STATUS LIKE 'perf%'` says that nothing was lost (all values are zero), the Performance Schema data is accurate and can be relied upon. If something was lost, the data is incomplete, and the Performance Schema could not record everything given the insufficient amount of memory it was given to use. In this case, the specific `Performance_schema_xxx_lost` variable indicates the problem area.

It might be appropriate in some cases to cause deliberate instrument starvation. For example, if you do not care about performance data for file I/O, you can start the server with all Performance Schema parameters related to file I/O set to 0. No memory will be allocated for file-related classes, instances, or handles, and all file events will be lost.

Use `SHOW ENGINE PERFORMANCE_SCHEMA STATUS` to inspect the internal operation of the Performance Schema code:
This statement is intended to help the DBA understand the effects that different Performance Schema options have on memory requirements. For a description of the field meanings, see Section 13.7.5.16, “SHOW ENGINE Statement”.

22.8 Performance Schema Tables for Current and Historical Events

The Performance Schema can monitor and store current wait events. In addition, when events end, the Performance Schema can store them in history tables. The Performance Schema uses three tables for storing current and historical events:

- **events_waits_current**: The “current events” table stores the current monitored event for each thread (one row per thread).

- **events_waits_history**: The “recent history” table stores the most recent events that have ended per thread (up to a maximum number of rows per thread).

- **events_waits_history_long**: The “long history” table stores the most recent events that have ended globally (across all threads, up to a maximum number of rows per table).

The **event_waits_current** table contains one row per thread, so there is no system variable for configuring its maximum size. The history tables by default store 10 rows per thread for **event_waits_history**, and 10,000 rows total for **event_waits_history_long**. These sizes can be configured explicitly at server startup using table-specific system variables, as indicated in the sections that describe the individual history tables.

The three tables have the same columns.

The **event_waits_current** table shows what is currently happening within the server. When a current event ends, it is removed from the table.

The **event_waits_history** and **event_waits_history_long** tables show what has happened in the recent past. When the history tables become full, old events are discarded as new events are added. Rows expire from the **event_waits_history** and **event_waits_history_long** tables in different ways because the tables serve different purposes:

- **event_waits_history** is meant to investigate individual threads, independently of the global server load.

- **event_waits_history_long** is meant to investigate the server globally, not each thread.
The difference between the two types of history tables relates to the data retention policy. Both tables contain the same data when an event is first seen. However, data within each table expires differently over time, so that data might be preserved for a longer or shorter time in each table:

- For **event_waits_history**, when the table contains the maximum number of rows for a given thread, the oldest thread row is discarded when a new row for that thread is added.

- For **event_waits_history_long**, when the table becomes full, the oldest row is discarded when a new row is added, regardless of which thread generated either row.

When a thread ends, all its rows are discarded from the **_history** table but not from the **_history_long** table.

The following example illustrates the differences in how events are added to and discarded from the two types of history tables. The example is based on these assumptions:

- The Performance Schema is configured to retain 10 rows per thread in the **event_waits_history** table and 10,000 rows total in the **event_waits_history_long** table.

- Thread A generates 1 event per second.

- Thread B generates 100 events per second.

- No other threads are running.

**After 5 seconds of execution:**

- A and B have generated 5 and 500 events, respectively.

- **event_waits_history** contains 5 rows for A and 10 rows for B. Because storage per thread is limited to 10 rows, no rows have been discarded for A, whereas 490 rows have been discarded for B.

- **event_waits_history_long** contains 5 rows for A and 500 rows for B. Because the table has a maximum size of 10,000 rows, no rows have been discarded for either thread.

**After 5 minutes (300 seconds) of execution:**

- A and B have generated 300 and 30,000 events, respectively.

- **event_waits_history** contains 10 rows for A and 10 rows for B. Because storage per thread is limited to 10 rows, 290 rows have been discarded for A, whereas 29,990 rows have been discarded for B. Rows for A include data up to 10 seconds old, whereas rows for B include data up to only .1 seconds old.

- **event_waits_history_long** contains 10,000 rows. Because A and B together generate 101 events per second, the table contains data up to approximately 10,000/101 = 99 seconds old, with a mix of rows approximately 100 to 1 from B as opposed to A.

### 22.9 Performance Schema General Table Characteristics

The name of the **performance_schema** database is lowercase, as are the names of tables within it. Queries should specify the names in lowercase.

Many tables in the **performance_schema** database are read only and cannot be modified:

```sql
mysql> TRUNCATE TABLE performance_schema.setup_instruments;
```
Some of the setup tables have columns that can be modified to affect Performance Schema operation. Truncation is permitted to clear collected events, so `TRUNCATE TABLE` can be used on tables containing those kinds of information, such as tables named with a prefix of `events_waits_`.

Summary tables can be truncated with `TRUNCATE TABLE`. The effect is to reset the summary columns to 0 or `NULL`, not to remove rows. This enables you to clear collected values and restart aggregation. That might be useful, for example, after you have made a runtime configuration change.

Privileges are as for other databases and tables:

- To retrieve from `performance_schema` tables, you must have the `SELECT` privilege.
- To change those columns that can be modified, you must have the `UPDATE` privilege.
- To truncate tables that can be truncated, you must have the `DROP` privilege.

Because only a limited set of privileges apply to Performance Schema tables, attempts to use `GRANT ALL` as shorthand for granting privileges at the database or table level fail with an error:

```
mysql> GRANT ALL ON performance_schema.*
    TO 'u1'@'localhost';
ERROR 1044 (42000): Access denied for user 'root'@'localhost'
to database 'performance_schema'

mysql> GRANT ALL ON performance_schema.setup_instruments
    TO 'u2'@'localhost';
ERROR 1044 (42000): Access denied for user 'root'@'localhost'
to database 'performance_schema'
```

Instead, grant exactly the desired privileges:

```
mysql> GRANT SELECT ON performance_schema.*
    TO 'u1'@'localhost';
Query OK, 0 rows affected (0.03 sec)

mysql> GRANT SELECT, UPDATE ON performance_schema.setup_instruments
    TO 'u2'@'localhost';
Query OK, 0 rows affected (0.02 sec)
```

### 22.10 Performance Schema Table Descriptions

Tables in the `performance_schema` database can be grouped as follows:

- **Setup tables.** These tables are used to configure and display monitoring characteristics.

  - **Current events table.** The `events_waits_current` table contains the most recent event for each thread.

  - **History tables.** These tables have the same structure as `events_waits_current` but contain more rows. The `events_waits_history` table contains the most recent 10 events per thread. `events_waits_history_long` contains the most recent 10,000 events.

    To change the sizes of these tables, set the `performance_schema_events_waits_history_size` and `performance_schema_events_waits_history_long_size` system variables at server startup.

- **Summary tables.** These tables contain information aggregated over groups of events, including those that have been discarded from the history tables.
• Instance tables. These tables document what types of objects are instrumented. An instrumented object, when used by the server, produces an event. These tables provide event names and explanatory notes or status information.

• Miscellaneous tables. These do not fall into any of the other table groups.

## 22.10.1 Performance Schema Table Index

The following table lists each Performance Schema table and provides a short description of each one.

**Table 22.1 Performance Schema Tables**

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cond_instances</td>
<td>synchronization object instances</td>
</tr>
<tr>
<td>events_waits_current</td>
<td>Current wait events</td>
</tr>
<tr>
<td>events_waits_history</td>
<td>Most recent wait events per thread</td>
</tr>
<tr>
<td>events_waits_history_long</td>
<td>Most recent wait events overall</td>
</tr>
<tr>
<td>events_waits_summary_by_instance</td>
<td>Wait events per instance</td>
</tr>
<tr>
<td>events_waits_summary_by_thread_by_event_name</td>
<td>Wait events per thread and event name</td>
</tr>
<tr>
<td>events_waits_summary_global_by_event_name</td>
<td>Wait events per event name</td>
</tr>
<tr>
<td>file_instances</td>
<td>File instances</td>
</tr>
<tr>
<td>file_summary_by_event_name</td>
<td>File events per event name</td>
</tr>
<tr>
<td>file_summary_by_instance</td>
<td>File events per file instance</td>
</tr>
<tr>
<td>mutex_instances</td>
<td>Mutex synchronization object instances</td>
</tr>
<tr>
<td>performance_timers</td>
<td>Which event timers are available</td>
</tr>
<tr>
<td>rwlock_instances</td>
<td>Lock synchronization object instances</td>
</tr>
<tr>
<td>setup_consumers</td>
<td>Consumers for which event information can be stored</td>
</tr>
<tr>
<td>setup_instruments</td>
<td>Classes of instrumented objects for which events can be collected</td>
</tr>
<tr>
<td>setup_timers</td>
<td>Current event timer</td>
</tr>
<tr>
<td>threads</td>
<td>Information about server threads</td>
</tr>
</tbody>
</table>

## 22.10.2 Performance Schema Setup Tables

The setup tables provide information about the current instrumentation and enable the monitoring configuration to be changed. For this reason, some columns in these tables can be changed if you have the `UPDATE` privilege.

The use of tables rather than individual variables for setup information provides a high degree of flexibility in modifying Performance Schema configuration. For example, you can use a single statement with standard SQL syntax to make multiple simultaneous configuration changes.

These setup tables are available:

- **setup_consumers**: The types of consumers for which event information can be stored
- **setup_instruments**: The classes of instrumented objects for which events can be collected
Performance Schema Setup Tables

- **setup_timers**: The current event timer

22.10.2.1 The setup_consumers Table

The `setup_consumers` table lists the types of consumers for which event information can be stored:

```
mysql> SELECT * FROM performance_schema.setup_consumers;
+----------------------------------------------+---------+
| NAME                                         | ENABLED |
|----------------------------------------------+---------|
| events_waits_current                         | YES     |
| events_waits_history                         | YES     |
| events_waits_history_long                    | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name           | YES     |
| events_waits_summary_by_instance             | YES     |
| file_summary_by_event_name                   | YES     |
| file_summary_by_instance                     | YES     |
+----------------------------------------------+---------+
```

The `setup_consumers` table has these columns:

- **NAME**
  The consumer name.

- **ENABLED**
  Whether the consumer is enabled. The value is **YES** or **NO**. This column can be modified. If you disable a consumer, the server does not spend time adding event information to it.

**TRUNCATE TABLE** is not permitted for the `setup_consumers` table.

Disabling the `events_waits_current` consumer disables everything else that depends on waits, such as the `events_waits_history` and `events_waits_history_long` tables, and all summary tables.

22.10.2.2 The setup_instruments Table

The `setup_instruments` table lists classes of instrumented objects for which events can be collected:

```
mysql> SELECT * FROM performance_schema.setup_instruments;
+----------------------------------------------------------------------+---------+-------+
| NAME                                                                | ENABLED | TIMED |
|----------------------------------------------------------------------+---------+-------|
| wait/synch/mutex/sql/LOCK_global_read_lock                        | YES     | YES   |
| wait/synch/mutex/sql/LOCK_global_system_variables                  | YES     | YES   |
| wait/synch/mutex/sql/LOCK_lock_db                                  | YES     | YES   |
| wait/synch/mutex/sql/LOCK_manager                                 | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_grant                                  | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_logger::LOCK_logger                    | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_connect                        | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_slave                         | YES     | YES   |
| wait/io/file/sql/binlog                                           | YES     | YES   |
| wait/io/file/sql/binlog_index                                      | YES     | YES   |
| wait/io/file/sql/casetest                                         | YES     | YES   |
| wait/io/file/sql/dbopt                                            | YES     | YES   |
+----------------------------------------------------------------------+---------+-------+
```

Each instrument added to the source code provides a row for the `setup_instruments` table, even when the instrumented code is not executed. When an instrument is enabled and executed, instrumented
instances are created, which are visible in the `xxx_instances` tables, such as `file_instances` or `rwlock_instances`.

The `setup_instruments` table has these columns:

- **NAME**
  
  The instrument name. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”. Events produced from execution of an instrument have an `EVENT_NAME` value that is taken from the instrument `NAME` value. (Events do not really have a “name,” but this provides a way to associate events with instruments.)

- **ENABLED**
  
  Whether the instrument is enabled. The value is `YES` or `NO`. A disabled instrument produces no events. This column can be modified, although setting `ENABLED` has no effect for instruments that have already been created.

- **TIMED**
  
  Whether the instrument is timed. The value is `YES` or `NO`. This column can be modified, although setting `TIMED` has no effect for instruments that have already been created.

If an enabled instrument is not timed, the instrument code is enabled, but the timer is not. Events produced by the instrument have `NULL` for the `TIMER_START`, `TIMER_END`, and `TIMER_WAIT` timer values. This in turn causes those values to be ignored when calculating the sum, minimum, maximum, and average time values in summary tables.

`TRUNCATE TABLE` is not permitted for the `setup_instruments` table.

### 22.10.2.3 The `setup_timers` Table

The `setup_timers` table shows the currently selected event timer:

```sql
mysql> SELECT * FROM performance_schema.setup_timers;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>TIMER_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait</td>
<td>CYCLE</td>
</tr>
</tbody>
</table>

The `setup_timers.TIMER_NAME` value can be changed to select a different timer. The value can be any of the values in the `performance_timers.TIMER_NAME` column. For an explanation of how event timing occurs, see Section 22.4.1, “Performance Schema Event Timing”.

Modifications to the `setup_timers` table affect monitoring immediately. Events already in progress use the original timer for the begin time and the new timer for the end time, which leads to unpredictable results. If you make timer changes, you may want to use `TRUNCATE TABLE` to reset Performance Schema statistics.

The `setup_timers` table has these columns:

- **NAME**
  
  The type of instrument the timer is used for.

- **TIMER_NAME**
Performance Schema Instance Tables

The timer that applies to the instrument type. This column can be modified.

TRUNCATE TABLE is not permitted for the setup_timers table.

22.10.3 Performance Schema Instance Tables

Instance tables document what types of objects are instrumented. They provide event names and explanatory notes or status information:

- **cond_instances**: Condition synchronization object instances
- **file_instances**: File instances
- **mutex_instances**: Mutex synchronization object instances
- **rwlock_instances**: Lock synchronization object instances

These tables list instrumented synchronization objects and files. There are three types of synchronization objects: cond, mutex, and rwlock. Each instance table has an EVENT_NAME or NAME column to indicate the instrument associated with each row. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”.

The mutex_instances.LOCKED_BY_THREAD_ID and rwlock_instances.WRITE_LOCKED_BY_THREAD_ID columns are extremely important for investigating performance bottlenecks or deadlocks. For examples of how to use them for this purpose, see Section 22.15, “Using the Performance Schema to Diagnose Problems”

22.10.3.1 The cond_instances Table

The cond_instances table lists all the conditions seen by the Performance Schema while the server executes. A condition is a synchronization mechanism used in the code to signal that a specific event has happened, so that a thread waiting for this condition can resume work.

When a thread is waiting for something to happen, the condition name is an indication of what the thread is waiting for, but there is no immediate way to tell which other thread, or threads, will cause the condition to happen.

The cond_instances table has these columns:

- **NAME**
  
  The instrument name associated with the condition.

- **OBJECT_INSTANCE_BEGIN**
  
  The address in memory of the instrumented condition.

TRUNCATE TABLE is not permitted for the cond_instances table.

22.10.3.2 The file_instances Table

The file_instances table lists all the files seen by the Performance Schema when executing file I/O instrumentation. If a file on disk has never been opened, it will not be in file_instances. When a file is deleted from the disk, it is also removed from the file_instances table.
The file_instances table has these columns:

- **FILE_NAME**
  The file name.

- **EVENT_NAME**
  The instrument name associated with the file.

- **OPEN_COUNT**
  The count of open handles on the file. If a file was opened and then closed, it was opened 1 time, but OPEN_COUNT will be 0. To list all the files currently opened by the server, use `WHERE OPEN_COUNT > 0`.

**TRUNCATE TABLE** is not permitted for the file_instances table.

### 22.10.3.3 The mutex_instances Table

The mutex_instances table lists all the mutexes seen by the Performance Schema while the server executes. A mutex is a synchronization mechanism used in the code to enforce that only one thread at a given time can have access to some common resource. The resource is said to be “protected” by the mutex.

When two threads executing in the server (for example, two user sessions executing a query simultaneously) do need to access the same resource (a file, a buffer, or some piece of data), these two threads will compete against each other, so that the first query to obtain a lock on the mutex will cause the other query to wait until the first is done and unlocks the mutex.

The work performed while holding a mutex is said to be in a “critical section,” and multiple queries do execute this critical section in a serialized way (one at a time), which is a potential bottleneck.

The mutex_instances table has these columns:

- **NAME**
  The instrument name associated with the mutex.

- **OBJECT_INSTANCE_BEGIN**
  The address in memory of the instrumented mutex.

- **LOCKED_BY_THREAD_ID**
  When a thread currently has a mutex locked, LOCKED_BY_THREAD_ID is the THREAD_ID of the locking thread, otherwise it is NULL.

**TRUNCATE TABLE** is not permitted for the mutex_instances table.

For every mutex instrumented in the code, the Performance Schema provides the following information.

- The setup_instruments table lists the name of the instrumentation point, with the prefix `wait/ synch/mutex/`.

- When some code creates a mutex, a row is added to the mutex_instances table. The OBJECT_INSTANCE_BEGIN column is a property that uniquely identifies the mutex.
• When a thread attempts to lock a mutex, the `events_waits_current` table shows a row for that thread, indicating that it is waiting on a mutex (in the `EVENT_NAME` column), and indicating which mutex is waited on (in the `OBJECT_INSTANCE_BEGIN` column).

• When a thread succeeds in locking a mutex:
  • `events_waits_current` shows that the wait on the mutex is completed (in the `TIMER_END` and `TIMER_WAIT` columns)
  • The completed wait event is added to the `events_waits_history` and `events_waits_history_long` tables
  • `mutex_instances` shows that the mutex is now owned by the thread (in the `THREAD_ID` column).

• When a thread unlocks a mutex, `mutex_instances` shows that the mutex now has no owner (the `THREAD_ID` column is `NULL`).

• When a mutex object is destroyed, the corresponding row is removed from `mutex_instances`.

By performing queries on both of the following tables, a monitoring application or a DBA can detect bottlenecks or deadlocks between threads that involve mutexes:

• `events_waits_current`, to see what mutex a thread is waiting for
• `mutex_instances`, to see which other thread currently owns a mutex

### 22.10.3.4 The `rwlock_instances` Table

The `rwlock_instances` table lists all the `rwlock` instances (read write locks) seen by the Performance Schema while the server executes. An `rwlock` is a synchronization mechanism used in the code to enforce that threads at a given time can have access to some common resource following certain rules. The resource is said to be “protected” by the `rwlock`. The access is either shared (many threads can have a read lock at the same time) or exclusive (only one thread can have a write lock at a given time).

Depending on how many threads are requesting a lock, and the nature of the locks requested, access can be either granted in shared mode, granted in exclusive mode, or not granted at all, waiting for other threads to finish first.

The `rwlock_instances` table has these columns:

• **NAME**
  The instrument name associated with the lock.

• **OBJECT_INSTANCE_BEGIN**
  The address in memory of the instrumented lock.

• **WRITE_LOCKED_BY_THREAD_ID**
  When a thread currently has an `rwlock` locked in exclusive (write) mode, `WRITE_LOCKED_BY_THREAD_ID` is the `THREAD_ID` of the locking thread, otherwise it is `NULL`.

• **READ_LOCKED_BY_COUNT**
  When a thread currently has an `rwlock` locked in shared (read) mode, `READ_LOCKED_BY_COUNT` is incremented by 1. This is a counter only, so it cannot be used directly to find which thread holds a read
Performance Schema Wait Event Tables

The Performance Schema instruments waits, which are events that take time.

These tables store wait events:

- **events_waits_current**: The current wait event for each thread.
- **events_waits_history**: The most recent wait events that have ended per thread.
- **events_waits_history_long**: The most recent wait events that have ended globally (across all threads).

The following sections describe the wait event tables. There are also summary tables that aggregate information about wait events; see Section 22.10.5.1, “Wait Event Summary Tables”.

For more information about the relationship between the three wait event tables, see Section 22.8, “Performance Schema Tables for Current and Historical Events”.

22.10.4 Performance Schema Wait Event Tables

Configuring Wait Event Collection

To control whether to collect wait events, set the state of the relevant instruments and consumers:

- The **setup_instruments** table contains instruments with names that begin with `wait`. Use these instruments to enable or disable collection of individual wait event classes.
- The **setup_consumers** table contains consumer values with names corresponding to the current and historical wait event table names. Use these consumers to filter collection of wait events.

The wait instruments are enabled by default. For example:

```sql
mysql> SELECT * FROM performance_schema.setup_instruments
    WHERE NAME LIKE 'wait/io/file/innodb%';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>ENABLED</th>
<th>TIMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>wait/io/file/innodb_data_file</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/io/file/innodb_log_file</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>wait/io/file/innodb_temp_file</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

The wait consumers are enabled by default:

```sql
mysql> SELECT *
```
To control wait event collection, update the `setup_instruments` and `setup_consumers` tables:

- **Enable:**
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = 'YES', TIMED = 'YES'
  WHERE NAME = 'wait/%';
  
  UPDATE performance_schema.setup_consumers
  SET ENABLED = 'YES'
  WHERE NAME LIKE 'events_waits%';
  ```

- **Disable:**
  ```sql
  UPDATE performance_schema.setup_instruments
  SET ENABLED = 'NO', TIMED = 'NO'
  WHERE NAME = 'wait/%';
  
  UPDATE performance_schema.setup_consumers
  SET ENABLED = 'NO'
  WHERE NAME LIKE 'events_waits%';
  ```

To collect only specific wait events, enable only the corresponding wait instruments. To collect wait events only for specific wait event tables, enable the wait instruments but only the wait consumers corresponding to the desired tables.

The `setup_timers` table contains a row with a `NAME` value of `wait` that indicates the unit for wait event timing. The default unit is `CYCLE`:

```sql
mysql> SELECT * FROM performance_schema.setup_timers WHERE NAME = 'wait';
+-------+-----------+
| NAME  | TIMER_NAME|
|-------|-----------+
| wait  | CYCLE     |
+-------+-----------+
```

To change the timing unit, modify the `TIMER_NAME` value:

```sql
UPDATE performance_schema.setup_timers
SET TIMER_NAME = 'NANOSECOND'
WHERE NAME = 'wait';
```

For additional information about configuring event collection, see Section 22.4, “Performance Schema Runtime Configuration”.

### 22.10.4.1 The `events_waits_current` Table

The `events_waits_current` table contains current wait events. The table stores one row per thread showing the current status of the thread's most recent monitored wait event, so there is no system variable for configuring the table size.
Of the tables that contain wait event rows, `events_waits_current` is the most fundamental. Other tables that contain wait event rows are logically derived from the current events. For example, the `events_waits_history` and `events_waits_history_long` tables are collections of the most recent wait events that have ended, up to a maximum number of rows per thread and globally across all threads, respectively.

For more information about the relationship between the three wait event tables, see Section 22.8, “Performance Schema Tables for Current and Historical Events”.

For information about configuring whether to collect wait events, see Section 22.10.4, “Performance Schema Wait Event Tables”.

The `events_waits_current` table has these columns:

- **THREAD_ID, EVENT_ID**
  
  The thread associated with the event and the thread current event number when the event starts. The `THREAD_ID` and `EVENT_ID` values taken together uniquely identify the row. No two rows have the same pair of values.

- **EVENT_NAME**
  
  The name of the instrument that produced the event. This is a `NAME` value from the `setup_instruments` table. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”.

- **SOURCE**
  
  The name of the source file containing the instrumented code that produced the event and the line number in the file at which the instrumentation occurs. This enables you to check the source to determine exactly what code is involved. For example, if a mutex or lock is being blocked, you can check the context in which this occurs.

- **TIMER_START, TIMER_END, TIMER_WAIT**
  
  Timing information for the event. The unit for these values is picoseconds (trillionths of a second). The `TIMER_START` and `TIMER_END` values indicate when event timing started and ended. `TIMER_WAIT` is the event elapsed time (duration).

  If an event has not finished, `TIMER_END` and `TIMER_WAIT` are NULL.

  If an event is produced from an instrument that has `TIMED = NO`, timing information is not collected, and `TIMER_START`, `TIMER_END`, and `TIMER_WAIT` are all NULL.

  For discussion of picoseconds as the unit for event times and factors that affect time values, see Section 22.4.1, “Performance Schema Event Timing”.

- **SPINS**
  
  For a mutex, the number of spin rounds. If the value is NULL, the code does not use spin rounds or spinning is not instrumented.

- **OBJECT_SCHEMA, OBJECT_NAME, OBJECT_TYPE, OBJECT_INSTANCE_BEGIN**
  
  These columns identify the object “being acted on.” What that means depends on the object type.

  For a synchronization object (cond, mutex, rwlock):
• **OBJECT_SCHEMA**, **OBJECT_NAME**, and **OBJECT_TYPE** are NULL.

• **OBJECT_INSTANCE_BEGIN** is the address of the synchronization object in memory.

For a file I/O object:

• **OBJECT_SCHEMA** is NULL.

• **OBJECT_NAME** is the file name.

• **OBJECT_TYPE** is **FILE**.

• **OBJECT_INSTANCE_BEGIN** is an address in memory.

An **OBJECT_INSTANCE_BEGIN** value itself has no meaning, except that different values indicate different objects. **OBJECT_INSTANCE_BEGIN** can be used for debugging. For example, it can be used with **GROUP BY OBJECT_INSTANCE_BEGIN** to see whether the load on 1,000 mutexes (that protect, say, 1,000 pages or blocks of data) is spread evenly or just hitting a few bottlenecks. This can help you correlate with other sources of information if you see the same object address in a log file or another debugging or performance tool.

• **NESTING_EVENT_ID**

  Always NULL.

• **OPERATION**

  The type of operation performed, such as **lock**, **read**, or **write**.

• **NUMBER_OF_BYTES**

  The number of bytes read or written by the operation.

• **FLAGS**

  Reserved for future use.

**TRUNCATE TABLE** is permitted for the **events_waits_current** table. It removes the rows.

### 22.10.4.2 The events_waits_history Table

The **events_waits_history** table contains the most recent 10 wait events that have ended per thread. Wait events are not added to the table until they have ended. When the table contains the maximum number of rows for a given thread, the oldest thread row is discarded when a new row for that thread is added. When a thread ends, all its rows are discarded.

To change the number of rows per thread, modify the **performance_schema_events_waits_history_size** system variable at server startup.

The **events_waits_history** table has the same columns as **events_waits_current**. See Section 22.10.4.1, “The events_waits_current Table”.

**TRUNCATE TABLE** is permitted for the **events_waits_history** table. It removes the rows.

For more information about the relationship between the three wait event tables, see Section 22.8, “Performance Schema Tables for Current and Historical Events”.

2796
22.10.4.3 The events_waits_history_long Table

The `events_waits_history_long` table contains the most recent 10,000 wait events that have ended globally, across all threads. Wait events are not added to the table until they have ended. When the table becomes full, the oldest row is discarded when a new row is added, regardless of which thread generated either row.

To change the table size, modify the `performance_schema_events_waits_history_long_size` system variable at server startup.

The `events_waits_history_long` table has the same columns as `events_waits_current`. See Section 22.10.4.1, “The events_waits_current Table”.

`TRUNCATE TABLE` is permitted for the `events_waits_history_long` table. It removes the rows.

For more information about the relationship between the three wait event tables, see Section 22.8, “Performance Schema Tables for Current and Historical Events”.

For information about configuring whether to collect wait events, see Section 22.10.4, “Performance Schema Wait Event Tables”.

22.10.5 Performance Schema Summary Tables

Summary tables provide aggregated information for terminated events over time. The tables in this group summarize event data in different ways.

Wait Event Summaries

- `events_waits_summary_by_instance`: Wait events per instance
- `events_waits_summary_by_thread_by_event_name`: Wait events per thread and event name
- `events_waits_summary_global_by_event_name`: Wait events per event name

File I/O Summaries

- `file_summary_by_event_name`: File events per event name
- `file_summary_by_instance`: File events per file instance

Each summary table has grouping columns that determine how to group the data to be aggregated, and summary columns that contain the aggregated values. Tables that summarize events in similar ways often have similar sets of summary columns and differ only in the grouping columns used to determine how events are aggregated.

Summary tables can be truncated with `TRUNCATE TABLE`. The effect is to reset the summary columns to 0 or `NULL`, not to remove rows. This enables you to clear collected values and restart aggregation. That might be useful, for example, after you have made a runtime configuration change.

22.10.5.1 Wait Event Summary Tables

The Performance Schema maintains tables for collecting current and recent wait events, and aggregates that information in summary tables. Section 22.10.4, “Performance Schema Wait Event Tables” describes
the events on which wait summaries are based. See that discussion for information about the content of
wait events, the current and recent wait event tables, and how to control wait event collection.

Example wait event summary information:

```
mysql> SELECT * FROM performance_schema.events_waits_summary_global_by_event_name
...                      6. row                           9. row
EVENT_NAME: wait/synch/mutex/sql/BINARY_LOG::LOCK_index
COUNT_STAR: 8
SUM_TIMER_WAIT: 2119302
MIN_TIMER_WAIT: 196092
AVG_TIMER_WAIT: 264912
MAX_TIMER_WAIT: 569421
...
EVENT_NAME: wait/synch/mutex/sql/hash_filo::lock
COUNT_STAR: 69
SUM_TIMER_WAIT: 16848828
MIN_TIMER_WAIT: 0
AVG_TIMER_WAIT: 244185
MAX_TIMER_WAIT: 735345
...
```

Each wait event summary table has one or more grouping columns to indicate how the table aggregates
events. Event names refer to names of event instruments in the `setup_instruments` table:

- `events_waits_summary_by_instance` has `EVENT_NAME` and `OBJECT_INSTANCE_BEGIN`
columns. Each row summarizes events for a given event name and object. If an instrument is used to
create multiple instances, each instance has a unique `OBJECT_INSTANCE_BEGIN` value, so these
instances are summarized separately in this table.

- `events_waits_summary_by_thread_by_event_name` has `THREAD_ID` and `EVENT_NAME`
columns. Each row summarizes events for a given thread and event name.

- `events_waits_summary_global_by_event_name` has an `EVENT_NAME` column. Each row
summarizes events for a given event name. An instrument might be used to create multiple instances
of the instrumented object. For example, if there is an instrument for a mutex that is created for each
connection, there are as many instances as there are connections. The summary row for the instrument
summarizes over all these instances.

Each wait event summary table has these summary columns containing aggregated values:

- **COUNT_STAR**
  The number of summarized events. This value includes all events, whether timed or nontimed.

- **SUM_TIMER_WAIT**
  The total wait time of the summarized timed events. This value is calculated only for timed events
  because nontimed events have a wait time of `NULL`. The same is true for the other `xxx_TIMER_WAIT`
  values.

- **MIN_TIMER_WAIT**
  The minimum wait time of the summarized timed events.

- **AVG_TIMER_WAIT**
  The average wait time of the summarized timed events.
Performance Schema Summary Tables

- **MAX_TIMER_WAIT**
  
The maximum wait time of the summarized timed events.

TRUNCATE TABLE is permitted for wait summary tables. It resets the summary columns to zero rather than removing rows.

### 22.10.5.2 File I/O Summary Tables

The Performance Schema maintains file I/O summary tables that aggregate information about I/O operations.

Example file I/O event summary information:

```
mysql> SELECT * FROM performance_schema.file_summary_by_instance\G
...  
*************************** 2. row ***************************
  FILE_NAME: /var/mysql/share/english/errmsg.sys
  EVENT_NAME: wait/io/file/sql/ERRMSG
  COUNT_READ: 3
  COUNT_WRITE: 0
  SUM_NUMBER_OF_BYTES_READ: 42211
  SUM_NUMBER_OF_BYTES_WRITE: 0

...  
*************************** 6. row ***************************
  FILE_NAME: /var/mysql/data/binlog.000001
  EVENT_NAME: wait/io/file/sql/binlog
  COUNT_READ: 0
  COUNT_WRITE: 0
  SUM_NUMBER_OF_BYTES_READ: 0
  SUM_NUMBER_OF_BYTES_WRITE: 0

...  
```

Each file I/O summary table has one or more grouping columns to indicate how the table aggregates events. Event names refer to names of event instruments in the `setup_instruments` table:

- **file_summary_by_event_name** has an EVENT_NAME column. Each row summarizes events for a given event name.

- **file_summary_by_instance** has FILE_NAME and EVENT_NAME columns. Each row summarizes events for a given file instrument instance.

Each file I/O summary table has these summary columns containing aggregated values:

- **COUNT_READ**
  
The number of read operations in the summarized events.

- **COUNT_WRITE**
  
The number of write operations in the summarized events.

- **SUM_NUMBER_OF_BYTES_READ**
  
The number of bytes read in the summarized events.

- **SUM_NUMBER_OF_BYTES_WRITE**
  
The number of bytes written in the summarized events.

TRUNCATE TABLE is permitted for file I/O summary tables. It resets the summary columns to zero rather than removing rows.
The MySQL server uses several techniques to avoid I/O operations by caching information read from files, so it is possible that statements you might expect to result in I/O events will not. You may be able to ensure that I/O does occur by flushing caches or restarting the server to reset its state.

22.10.6 Performance Schema Miscellaneous Tables

The following sections describe tables that do not fall into the table categories discussed in the preceding sections:

- **performance_timers**: Which event timers are available
- **threads**: Information about server threads

### 22.10.6.1 The performance_timers Table

The **performance_timers** table shows which event timers are available:

```sql
code
mysql> SELECT * FROM performance_schema.performance_timers;
+-------------+-----------------+------------------+----------------+
| TIMER_NAME  | TIMER_FREQUENCY | TIMER_RESOLUTION | TIMER_OVERHEAD |
+-------------+-----------------+------------------+----------------+
| CYCLE       | 2389029850      | 1                | 72             |
| NANOSECOND  | NULL            | NULL             | NULL           |
| MICROSECOND | 1000000         | 1                | 585            |
| MILLISECOND | 1035            | 1                | 738            |
| TICK        | 101             | 1                | 630            |
+-------------+-----------------+------------------+----------------+
```

If the values associated with a given timer name are **NULL**, that timer is not supported on your platform. The rows that do not contain **NULL** indicate which timers you can use in **setup_timers**. For an explanation of how event timing occurs, see Section 22.4.1, “Performance Schema Event Timing”.

The **performance_timers** table has these columns:

- **TIMER_NAME**
  The name by which to refer to the timer when configuring the **setup_timers** table.

- **TIMER_FREQUENCY**
  The number of timer units per second. For a cycle timer, the frequency is generally related to the CPU speed. For example, on a system with a 2.4GHz processor, the **CYCLE** may be close to 2400000000.

- **TIMER_RESOLUTION**
  Indicates the number of timer units by which timer values increase. If a timer has a resolution of 10, its value increases by 10 each time.

- **TIMER_OVERHEAD**
  The minimal number of cycles of overhead to obtain one timing with the given timer. The Performance Schema determines this value by invoking the timer 20 times during initialization and picking the smallest value. The total overhead really is twice this amount because the instrumentation invokes the timer at the start and end of each event. The timer code is called only for timed events, so this overhead does not apply for nontimed events.

**TRUNCATE TABLE** is not permitted for the **performance_timers** table.

### 22.10.6.2 The threads Table
The `threads` table contains a row for each server thread:

```sql
mysql> SELECT * FROM performance_schema.threads;
+-----------+----------------+----------------------------------------+
| THREAD_ID | PROCESSLIST_ID | NAME                                   |
+-----------+----------------+----------------------------------------+
|         0 |              0 | thread/sql/main                        |
|         1 |              0 | thread/innodb/io_handler_thread        |
|        16 |              0 | thread/sql/signal_handler              |
|        23 |              7 | thread/sql/one_connection              |
|         5 |              0 | thread/innodb/io_handler_thread        |
|        12 |              0 | thread/innodb/srv_lock_timeout_thread  |
|        22 |              6 | thread/sql/one_connection              |
|          ... |
```

Note

For `INFORMATION_SCHEMA.PROCESSLIST` and `SHOW PROCESSLIST`, information about threads for other users is shown only if the current user has the `PROCESS` privilege. That is not true of the `threads` table; all rows are shown to any user who has the `SELECT` privilege for the table. Users who should not be able to see threads for other users should not be given that privilege.

The `threads` table has these columns:

- **THREAD_ID**
  
  This is the unique identifier of an instrumented thread.

- **PROCESSLIST_ID**
  
  For threads that are displayed in the `INFORMATION_SCHEMA.PROCESSLIST` table, this is the same value displayed in the `ID` column of that table. It is also the value displayed in the `Id` column of `SHOW PROCESSLIST` output, and the value that `CONNECTION_ID()` would return within that thread.

  For background threads (threads not associated with a user connection), `PROCESSLIST_ID` is 0, so the values are not unique.

- **NAME**
  
  `NAME` is the name associated with the instrumentation of the code in the server. For example, `thread/sql/one_connection` corresponds to the thread function in the code responsible for handling a user connection, and `thread/sql/main` stands for the `main()` function of the server.

`TRUNCATE TABLE` is not permitted for the `threads` table.

### 22.11 Performance Schema Option and Variable Reference

#### Table 22.2 Performance Schema Variable Reference

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>performance_schema</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Performance_schema_cond_classes_lost</td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Performance_schema_cond_instances_lost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_events_waits_history_long_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_events_waits_history_size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>Performance_schema_file_classes_lost</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td>Global</td>
<td>No</td>
</tr>
</tbody>
</table>
Performance Schema System Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Cmd-Line</th>
<th>Option File</th>
<th>System Var</th>
<th>Status Var</th>
<th>Var Scope</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance_schema_file_handles_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>performance_schema_max_cond_classes</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_file_handles</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_mutex_classes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_mutex_instances</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_rwlock_classes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_rwlock_instances</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_table_handles</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_max_table_instances</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_mutex_classes_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_mutex_instances_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_rwlock_classes_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_rwlock_instances_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_table_handles_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_table_instances_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_thread_classes_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
<tr>
<td>performance_schema_thread_instances_lost</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Global</td>
<td>No</td>
</tr>
</tbody>
</table>

22.12 Performance Schema System Variables

The Performance Schema implements several system variables that provide configuration information:

```
mysql> SHOW VARIABLES LIKE 'perf%';
+----------------+---------+
| Variable_name   | Value   |
+----------------+---------+
| performance_schema | ON      |
| performance_schema_events_waits_history_long_size | 10000 |
| performance_schema_events_waits_history_size | 10     |
| performance_schema_max_cond_classes | 80     |
| performance_schema_max_cond_instances | 1000   |
| performance_schema_max_file_classes | 50     |
| performance_schema_max_file_handles | 32768  |
| performance_schema_max_file_instances | 10000  |
| performance_schema_max_mutex_classes | 200    |
| performance_schema_max_mutex_instances | 100000  |
| performance_schema_max_rwlock_classes | 30     |
| performance_schema_max_rwlock_instances | 100000 |
| performance_schema_max_table_handles | 100000 |
| performance_schema_max_table_instances | 50000  |
```
Performance Schema system variables can be set at server startup on the command line or in option files, and many can be set at runtime. See Section 22.11, “Performance Schema Option and Variable Reference”.

Performance Schema system variables have the following meanings:

- **performance_schema**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>`--performance-schema=[{OFF</td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Boolean</td>
</tr>
<tr>
<td>Default Value</td>
<td>OFF</td>
</tr>
</tbody>
</table>

The value of this variable is **ON** or **OFF** to indicate whether the Performance Schema is enabled. By default, the value is **OFF**. At server startup, you can specify this variable with no value or a value of 1 to enable it, or with a value of 0 to disable it.

- **performance_schema_events_waits_history_long_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-events-waits-history-long-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_events_waits_history_long_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10000</td>
</tr>
</tbody>
</table>

The number of rows in the `events_waits_history_long` table.

- **performance_schema_events_waits_history_size**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-events-waits-history-size=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_events_waits_history_size</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10</td>
</tr>
</tbody>
</table>

The number of rows per thread in the `events_waits_history` table.

- **performance_schema_max_cond_classes**

<table>
<thead>
<tr>
<th>performance_schema_max_thread_classes</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>performance_schema_max_thread_instances</td>
<td>1000</td>
</tr>
</tbody>
</table>
Performance Schema System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-cond-classes=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_cond_classes</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>80</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>256</td>
</tr>
</tbody>
</table>

The maximum number of condition instruments. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- performance_schema_max_cond_instances

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-cond-instances=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_cond_instances</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented condition objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- performance_schema_max_file_classes

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-file-classes=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_file_classes</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>50</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>256</td>
</tr>
</tbody>
</table>

The maximum number of file instruments. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- performance_schema_max_file_handles

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-file-handles=#</td>
</tr>
</tbody>
</table>
### Performance Schema System Variables

<table>
<thead>
<tr>
<th>System Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>performance_schema_max_file_handles</td>
<td></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>32768</td>
</tr>
</tbody>
</table>

The maximum number of opened file objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

The value of `performance_schema_max_file_handles` should be greater than the value of `open_files_limit`: `open_files_limit` affects the maximum number of open file handles the server can support and `performance_schema_max_file_handles` affects how many of these file handles can be instrumented.

- `performance_schema_max_file_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-file-instances=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_file_instances</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>10000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented file objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- `performance_schema_max_mutex_classes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-mutex-classes=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_mutex_classes</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>200</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>256</td>
</tr>
</tbody>
</table>

The maximum number of mutex instruments. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- `performance_schema_max_mutex_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-mutex-instances=#</code></td>
</tr>
</tbody>
</table>
### Performance Schema System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_mutex_instances</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented mutex objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

• `performance_schema_max_rwlock_classes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-rwlock-classes=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_rwlock_classes</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>30</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>256</td>
</tr>
</tbody>
</table>

The maximum number of rwlock instruments. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

• `performance_schema_max_rwlock_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-rwlock-instances=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_rwlock_instances</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented rwlock objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

• `performance_schema_max_table_handles`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td><code>--performance-schema-max-table-handles=#</code></td>
</tr>
<tr>
<td>System Variable</td>
<td><code>performance_schema_max_table_handles</code></td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
</tbody>
</table>

2806
Performance Schema System Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>100000</td>
</tr>
</tbody>
</table>

The maximum number of opened table objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- `performance_schema_max_table_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-table-instances=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_table_instances</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>50000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented table objects. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- `performance_schema_max_thread_classes`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-thread-classes=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_thread_classes</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
<tr>
<td>Default Value</td>
<td>50</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>256</td>
</tr>
</tbody>
</table>

The maximum number of thread instruments. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

- `performance_schema_max_thread_instances`

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command-Line Format</td>
<td>--performance-schema-max-thread-instances=#</td>
</tr>
<tr>
<td>System Variable</td>
<td>performance_schema_max_thread_instances</td>
</tr>
<tr>
<td>Scope</td>
<td>Global</td>
</tr>
<tr>
<td>Dynamic</td>
<td>No</td>
</tr>
<tr>
<td>Type</td>
<td>Integer</td>
</tr>
</tbody>
</table>
### Performance Schema Status Variables

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default Value</td>
<td>1000</td>
</tr>
</tbody>
</table>

The maximum number of instrumented thread objects. The value controls the size of the `threads` table. If this maximum is exceeded such that a thread cannot be instrumented, the Performance Schema increments the `Performance_schema_thread_instances_lost` status variable. For information about how to set and use this variable, see Section 22.7, “Performance Schema Status Monitoring”.

The `max_connections` and `max_delayed_threads` system variables affect how many threads are run in the server. `performance_schema_max_thread_instances` affects how many of these running threads can be instrumented. If you increase `max_connections` or `max_delayed_threads`, you should consider increasing `performance_schema_max_thread_instances` so that `performance_schema_max_thread_instances` is greater than the sum of `max_connections` and `max_delayed_threads`.

#### 22.13 Performance Schema Status Variables

The Performance Schema implements several status variables that provide information about instrumentation that could not be loaded or created due to memory constraints:

```sql
mysql> SHOW STATUS LIKE 'perf%';
+------------------------------------------+-------+
| Variable_name                            | Value |
+------------------------------------------+-------+
| Performance_schema_cond_classes_lost     | 0     |
| Performance_schema_cond_instances_lost   | 0     |
| Performance_schema_file_classes_lost     | 0     |
| Performance_schema_file_handles_lost     | 0     |
| Performance_schema_file_instances_lost   | 0     |
| Performance_schema_locker_lost           | 0     |
| Performance_schema_mutex_classes_lost    | 0     |
| Performance_schema_mutex_instances_lost  | 0     |
| Performance_schema_rwlock_classes_lost   | 0     |
| Performance_schema_rwlock_instances_lost | 0     |
| Performance_schema_table_handles_lost    | 0     |
| Performance_schema_table_instances_lost  | 0     |
| Performance_schema_thread_classes_lost   | 0     |
| Performance_schema_thread_instances_lost | 0     |
+------------------------------------------+-------+
```

For information on using these variables to check Performance Schema status, see Section 22.7, “Performance Schema Status Monitoring”.

Performance Schema status variables have the following meanings:

- **Performance_schema_cond_classes_lost**
  How many condition instruments could not be loaded.

- **Performance_schema_cond_instances_lost**
  How many condition instrument instances could not be created.

- **Performance_schema_file_classes_lost**
  How many file instruments could not be loaded.

- **Performance_schema_file_handles_lost**
  How many file instrument instances could not be opened.
22.14 Performance Schema and Plugins

Removing a plugin with `UNINSTALL PLUGIN` does not affect information already collected for code in that plugin. Time spent executing the code while the plugin was loaded was still spent even if the plugin is unloaded later. The associated event information, including aggregate information, remains readable in `performance_schema` database tables. For additional information about the effect of plugin installation and removal, see Section 22.7, “Performance Schema Status Monitoring”.

A plugin implementor who instruments plugin code should document its instrumentation characteristics to enable those who load the plugin to account for its requirements. For example, a third-party storage engine should include in its documentation how much memory the engine needs for mutex and other instruments.
22.15 Using the Performance Schema to Diagnose Problems

The Performance Schema is a tool to help a DBA do performance tuning by taking real measurements instead of "wild guesses." This section demonstrates some ways to use the Performance Schema for this purpose. The discussion here relies on the use of event filtering, which is described in Section 22.4.2, "Performance Schema Event Filtering".

The following example provides one methodology that you can use to analyze a repeatable problem, such as investigating a performance bottleneck. To begin, you should have a repeatable use case where performance is deemed “too slow” and needs optimization, and you should enable all instrumentation (no pre-filtering at all).

1. Run the use case.

2. Using the Performance Schema tables, analyze the root cause of the performance problem. This analysis will rely heavily on post-filtering.

3. For problem areas that are ruled out, disable the corresponding instruments. For example, if analysis shows that the issue is not related to file I/O in a particular storage engine, disable the file I/O instruments for that engine. Then truncate the history and summary tables to remove previously collected events.

4. Repeat the process at step 1.

At each iteration, the Performance Schema output, particularly the `events_waits_history_long` table, will contain less and less "noise" caused by nonsignificant instruments, and given that this table has a fixed size, will contain more and more data relevant to the analysis of the problem at hand.

At each iteration, investigation should lead closer and closer to the root cause of the problem, as the "signal/noise" ratio will improve, making analysis easier.

5. Once a root cause of performance bottleneck is identified, take the appropriate corrective action, such as:
   - Tune the server parameters (cache sizes, memory, and so forth).
   - Tune a query by writing it differently,
   - Tune the database schema (tables, indexes, and so forth).
   - Tune the code (this applies to storage engine or server developers only).

6. Start again at step 1, to see the effects of the changes on performance.

The `mutex_instances.LOCKED_BY_THREAD_ID` and `rwlock_instances.WRITE_LOCKED_BY_THREAD_ID` columns are extremely important for investigating performance bottlenecks or deadlocks. This is made possible by Performance Schema instrumentation as follows:

1. Suppose that thread 1 is stuck waiting for a mutex.

2. You can determine what the thread is waiting for:

   ```sql
   SELECT * FROM performance_schema.events_waits_current
   WHERE THREAD_ID = thread_1;
   ```

   Say the query result identifies that the thread is waiting for mutex A, found in `events_waits_current.OBJECT_INSTANCE_BEGIN`. 

---

2810
3. You can determine which thread is holding mutex A:

```sql
SELECT * FROM performance_schema.mutex_instances
WHERE OBJECT_INSTANCE_BEGIN = mutex_A;
```

Say the query result identifies that it is thread 2 holding mutex A, as found in `mutex_instances.Locked_By_Thread_ID`.

4. You can see what thread 2 is doing:

```sql
SELECT * FROM performance_schema.events_waits_current
WHERE THREAD_ID = thread_2;
```

### 22.16 Restrictions on Performance Schema

The Performance Schema avoids using mutexes to collect or produce data, so there are no guarantees of consistency and results can sometimes be incorrect. Event values in `performance_schema` tables are nondeterministic and nonrepeatable.

If you save event information in another table, you should not assume that the original events will still be available later. For example, if you select events from a `performance_schema` table into a temporary table, intending to join that table with the original table later, there might be no matches.

`mysqldump` and `BACKUP DATABASE` ignore tables in the `performance_schema` database.

Tables in the `performance_schema` database cannot be locked with `LOCK TABLES`, except the `setup_XXX` tables.

Tables in the `performance_schema` database cannot be indexed.

Results for queries that refer to tables in the `performance_schema` database are not saved in the query cache.

Tables in the `performance_schema` database are not replicated.

The Performance Schema is not available in `libmysqld`, the embedded server.

The types of timers might vary per platform. The `performance_timers` table shows which event timers are available. If the values in this table for a given timer name are `NULL`, that timer is not supported on your platform.

Instruments that apply to storage engines might not be implemented for all storage engines. Instrumentation of each third-party engine is the responsibility of the engine maintainer.
Chapter 23 Connectors and APIs

Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.1 MySQL Connector/C++</td>
<td>2816</td>
</tr>
<tr>
<td>23.2 MySQL Connector/J</td>
<td>2816</td>
</tr>
<tr>
<td>23.3 MySQL Connector/NET</td>
<td>2816</td>
</tr>
<tr>
<td>23.4 MySQL Connector/ODBC</td>
<td>2816</td>
</tr>
<tr>
<td>23.5 MySQL Connector/Python</td>
<td>2816</td>
</tr>
<tr>
<td>23.6 libmysql, the Embedded MySQL Server Library</td>
<td>2817</td>
</tr>
<tr>
<td>23.6.1 Compiling Programs with libmysql</td>
<td>2817</td>
</tr>
<tr>
<td>23.6.2 Restrictions When Using the Embedded MySQL Server</td>
<td>2818</td>
</tr>
<tr>
<td>23.6.3 Options with the Embedded Server</td>
<td>2818</td>
</tr>
<tr>
<td>23.6.4 Embedded Server Examples</td>
<td>2819</td>
</tr>
<tr>
<td>23.7 MySQL C API</td>
<td>2822</td>
</tr>
<tr>
<td>23.7.1 MySQL C API Implementations</td>
<td>2823</td>
</tr>
<tr>
<td>23.7.2 Example C API Client Programs</td>
<td>2824</td>
</tr>
<tr>
<td>23.7.3 Building and Running C API Client Programs</td>
<td>2824</td>
</tr>
<tr>
<td>23.7.4 C API Data Structures</td>
<td>2829</td>
</tr>
<tr>
<td>23.7.5 C API Function Overview</td>
<td>2834</td>
</tr>
<tr>
<td>23.7.6 C API Function Descriptions</td>
<td>2839</td>
</tr>
<tr>
<td>23.7.7 C API Prepared Statements</td>
<td>2892</td>
</tr>
<tr>
<td>23.7.8 C API Prepared Statement Data Structures</td>
<td>2892</td>
</tr>
<tr>
<td>23.7.9 C API Prepared Statement Function Overview</td>
<td>2899</td>
</tr>
<tr>
<td>23.7.10 C API Prepared Statement Function Descriptions</td>
<td>2902</td>
</tr>
<tr>
<td>23.7.11 C API Threaded Function Descriptions</td>
<td>2927</td>
</tr>
<tr>
<td>23.7.12 C API Embedded Server Function Descriptions</td>
<td>2928</td>
</tr>
<tr>
<td>23.7.13 C API Client Plugin Functions</td>
<td>2929</td>
</tr>
<tr>
<td>23.7.14 C API Encrypted Connection Support</td>
<td>2932</td>
</tr>
<tr>
<td>23.7.15 C API Multiple Statement Execution Support</td>
<td>2934</td>
</tr>
<tr>
<td>23.7.16 C API Prepared Statement Handling of Date and Time Values</td>
<td>2937</td>
</tr>
<tr>
<td>23.7.17 C API Prepared CALL Statement Support</td>
<td>2938</td>
</tr>
<tr>
<td>23.7.18 C API Prepared Statement Problems</td>
<td>2942</td>
</tr>
<tr>
<td>23.7.19 C API Automatic Reconnection Control</td>
<td>2942</td>
</tr>
<tr>
<td>23.7.20 C API Common Issues</td>
<td>2943</td>
</tr>
<tr>
<td>23.8 MySQL PHP API</td>
<td>2945</td>
</tr>
<tr>
<td>23.9 MySQL Perl API</td>
<td>2945</td>
</tr>
<tr>
<td>23.10 MySQL Python API</td>
<td>2946</td>
</tr>
<tr>
<td>23.11 MySQL Ruby APIs</td>
<td>2946</td>
</tr>
<tr>
<td>23.11.1 The MySQL/Ruby API</td>
<td>2946</td>
</tr>
<tr>
<td>23.11.2 The Ruby/MySQL API</td>
<td>2946</td>
</tr>
<tr>
<td>23.12 MySQL Tcl API</td>
<td>2946</td>
</tr>
<tr>
<td>23.13 MySQL Eiffel Wrapper</td>
<td>2946</td>
</tr>
</tbody>
</table>

MySQL Connectors provide connectivity to the MySQL server for client programs. APIs provide low-level access to the MySQL protocol and MySQL resources. Both Connectors and the APIs enable you to connect and execute MySQL statements from another language or environment, including ODBC, Java (JDBC), Perl, Python, PHP, Ruby, and native C and embedded MySQL instances.

MySQL Connectors

Oracle develops a number of connectors:
The MySQL C API

- **Connector/C++** enables C++ applications to connect to MySQL.

- **Connector/J** provides driver support for connecting to MySQL from Java applications using the standard Java Database Connectivity (JDBC) API.

- **Connector/NET** enables developers to create .NET applications that connect to MySQL. Connector/NET implements a fully functional ADO.NET interface and provides support for use with ADO.NET aware tools. Applications that use Connector/NET can be written in any supported .NET language.

- **MySQL for Visual Studio** works with Connector/NET and Microsoft Visual Studio 2012, 2013, 2015, and 2017. MySQL for Visual Studio provides access to MySQL objects and data from Visual Studio. As a Visual Studio package, it integrates directly into Server Explorer providing the ability to create new connections and work with MySQL database objects.

- **Connector/ODBC** provides driver support for connecting to MySQL using the Open Database Connectivity (ODBC) API. Support is available for ODBC connectivity from Windows, Unix, and macOS platforms.

- **Connector/Python** provides driver support for connecting to MySQL from Python applications using an API that is compliant with the Python DB API version 2.0. No additional Python modules or MySQL client libraries are required.

### The MySQL C API

For direct access to using MySQL natively within a C application, there are two methods:

- **The C API** provides low-level access to the MySQL client/server protocol through the *libmysqlclient* client library. This is the primary method used to connect to an instance of the MySQL server, and is used both by MySQL command-line clients and many of the MySQL Connectors and third-party APIs detailed here.

  *libmysqlclient* is included in MySQL distributions.

- **libmysqld** is an embedded MySQL server library that enables you to embed an instance of the MySQL server into your C applications.

  *libmysqld* is included in MySQL distributions.

See also Section 23.7.1, “MySQL C API Implementations”.

To access MySQL from a C application, or to build an interface to MySQL for a language not supported by the Connectors or APIs in this chapter, the **C API** is where to start. A number of programmer’s utilities are available to help with the process; see Section 4.7, “Program Development Utilities”.

### Third-Party MySQL APIs

The remaining APIs described in this chapter provide an interface to MySQL from specific application languages. These third-party solutions are not developed or supported by Oracle. Basic information on their usage and abilities is provided here for reference purposes only.

All the third-party language APIs are developed using one of two methods, using *libmysqlclient* or by implementing a native driver. The two solutions offer different benefits:

- Using *libmysqlclient* offers complete compatibility with MySQL because it uses the same libraries as the MySQL client applications. However, the feature set is limited to the implementation and interfaces exposed through *libmysqlclient* and the performance may be lower as data is copied between the native language, and the MySQL API components.
• **Native drivers** are an implementation of the MySQL network protocol entirely within the host language or environment. Native drivers are fast, as there is less copying of data between components, and they can offer advanced functionality not available through the standard MySQL API. Native drivers are also easier for end users to build and deploy because no copy of the MySQL client libraries is needed to build the native driver components.

Table 23.1, “MySQL APIs and Interfaces” lists many of the libraries and interfaces available for MySQL.

### Table 23.1 MySQL APIs and Interfaces

<table>
<thead>
<tr>
<th>Environment</th>
<th>API</th>
<th>Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ada</td>
<td>GNU Ada MySQL Bindings</td>
<td>libmysqlclient</td>
<td>See MySQL Bindings for GNU Ada</td>
</tr>
<tr>
<td>C</td>
<td>C API</td>
<td>libmysqlclient</td>
<td>See Section 23.7, “MySQL C API”.</td>
</tr>
<tr>
<td>C++</td>
<td>Connector/C++</td>
<td>libmysqlclient</td>
<td>See MySQL Connector/C++ 8.0 Developer Guide.</td>
</tr>
<tr>
<td></td>
<td>MySQL++</td>
<td>libmysqlclient</td>
<td>See MySQL++ website.</td>
</tr>
<tr>
<td></td>
<td>MySQL wrapped</td>
<td>libmysqlclient</td>
<td>See MySQL wrapped.</td>
</tr>
<tr>
<td>D</td>
<td>MySQL for D</td>
<td>libmysqlclient</td>
<td>See MySQL for D.</td>
</tr>
<tr>
<td>Eiffel</td>
<td>Eiffel MySQL</td>
<td>libmysqlclient</td>
<td>See Section 23.13, “MySQL Eiffel Wrapper”.</td>
</tr>
<tr>
<td>Erlang</td>
<td>erlang-mysql-driver</td>
<td>libmysqlclient</td>
<td>See erlang-mysql-driver.</td>
</tr>
<tr>
<td>Haskell</td>
<td>Haskell MySQL Bindings</td>
<td>Native Driver</td>
<td>See Brian O’Sullivan’s pure Haskell MySQL bindings.</td>
</tr>
<tr>
<td></td>
<td>hsql-mysql</td>
<td>libmysqlclient</td>
<td>See MySQL driver for Haskell.</td>
</tr>
<tr>
<td>Java/JDBC</td>
<td>Connector/J</td>
<td>Native Driver</td>
<td>See MySQL Connector/J 5.1 Developer Guide.</td>
</tr>
<tr>
<td>Kaya</td>
<td>MyDB</td>
<td>libmysqlclient</td>
<td>See MyDB.</td>
</tr>
<tr>
<td>Lua</td>
<td>LuaSQL</td>
<td>libmysqlclient</td>
<td>See LuaSQL.</td>
</tr>
<tr>
<td>.NET/Mono</td>
<td>Connector/NET</td>
<td>Native Driver</td>
<td>See MySQL Connector/NET Developer Guide.</td>
</tr>
<tr>
<td>Objective Caml</td>
<td>Objective Caml MySQL Bindings</td>
<td>libmysqlclient</td>
<td>See MySQL Bindings for Objective Caml.</td>
</tr>
<tr>
<td>Octave</td>
<td>Database bindings for GNU Octave</td>
<td>libmysqlclient</td>
<td>See Database bindings for GNU Octave.</td>
</tr>
<tr>
<td>ODBC</td>
<td>Connector/ODBC</td>
<td>libmysqlclient</td>
<td>See MySQL Connector/ODBC Developer Guide.</td>
</tr>
<tr>
<td>Perl</td>
<td>DBI::DBD::mysql</td>
<td>libmysqlclient</td>
<td>See Section 23.9, “MySQL Perl API”.</td>
</tr>
<tr>
<td></td>
<td>Net::MySQL</td>
<td>Native Driver</td>
<td>See Net::MySQL at CPAN</td>
</tr>
<tr>
<td>PHP</td>
<td>mysql, ext/mysql interface (deprecated)</td>
<td>libmysqlclient</td>
<td>See Original MySQL API.</td>
</tr>
<tr>
<td></td>
<td>mysql1, ext/mysql1 interface</td>
<td>libmysqlclient</td>
<td>See MySQL Improved Extension.</td>
</tr>
<tr>
<td></td>
<td>PDO_MYSQL</td>
<td>libmysqlclient</td>
<td>See MySQL Functions (PDO_MYSQL).</td>
</tr>
<tr>
<td></td>
<td>PDO mysqlind</td>
<td>Native Driver</td>
<td></td>
</tr>
</tbody>
</table>
### MySQL Connector/C++

<table>
<thead>
<tr>
<th>Environment</th>
<th>Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python</td>
<td>Connector/Python</td>
<td>Native Driver</td>
</tr>
<tr>
<td>Python</td>
<td>Connector/Python C Extension</td>
<td>libmysqlclient See MySQL Connector/Python Developer Guide.</td>
</tr>
<tr>
<td>MySQLdb</td>
<td>libmysqlclient See Section 23.10, “MySQL Python API”.</td>
<td></td>
</tr>
<tr>
<td>Ruby</td>
<td>MySQL/Ruby</td>
<td>libmysqlclient See Section 23.11.1, “The MySQL/Ruby API”.</td>
</tr>
<tr>
<td>Ruby/MySQL</td>
<td>Native Driver</td>
<td>See Section 23.11.2, “The Ruby/MySQL API”.</td>
</tr>
<tr>
<td>Scheme</td>
<td>Myscsh</td>
<td>libmysqlclient See Myscsh.</td>
</tr>
<tr>
<td>SPL</td>
<td>sql_mysql</td>
<td>libmysqlclient See sql_mysql for SPL.</td>
</tr>
<tr>
<td>Tcl</td>
<td>MySQLtcl</td>
<td>libmysqlclient See Section 23.12, “MySQL Tcl API”.</td>
</tr>
</tbody>
</table>

#### 23.1 MySQL Connector/C++

The MySQL Connector/C++ manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/C++ 8.0 Developer Guide
- Release notes: MySQL Connector/C++ Release Notes

#### 23.2 MySQL Connector/J

The MySQL Connector/J manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/J Developer Guide
- Release notes: MySQL Connector/J Release Notes

#### 23.3 MySQL Connector/NET

The MySQL Connector/NET manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/NET Developer Guide
- Release notes: MySQL Connector/NET Release Notes

#### 23.4 MySQL Connector/ODBC

The MySQL Connector/ODBC manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/ODBC Developer Guide
- Release notes: MySQL Connector/ODBC Release Notes

#### 23.5 MySQL Connector/Python
The MySQL Connector/Python manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/Python Developer Guide
- Release notes: MySQL Connector/Python Release Notes

23.6 libmysqld, the Embedded MySQL Server Library

The embedded MySQL server library makes it possible to run a full-featured MySQL server inside a client application. The main benefits are increased speed and more simple management for embedded applications.

The embedded server library is based on the client/server version of MySQL, which is written in C/C++. Consequently, the embedded server also is written in C/C++. There is no embedded server available in other languages.

The API is identical for the embedded MySQL version and the client/server version. To change an old threaded application to use the embedded library, you normally only have to add calls to the following functions.

<table>
<thead>
<tr>
<th>Function</th>
<th>When to Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>mysql_library_init()</td>
<td>Call it before any other MySQL function is called, preferably early in the</td>
</tr>
<tr>
<td></td>
<td>main() function.</td>
</tr>
<tr>
<td>mysql_library_end()</td>
<td>Call it before your program exits.</td>
</tr>
<tr>
<td>mysql_thread_init()</td>
<td>Call it in each thread you create that accesses MySQL.</td>
</tr>
<tr>
<td>mysql_thread_end()</td>
<td>Call it before calling pthread_exit().</td>
</tr>
</tbody>
</table>

Then you must link your code with libmysqld.a instead of libmysqlclient.a. To ensure binary compatibility between your application and the server library, be sure to compile your application against headers for the same series of MySQL that was used to compile the server library. For example, if libmysqld was compiled against MySQL 5.1 headers, do not compile your application against MySQL 5.5 headers, or vice versa.

The mysql_library_xxx() functions are also included in libmysqlclient.a to enable you to change between the embedded and the client/server version by just linking your application with the right library. See Section 23.7.6.40, “mysql_library_init()”.

One difference between the embedded server and the standalone server is that for the embedded server, authentication for connections is disabled by default.

23.6.1 Compiling Programs with libmysqld

In precompiled binary MySQL distributions that include libmysqld, the embedded server library, MySQL builds the library using the appropriate vendor compiler if there is one.

To get a libmysqld library if you build MySQL from source yourself, you should configure MySQL with the --with-embedded-server=1 option. See Section 2.9.7, “MySQL Source-Configuration Options”.

When you link your program with libmysqld, you must also include the system-specific pthread libraries and some libraries that the MySQL server uses. You can get the full list of libraries by executing mysql_config --libmysqld-libs.
The correct flags for compiling and linking a threaded program must be used, even if you do not directly call any thread functions in your code.

To compile a C program to include the necessary files to embed the MySQL server library into an executable version of a program, the compiler will need to know where to find various files and need instructions on how to compile the program. The following example shows how a program could be compiled from the command line, assuming that you are using gcc, use the GNU C compiler:

```
gcc mysql_test.c -o mysql_test \
`/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```

Immediately following the gcc command is the name of the C program source file. After it, the -o option is given to indicate that the file name that follows is the name that the compiler is to give to the output file, the compiled program. The next line of code tells the compiler to obtain the location of the include files and libraries and other settings for the system on which it is compiled. The mysql_config command is contained in backticks, not single quotation marks.

On some non-gcc platforms, the embedded library depends on C++ runtime libraries and linking against the embedded library might result in missing-symbol errors. To solve this, link using a C++ compiler or explicitly list the required libraries on the link command line.

### 23.6.2 Restrictions When Using the Embedded MySQL Server

The embedded server has the following limitations:

- No user-defined functions (UDFs).
- No stack trace on core dump.
- You cannot set this up as a master or a slave (no replication).
- Very large result sets may be unusable on low memory systems.
- You cannot connect to an embedded server from an outside process with sockets or TCP/IP. However, you can connect to an intermediate application, which in turn can connect to an embedded server on the behalf of a remote client or outside process.
- libmysqld does not support encrypted connections. An implication is that if an application linked against libmysqld establishes a connection to a remote server, the connection cannot be encrypted.
- InnoDB is not reentrant in the embedded server and cannot be used for multiple connections, either successively or simultaneously.
- The Event Scheduler is not available. Because of this, the event_scheduler system variable is disabled.
- The Performance Schema is not available.

Some of these limitations can be changed by editing the mysql_embed.h include file and recompiling MySQL.

### 23.6.3 Options with the Embedded Server

Any options that may be given with the mysqld server daemon, may be used with an embedded server library. Server options may be given in an array as an argument to the mysql_library_init(), which initializes the server. They also may be given in an option file like my.cnf. To specify an option file for a C program, use the --defaults-file option as one of the elements of the second argument of the mysql_library_init() function. See Section 23.7.6.40, “mysql_library_init()”, for more information on the mysql_library_init() function.
Using option files can make it easier to switch between a client/server application and one where MySQL is embedded. Put common options under the [server] group. These are read by both MySQL versions. Client/server-specific options should go under the [mysqld] section. Put options specific to the embedded MySQL server library in the [embedded] section. Options specific to applications go under section labeled [ApplicationName_SERVER]. See Section 4.2.2.2, “Using Option Files”.

23.6.4 Embedded Server Examples

These two example programs should work without any changes on a Linux or FreeBSD system. For other operating systems, minor changes are needed, mostly with file paths. These examples are designed to give enough details for you to understand the problem, without the clutter that is a necessary part of a real application. The first example is very straightforward. The second example is a little more advanced with some error checking. The first is followed by a command-line entry for compiling the program. The second is followed by a GNUmake file that may be used for compiling instead.

Example 1

test1_libmysqld.c

```
#include <stdio.h>
#include <stdlib.h>
#include <stdarg.h>
#include "mysql.h"

MYSQL *mysql;
MYSQL_RES *results;
MYSQL_ROW record;
static char *server_options[] = 
    { "mysql_test", "--defaults-file=my.cnf", NULL };
int num_elements = (sizeof(server_options) / sizeof(char *)) - 1;
static char *server_groups[] = { "libmysqld_server",
                                "libmysqld_client", NULL };

int main(void)
{
    mysql_library_init(num_elements, server_options, server_groups);
    mysql = mysql_init(NULL);
    mysql_options(mysql, MYSQL_READ_DEFAULT_GROUP, "libmysqld_client");
    mysql_options(mysql, MYSQL_OPT_USE_EMBEDDED_CONNECTION, NULL);
    mysql_real_connect(mysql, NULL, NULL, NULL, "database1", 0, NULL, 0);
    mysql_query(mysql, "SELECT column1, column2 FROM table1");
    results = mysql_store_result(mysql);
    while((record = mysql_fetch_row(results))) {
        printf("%s - %s \n", record[0], record[1]);
    }
    mysql_free_result(results);
    mysql_close(mysql);
    mysql_library_end();
    return 0;
}
```

Here is the command line for compiling the above program:

```
gcc test1_libmysqld.c -o test1_libmysqld \
`/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```
Example 2

To try the example, create an `test2_libmysqld` directory at the same level as the MySQL source directory. Save the `test2_libmysqld.c` source and the `GNUmakefile` in the directory, and run GNU `make` from inside the `test2_libmysqld` directory.

test2_libmysqld.c

```c
/*
   * A simple example client, using the embedded MySQL server library
   */
#include <mysql.h>
#include <stdarg.h>
#include <stdio.h>
#include <stdlib.h>
MYSQL *db_connect(const char *dbname);
void db_disconnect(MYSQL *db);
void db_do_query(MYSQL *db, const char *query);
const char *server_groups[] = {
    "test2_libmysqld_SERVER", "embedded", "server", NULL
};

int
main(int argc, char **argv)
{
    MYSQL *one, *two;
    /* mysql_library_init() must be called before any other mysql
       * functions.
       * You can use mysql_library_init(0, NULL, NULL), and it
       * initializes the server using groups = {
       *   "server", "embedded", NULL
       * },
       * In your $HOME/.my.cnf file, you probably want to put:
       [test2_libmysqld_SERVER]
       language = /path/to/source/of/mysql/sql/share/english
       * You could, of course, modify argc and argv before passing
       * them to this function. Or you could create new ones in any
       * way you like. But all of the arguments in argv (except for
       * argv[0], which is the program name) should be valid options
       * for the MySQL server.
       *
       * If you link this client against the normal mysqlclient
       * library, this function is just a stub that does nothing.
       */
    mysql_library_init(argc, argv, (char **)server_groups);
    one = db_connect("test");
    two = db_connect(NULL);
    db_do_query(one, "SHOW TABLE STATUS");
    db_do_query(two, "SHOW DATABASES");
    mysql_close(two);
    mysql_close(one);
    /* This must be called after all other mysql functions */
    mysql_library_end();
}
```
exit(EXIT_SUCCESS);
}

static void
die(MYSQL *db, char *fmt, ...)
{
    va_list ap;
    va_start(ap, fmt);
    vfprintf(stderr, fmt, ap);
    va_end(ap);
    (void)putc('
', stderr);
    if (db)
        db_disconnect(db);
    exit(EXIT_FAILURE);
}

MYSQL *
db_connect(const char *dbname)
{
    MYSQL *db = mysql_init(NULL);
    if (!db)
        die(db, "mysql_init failed: no memory");
    /*
     * Notice that the client and server use separate group names.
     * This is critical, because the server does not accept the
     * client's options, and vice versa.
     */
    mysql_options(db, MYSQL_READ_DEFAULT_GROUP, "test2_libmysqld_CLIENT");
    if (!mysql_real_connect(db, NULL, NULL, NULL, dbname, 0, NULL, 0))
        die(db, "mysql_real_connect failed: %s", mysql_error(db));
    return db;
}

void
db_disconnect(MYSQL *db)
{
    mysql_close(db);
}

void
db_do_query(MYSQL *db, const char *query)
{
    if (mysql_query(db, query) != 0)
        goto err;

    if (mysql_field_count(db) > 0)
    {
        MYSQL_RES   *res;
        MYSQL_ROW    row, end_row;
        int num_fields;

        if (!(res = mysql_store_result(db)))
            goto err;
        num_fields = mysql_num_fields(res);
        while ((row = mysql_fetch_row(res)))
        {
            (void)fputs(">> ", stdout);
            for (end_row = row + num_fields; row < end_row; ++row)
                (void)printf("%s\t", row ? (char*)*row : "NULL");
            (void)fputc('\n', stdout);
        }
        mysql_free_result(res);
    }
    else
        (void)printf("Affected rows: %lld\n", mysql_affected_rows(db));
23.7 MySQL C API

The C API provides low-level access to the MySQL client/server protocol and enables C programs to access database contents. The C API code is distributed with MySQL and implemented in the libmysqlclient library. See Section 23.7.1, “MySQL C API Implementations”.

Most other client APIs use the libmysqlclient library to communicate with the MySQL server. (Exceptions are Connector/J and Connector/NET.) This means that, for example, you can take advantage of many of the same environment variables that are used by other client programs because they are referenced from the library. For a list of these variables, see Section 4.1, “Overview of MySQL Programs”.

For instructions on building client programs using the C API, see Section 23.7.3.1, “Building C API Client Programs”. For programming with threads, see Section 23.7.3.2, “Writing C API Threaded Client Programs”. To create a standalone application which includes the “server” and “client” in the same program (and does not communicate with an external MySQL server), see Section 23.6, “libmysqld, the Embedded MySQL Server Library”. 

```
return;

err:
  die(db, "db_do_query failed: %s [%s]", mysql_error(db), query);
}
```

```
GNUmakefile

# This assumes the MySQL software is installed in /usr/local/mysql
inc := /usr/local/mysql/include/mysql
lib := /usr/local/mysql/lib

# If you have not installed the MySQL software yet, try this instead
#inc := $(HOME)/mysql-5.5/include
#lib := $(HOME)/mysql-5.5/libmysqld

CC       := gcc
CPPFLAGS := -I$(inc) -D_THREAD_SAFE -D_REENTRANT
CFLAGS   := -g -W -Wall
LDFLAGS  := -static

# You can change -lmysqld to -lmysqlclient to use the
# client/server library
LDLIBS   := -L$(lib) -lmysqld -lm -ldl -lcrypt

ifeq (,$(shell grep FreeBSD /COPYRIGHT 2>/dev/null))
  # FreeBSD
  LDFLAGS += -pthread
else
  # Assume Linux
  LDLIBS += -lpthread
endif

# This works for simple one-file test programs
sources := $(wildcard *.c)
objects := $(patsubst %c,%o,$(sources))
targets := $(basename $(sources))

all: $(targets)
clean:
  rm -f $(targets) $(objects) *.core
```
Note

If, after an upgrade, you experience problems with compiled client programs, such as \textit{Commands out of sync} or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the \texttt{mysql.h} file and \texttt{libmysqlclient.a} library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from \texttt{libmysqlclient.so.17} to \texttt{libmysqlclient.so.18}). For additional compatibility information, see \textit{Section 23.7.3.3, “Running C API Client Programs”}. 

Clients have a maximum communication buffer size. The size of the buffer that is allocated initially (16KB) is automatically increased up to the maximum size (16MB by default). Because buffer sizes are increased only as demand warrants, simply increasing the maximum limit does not in itself cause more resources to be used. This size check is mostly a precaution against erroneous statements and communication packets.

The communication buffer must be large enough to contain a single SQL statement (for client-to-server traffic) and one row of returned data (for server-to-client traffic). Each session's communication buffer is dynamically enlarged to handle any query or row up to the maximum limit. For example, if you have BLOB values that contain up to 16MB of data, you must have a communication buffer limit of at least 16MB (in both server and client). The default maximum built into the client library is 1GB, but the default maximum in the server is 1MB. You can increase this by changing the value of the \texttt{max_allowed_packet} parameter at server startup. See \textit{Section 5.1.1, “Configuring the Server”}.

The MySQL server shrinks each communication buffer to \texttt{net_buffer_length} bytes after each query. For clients, the size of the buffer associated with a connection is not decreased until the connection is closed, at which time client memory is reclaimed.

\section*{23.7.1 MySQL C API Implementations}

The MySQL C API is a C-based API that client applications written in C can use to communicate with MySQL Server. Client programs refer to C API header files at compile time and link to a C API library file at link time. The library comes in two versions, depending on how the application is intended to communicate with the server:

- \texttt{libmysqlclient}: The client version of the library, used for applications that communicate over a network connection as a client of a standalone server process.

- \texttt{libmysqld}: The embedded server version of the library, used for applications intended to include an embedded MySQL server within the application itself. The application communicates with its own private server instance.

Both libraries have the same interface. In terms of C API calls, an application communicates with a standalone server the same way it communicates with an embedded server. A given client can be built to communicate with a standalone or embedded server, depending on whether it is linked against \texttt{libmysqlclient} or \texttt{libmysqld} at build time.

To obtain the C API header and library files required to build C API client programs, install a MySQL Server distribution. Server distributions include both \texttt{libmysqlclient} and \texttt{libmysqld}.

You can install a binary distribution that contains the C API files pre-built, or you can use a source distribution and build the C API files yourself.

The names of the library files to use when linking C API client applications depend on the library type and platform for which a distribution is built:
• On Unix (and Unix-like) systems, the static library is `libmysqlclient.a`. The dynamic library is `libmysqlclient.so` on most Unix systems and `libmysqlclient.dylib` on macOS.

For distributions that include embedded server libraries, the corresponding library names begin with `libmysqld` rather than `libmysqlclient`.

• On Windows, the static library is `mysqlclient.lib` and the dynamic library is `libmysql.dll`. Windows distributions also include `libmysql.lib`, a static import library needed for using the dynamic library.

For distributions that include embedded server libraries, the corresponding library names are `mysqlserver.lib`, `libmysqld.dll`, and `libmysqld.lib`.

Windows distributions also include a set of debug libraries. These have the same names as the nondebug libraries, but are located in the `lib/debug` library. You must use the debug libraries when compiling clients built using the debug C runtime.

On Unix, you may also see libraries that include `_r` in the names. Before MySQL 5.5, these were built as thread-safe (re-entrant) libraries separately from the non-_r libraries. As of 5.5, both libraries are the same and the _r names are symbolic links to the corresponding non-_r names. There is no need to use the _r libraries. For example, if you use `mysql_config` to obtain linker flags, you can use `mysql_config --libs` in all cases, even for threaded clients. There is no need to use `mysql_config --libs_r`.

### 23.7.2 Example C API Client Programs

Many of the clients in MySQL source distributions are written in C, such as `mysql`, `mysqladmin`, and `mysqlshow`. If you are looking for examples that demonstrate how to use the C API, take a look at those clients: Obtain a source distribution and look in its `client` directory. See Section 2.1.2, “How to Get MySQL”.

For information about individual C API functions, the sections for most functions include usage examples.

### 23.7.3 Building and Running C API Client Programs

The following sections provide information on building client programs that use the C API. Topics include compiling and linking clients, writing threaded clients, and troubleshooting runtime problems.

#### 23.7.3.1 Building C API Client Programs

This section provides guidelines for compiling C programs that use the MySQL C API.

• [Compiling MySQL Clients on Unix](#)

• [Compiling MySQL Clients on Microsoft Windows](#)

• [Troubleshooting Problems Linking to the MySQL Client Library](#)

#### Compiling MySQL Clients on Unix

The examples here use `gcc` as the compiler. A different compiler might be appropriate on some systems (for example, `clang` on macOS or FreeBSD, or Sun Studio on Solaris). Adjust the examples as necessary.

You may need to specify an `-I` option when you compile client programs that use MySQL header files, so that the compiler can find them. For example, if the header files are installed in `/usr/local/mysql/include`, use this option in the compile command:

```
-I/usr/local/mysql/include
```
Building and Running C API Client Programs

You can link your code with either the dynamic or static MySQL C client library. The static library is named `libmysqlclient.a`. The dynamic library base name is `libmysqlclient` and the suffix differs by platform (for example, `.so` for Linux, `.dylib` for macOS).

MySQL clients must be linked using the `-lmysqlclient` option in the link command. You may also need to specify a `-L` option to tell the linker where to find the library. For example, if the library is installed in `/usr/local/mysql/lib`, use these options in the link command:

```
-L/usr/local/mysql/lib -lmysqlclient
```

The path names may differ on your system. Adjust the `-I` and `-L` options as necessary.

To make it simpler to compile MySQL programs on Unix, use the `mysql_config` script. See Section 4.7.2, “mysql_config — Display Options for Compiling Clients”.

`mysql_config` displays the options needed for compiling or linking:

```
mysql_config --cflags
mysql_config --libs
```

You can invoke those commands at the command line to get the proper options and add them manually to compilation or link commands. Alternatively, include the output from `mysql_config` directly within command lines using backticks:

```
gcc -c `mysql_config --cflags` proname.c
gcc -o proname proname.o `mysql_config --libs`
```

On Unix, linking uses dynamic libraries by default. To link to the static client library instead, add its path name to the link command. For example, if the library is located in `/usr/local/mysql/lib`, link like this:

```
gcc -o proname proname.o /usr/local/mysql/lib/libmysqlclient.a
```

Or use `mysql_config` to provide the library name:

```
gcc -o proname proname.o `mysql_config --variable=pkglibdir'/libmysqlclient.a
```

`mysql_config` does not currently provide a way to list all libraries needed for static linking, so it might be necessary to name additional libraries on the link command (for example, `-lnsl -lsocket` on Solaris). To get an idea which libraries to add, use `mysql_config --libs` and `ldd libmysqlclient.so` (or `otool -L libmysqlclient.dylib` on macOS).

**Compiling MySQL Clients on Microsoft Windows**

To specify header and library file locations, use the facilities provided by your development environment.

To build C API clients on Windows, you must link in the C client library, as well as the Windows ws2_32 sockets library and Secur32 security library.

You can link your code with either the dynamic or static MySQL C client library. On Windows, the static library is named `mysqlclient.lib` and the dynamic library is named `libmysql.dll`. In addition, the `libmysql.lib` static import library is needed for using the dynamic library. To link with the static C client library, the client application must be compiled with the same version of Visual Studio used to compile the C client library (which is Visual Studio 2008 for the static C client library built by Oracle).

When using the Oracle-built MySQL C client library, follow these rules when it comes to linking the C runtime for your client application:

- For the MySQL C client library from a Community distribution of MySQL:
• **For MySQL 5.5.55 and higher**: Always link dynamically to the C runtime (use the `/MD` compiler option), whether you are linking to the static or dynamic C client library. Also, target hosts running the client application must have the Visual C++ Redistributable for Visual Studio 2008 installed. The redistributable packages are available at the Microsoft Download Center.

• **For MySQL 5.5.54 and lower**:
  - If linking to the static C client library, link statically to the C runtime (use the `/MT` compiler option).
  - If linking to the dynamic C client library, link either statically or dynamically to the C runtime (use either `/MT` or `/MD` compiler option).

• For the MySQL C client library from a Commercial distribution of MySQL:
  - If linking to the static C client library, link statically to the C runtime (use the `/MT` compiler option).
  - If linking to the dynamic C client library, link either statically or dynamically to the C runtime (use either `/MT` or `/MD` compiler option).

In general, when linking to a static MySQL C client library, the client library and the client application must use the same compiler options when it comes to linking the C runtime—that is, if your C client library is compiled with the `/MT` option, your client application should also be compiled with the `/MT` option, and so on (see the MSDN page describing the C library linking options for more details). Follow this rule when you build your own static MySQL C client library from a source distribution of MySQL and link your client application to it.

**Note**

**Debug Mode**: Because of the just-mentioned linking rule, you cannot build your application in debug mode (with the `/MTd` or `/MDd` compiler option) and link it to a static C client library built by Oracle, which is not built with the debug options. Instead, you must build the static client library from source with the debug options.

**Troubleshooting Problems Linking to the MySQL Client Library**

If the linker cannot find the MySQL client library, you might get undefined-reference errors for symbols that start with `mysql_`, such as those shown here:

```
/tmp/ccFKsdPa.o: In function `main':
/tmp/ccFKsdPa.o(.text+0x0b): undefined reference to `mysql_init'
/tmp/ccFKsdPa.o(.text+0x31): undefined reference to `mysql_real_connect'
/tmp/ccFKsdPa.o(.text+0x69): undefined reference to `mysql_error'
/tmp/ccFKsdPa.o(.text+0x9a): undefined reference to `mysql_close'
```

You should be able to solve this problem by adding `-Ldir_path -lmysqlclient` at the end of your link command, where `dir_path` represents the path name of the directory where the client library is located. To determine the correct directory, try this command:

```
mysql_config --libs
```

The output from `mysql_config` might indicate other libraries that should be specified on the link command as well. You can include `mysql_config` output directly in your compile or link command using backticks. For example:

```
gcc -o proname proname.o `mysql_config --libs`
```

If an error occurs at link time that the `floor` symbol is undefined, link to the math library by adding `-lm` to the end of the compile/link line. Similarly, if you get undefined-reference errors for other functions that
Building and Running C API Client Programs

should exist on your system, such as `connect()`, check the manual page for the function in question to
determine which libraries you should add to the link command.

If you get undefined-reference errors such as the following for functions that do not exist on your system, it
usually means that your MySQL client library was compiled on a system that is not 100% compatible with
yours:

```
mf_format.o(.text+0x201): undefined reference to `_lxstat'
```

In this case, you should download a source distribution for the latest version of MySQL and compile the
MySQL client library yourself. See Section 2.9, “Installing MySQL from Source”.

23.7.3.2 Writing C API Threaded Client Programs

This section provides guidance for writing client programs that use the thread-related functions in the
MySQL C API. For further information about these functions, see Section 23.7.11, “C API Threaded
Function Descriptions”. For examples of source code that uses them, look in the `client`
directory of a
MySQL source distribution:

- The source for `mysqlimport` uses threading in the code associated with the `--use-threads` option.

- The source for `mysqlslap` uses threads to set up simultaneous workloads, to test server operation
under high load.

If undefined-reference errors occur when linking a threaded program against the MySQL client library, the
most likely cause is that you did not include the thread libraries on the link/compile command.

The client library is almost thread-safe. The biggest problem is that the subroutines in `sql/net_serv.cc`
that read from sockets are not interrupt-safe. This was done with the thought that you might want to have
your own alarm that can break a long read to a server. If you install interrupt handlers for the `SIGPIPE`
interrupt, socket handling should be thread-safe.

To avoid aborting the program when a connection terminates, MySQL blocks `SIGPIPE` on the first call to
`mysql_library_init()`, `mysql_init()`, or `mysql_connect()`. To use your own `SIGPIPE` handler,
first call `mysql_library_init()`, then install your handler.

The client library is thread-safe per connection. Two threads can share the same connection with the
following caveats:

- Multiple threads cannot send a query to the MySQL server at the same time on the same connection.
  In particular, you must ensure that between calls to `mysql_query()` and `mysql_store_result()`
in one thread, no other thread uses the same connection. To do this, use a mutex lock around your pair
of `mysql_query()` and `mysql_store_result()` calls. After `mysql_store_result()` returns, the
lock can be released and other threads may query the same connection.

  If you use POSIX threads, you can use `pthread_mutex_lock()` and `pthread_mutex_unlock()` to
establish and release a mutex lock.

- Multiple threads can access different result sets that are retrieved with `mysql_store_result()`.

- To use `mysql_use_result()`, you must ensure that no other thread uses the same connection until
the result set is closed. However, it really is best for threaded clients that share the same connection to
use `mysql_store_result()`.

If a thread does not create the connection to the MySQL database but calls MySQL functions, take the
following into account:
When you call `mysql_init()`, MySQL creates a thread-specific variable for the thread that is used by the debug library (among other things). If you call a MySQL function before the thread has called `mysql_init()`, the thread does not have the necessary thread-specific variables in place and you are likely to end up with a core dump sooner or later. To avoid problems, you must do the following:

1. Call `mysql_library_init()` before any other MySQL functions. It is not thread-safe, so call it before threads are created, or protect the call with a mutex.

2. Arrange for `mysql_thread_init()` to be called early in the thread handler before calling any MySQL function. (If you call `mysql_init()`, it calls `mysql_thread_init()` for you.)

3. In the thread, call `mysql_thread_end()` before calling `pthread_exit()`. This frees the memory used by MySQL thread-specific variables.

The preceding notes regarding `mysql_init()` also apply to `mysql_connect()`, which calls `mysql_init()`.

### 23.7.3.3 Running C API Client Programs

If, after an upgrade, you experience problems with compiled client programs, such as Commands out of sync or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the `mysql.h` header file and `libmysqlclient.a` library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.17` to `libmysqlclient.so.18`).

The major shared client library version determines compatibility. (For example, for `libmysqlclient.so.18.1.0`, the major version is 18.) Libraries shipped with newer versions of MySQL are drop-in replacements for older versions that have the same major number. As long as the major library version is the same, you can upgrade the library and old applications should continue to work with it.

Undefined-reference errors might occur at runtime when you try to execute a MySQL program. If these errors specify symbols that start with `mysql_` or indicate that the `libmysqlclient` library cannot be found, it means that your system cannot find the shared `libmysqlclient.so` library. The solution to this problem is to tell your system to search for shared libraries in the directory where that library is located. Use whichever of the following methods is appropriate for your system:

- Add the path of the directory where `libmysqlclient.so` is located to the `LD_LIBRARY_PATH` or `LD_LIBRARY` environment variable.

- On macOS, add the path of the directory where `libmysqlclient.dylib` is located to the `DYLD_LIBRARY_PATH` environment variable.

- Copy the shared-library files (such as `libmysqlclient.so`) to some directory that is searched by your system, such as `/lib`, and update the shared library information by executing `ldconfig`. Be sure to copy all related files. A shared library might exist under several names, using symlinks to provide the alternate names.

If the application is linked to the embedded server library, runtime error messages indicate the `libmysqld` rather than `libmysqlclient` library, but the solution to the problem is the same as just described.

### 23.7.3.4 C API Server Version and Client Library Version

The string and numeric forms of the MySQL server version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_server_info()` and `mysql_get_server_version()` functions.
C API Data Structures

The client library version is the MySQL version. The string and numeric forms of this version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_client_info()` and `mysql_get_client_version()` functions.

23.7.4 C API Data Structures

This section describes C API data structures other than those used for prepared statements. For information about the latter, see Section 23.7.8, “C API Prepared Statement Data Structures”.

- **MYSQL**
  This structure represents handler for one database connection. It is used for almost all MySQL functions. Do not try to make a copy of a `MYSQL` structure. There is no guarantee that such a copy will be usable.

- **MYSQL_RES**
  This structure represents the result of a query that returns rows (SELECT, SHOW, DESCRIBE, EXPLAIN). The information returned from a query is called the *result set* in the remainder of this section.

- **MYSQL_ROW**
  This is a type-safe representation of one row of data. It is currently implemented as an array of counted byte strings. (You cannot treat these as null-terminated strings if field values may contain binary data, because such values may contain null bytes internally.) Rows are obtained by calling `mysql_fetch_row()`.

- **MYSQL_FIELD**
  This structure contains metadata: information about a field, such as the field's name, type, and size. Its members are described in more detail later in this section. You may obtain the `MYSQL_FIELD` structures for each field by calling `mysql_fetch_field()` repeatedly. Field values are not part of this structure; they are contained in a `MYSQL_ROW` structure.

- **MYSQL_FIELD_OFFSET**
  This is a type-safe representation of an offset into a MySQL field list. (Used by `mysql_field_seek()`.) Offsets are field numbers within a row, beginning at zero.

- **my_ulonglong**
  The type used for the number of rows and for `mysql_affected_rows()`, `mysql_num_rows()`, and `mysql_insert_id()`. This type provides a range of 0 to 1.84e19.

  Some functions that return a row count using this type return -1 as an unsigned value to indicate an error or exceptional condition. You can check for -1 by comparing the return value to `(my_ulonglong)-1` (or to `(my_ulonglong)~0`, which is equivalent).

  On some systems, attempting to print a value of type `my_ulonglong` does not work. To print such a value, convert it to `unsigned long` and use a `%lu` print format. Example:

  ```c
  printf ("Number of rows: %lu\n",
          (unsigned long) mysql_num_rows(result));
  ```

- **my_bool**
  A boolean type, for values that are true (nonzero) or false (zero).
The `MYSQL_FIELD` structure contains the members described in the following list. The definitions apply primarily for columns of result sets such as those produced by `SELECT` statements. `MYSQL_FIELD` structures are also used to provide metadata for `OUT` and `INOUT` parameters returned from stored procedures executed using prepared `CALL` statements. For such parameters, some of the structure members have a meaning different from the meaning for column values.

- **char * name**
  
  The name of the field, as a null-terminated string. If the field was given an alias with an `AS` clause, the value of `name` is the alias. For a procedure parameter, the parameter name.

- **char * org_name**
  
  The name of the field, as a null-terminated string. Aliases are ignored. For expressions, the value is an empty string. For a procedure parameter, the parameter name.

- **char * table**
  
  The name of the table containing this field, if it is not a calculated field. For calculated fields, the `table` value is an empty string. If the column is selected from a view, `table` names the view. If the table or view was given an alias with an `AS` clause, the value of `table` is the alias. For a `UNION`, the value is the empty string. For a procedure parameter, the procedure name.

- **char * org_table**
  
  The name of the table, as a null-terminated string. Aliases are ignored. If the column is selected from a view, `org_table` names the view. For a `UNION`, the value is the empty string. For a procedure parameter, the procedure name.

- **char * db**
  
  The name of the database that the field comes from, as a null-terminated string. If the field is a calculated field, `db` is an empty string. For a `UNION`, the value is the empty string. For a procedure parameter, the name of the database containing the procedure.

- **char * catalog**
  
  The catalog name. This value is always "def".

- **char * def**
  
  The default value of this field, as a null-terminated string. This is set only if you use `mysql_list_fields()`.

- **unsigned long length**
  
  The width of the field. This corresponds to the display length, in bytes.

  The server determines the `length` value before it generates the result set, so this is the minimum length required for a data type capable of holding the largest possible value from the result column, without knowing in advance the actual values that will be produced by the query for the result set.

- **unsigned long max_length**
  
  The maximum width of the field for the result set (the length in bytes of the longest field value for the rows actually in the result set). If you use `mysql_store_result()` or `mysql_list_fields()`, this contains the maximum length for the field. If you use `mysql_use_result()`, the value of this variable is zero.
The value of `max_length` is the length of the string representation of the values in the result set. For example, if you retrieve a `FLOAT` column and the “widest” value is `-12.345`, `max_length` is 7 (the length of `' -12.345'`).

If you are using prepared statements, `max_length` is not set by default because for the binary protocol the lengths of the values depend on the types of the values in the result set. (See Section 23.7.8, “C API Prepared Statement Data Structures”.) If you want the `max_length` values anyway, enable the `STMT_ATTR_UPDATE_MAX_LENGTH` option with `mysql_stmt_attr_set()` and the lengths will be set when you call `mysql_stmt_store_result()`. (See Section 23.7.10.3, “mysql_stmt_attr_set()”, and Section 23.7.10.28, “mysql_stmt_store_result()”.)

- **unsigned int name_length**
  The length of `name`.

- **unsigned int org_name_length**
  The length of `org_name`.

- **unsigned int table_length**
  The length of `table`.

- **unsigned int org_table_length**
  The length of `org_table`.

- **unsigned int db_length**
  The length of `db`.

- **unsigned int catalog_length**
  The length of `catalog`.

- **unsigned int def_length**
  The length of `def`.

- **unsigned int flags**
  Bit-flags that describe the field. The `flags` value may have zero or more of the bits set that are shown in the following table.

<table>
<thead>
<tr>
<th>Flag Value</th>
<th>Flag Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT_NULL_FLAG</td>
<td>Field cannot be <code>NULL</code></td>
</tr>
<tr>
<td>PRI_KEY_FLAG</td>
<td>Field is part of a primary key</td>
</tr>
<tr>
<td>UNIQUE_KEY_FLAG</td>
<td>Field is part of a unique key</td>
</tr>
<tr>
<td>MULTIPLE_KEY_FLAG</td>
<td>Field is part of a nonunique key</td>
</tr>
<tr>
<td>UNSIGNED_FLAG</td>
<td>Field has the <code>UNSIGNED</code> attribute</td>
</tr>
<tr>
<td>ZEROFILL_FLAG</td>
<td>Field has the <code>ZEROFILL</code> attribute</td>
</tr>
<tr>
<td>BINARY_FLAG</td>
<td>Field has the <code>BINARY</code> attribute</td>
</tr>
<tr>
<td>AUTO_INCREMENT_FLAG</td>
<td>Field has the <code>AUTO_INCREMENT</code> attribute</td>
</tr>
</tbody>
</table>
Flag Value | Flag Description
--- | ---
ENUM_FLAG | Field is an ENUM
SET_FLAG | Field is a SET
BLOB_FLAG | Field is a BLOB or TEXT (deprecated)
TIMESTAMP_FLAG | Field is a TIMESTAMP (deprecated)
NUM_FLAG | Field is numeric; see additional notes following table
NO_DEFAULT_VALUE_FLAG | Field has no default value; see additional notes following table

Some of these flags indicate data type information and are superseded by or used in conjunction with the MYSQL_TYPE_XXX value in the field->type member described later:

- To check for BLOB or TIMESTAMP values, check whether type is MYSQL_TYPE_BLOB or MYSQL_TYPE_TIMESTAMP. (The BLOB_FLAG and TIMESTAMP_FLAG flags are unneeded.)
- ENUM and SET values are returned as strings. For these, check that the type value is MYSQL_TYPE_STRING and that the ENUM_FLAG or SET_FLAG flag is set in the flags value.

NUM_FLAG indicates that a column is numeric. This includes columns with a type of MYSQL_TYPE_DECIMAL, MYSQL_TYPE_NEWDECIMAL, MYSQL_TYPE_TINY, MYSQL_TYPE_SHORT, MYSQL_TYPE_LONG, MYSQL_TYPE_FLOAT, MYSQL_TYPE_DOUBLE, MYSQL_TYPE_NULL, MYSQL_TYPE_LONGLONG, MYSQL_TYPE_INT24, and MYSQL_TYPE_YEAR.

NO_DEFAULT_VALUE_FLAG indicates that a column has no DEFAULT clause in its definition. This does not apply to NULL columns (because such columns have a default of NULL), or to AUTO_INCREMENT columns (which have an implied default value).

The following example illustrates a typical use of the flags value:

```c
if (field->flags & NOT_NULL_FLAG)
    printf("Field cannot be null\n");
```

You may use the convenience macros shown in the following table to determine the boolean status of the flags value.

<table>
<thead>
<tr>
<th>Flag Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS_NOT_NULL(flags)</td>
<td>True if this field is defined as NOT NULL</td>
</tr>
<tr>
<td>IS_PRI_KEY(flags)</td>
<td>True if this field is a primary key</td>
</tr>
<tr>
<td>IS_BLOB(flags)</td>
<td>True if this field is a BLOB or TEXT (deprecated; test field-&gt;type instead)</td>
</tr>
</tbody>
</table>

- unsigned int decimals

The number of decimals for numeric fields.

- unsigned int charsetnr

An ID number that indicates the character set/collation pair for the field.

Normally, character values in result sets are converted to the character set indicated by the character_set_results system variable. In this case, charsetnr corresponds to the character set indicated by that variable. Character set conversion can be suppressed by setting
character_set_results to NULL. In this case, charsetnr corresponds to the character set of the original table column or expression. See also Section 10.4, “Connection Character Sets and Collations”.

To distinguish between binary and nonbinary data for string data types, check whether the charsetnr value is 63. If so, the character set is binary, which indicates binary rather than nonbinary data. This enables you to distinguish BINARY from CHAR, VARBINARY from VARCHAR, and the BLOB types from the TEXT types.

charsetnr values are the same as those displayed in the Id column of the SHOW COLLATION statement or the ID column of the INFORMATION_SCHEMA COLLATIONS table. You can use those information sources to see which character set and collation specific charsetnr values indicate:

```
mysql> SHOW COLLATION WHERE Id = 63;
+-----------+---------+----+---------+----------+---------+
| Collation | Charset | Id | Default | Compiled | Sortlen |
+-----------+---------+----+---------+----------+---------+
| binary    | binary  | 63 | Yes     | Yes      |       1 |
+-----------+---------+----+---------+----------+---------+
mysql> SELECT COLLATION_NAME, CHARACTER_SET_NAME
FROM INFORMATION_SCHEMA.COLLATIONS WHERE ID = 33;
+-----------------+--------------------+
| COLLATION_NAME   | CHARACTER_SET_NAME |
+-----------------+--------------------+
| utf8_general_ci | utf8               |
+-----------------+--------------------+
```

• enum enum_field_types type

The type of the field. The type value may be one of the MYSQL_TYPE_ symbols shown in the following table.

<table>
<thead>
<tr>
<th>Type Value</th>
<th>Type Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYSQL_TYPE_TINY</td>
<td>TINYINT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_SHORT</td>
<td>SMALLINT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_LONG</td>
<td>INTEGER field</td>
</tr>
<tr>
<td>MYSQL_TYPE_INT24</td>
<td>MEDIUMINT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_LONGLONG</td>
<td>BIGINT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_DECIMAL</td>
<td>DECIMAL or NUMERIC field</td>
</tr>
<tr>
<td>MYSQL_TYPE_NEWDECIMAL</td>
<td>Precision math DECIMAL or NUMERIC</td>
</tr>
<tr>
<td>MYSQL_TYPE_FLOAT</td>
<td>FLOAT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_DOUBLE</td>
<td>DOUBLE or REAL field</td>
</tr>
<tr>
<td>MYSQL_TYPE_BIT</td>
<td>BIT field</td>
</tr>
<tr>
<td>MYSQL_TYPE_TIMESTAMP</td>
<td>TIMESTAMP field</td>
</tr>
<tr>
<td>MYSQL_TYPE_DATE</td>
<td>DATE field</td>
</tr>
<tr>
<td>MYSQL_TYPE_TIME</td>
<td>TIME field</td>
</tr>
<tr>
<td>MYSQL_TYPE_DATETIME</td>
<td>DATETIME field</td>
</tr>
<tr>
<td>MYSQL_TYPE_YEAR</td>
<td>YEAR field</td>
</tr>
<tr>
<td>MYSQL_TYPE_STRING</td>
<td>CHAR or BINARY field</td>
</tr>
<tr>
<td>MYSQL_TYPE_VAR_STRING</td>
<td>VARCHAR or VARBINARY field</td>
</tr>
</tbody>
</table>
You can use the `IS_NUM()` macro to test whether a field has a numeric type. Pass the `type` value to `IS_NUM()` and it evaluates to TRUE if the field is numeric:

```c
if (IS_NUM(field->type))
    printf("Field is numeric\n");
```

ENUM and SET values are returned as strings. For these, check that the `type` value is `MYSQL_TYPE_STRING` and that the ENUM_FLAG or SET_FLAG flag is set in the `flags` value.

### 23.7.5 C API Function Overview

The following list summarizes the functions available in the C API. For greater detail, see the descriptions in Section 23.7.6, “C API Function Descriptions”.

- **my_init()**: Initializes global variables and the thread handler in thread-safe programs.
- **mysql_affected_rows()**: Returns the number of rows changed/deleted/inserted by the last UPDATE, DELETE, or INSERT query.
- **mysql_autocommit()**: Toggles autocommit mode on/off.
- **mysql_change_user()**: Changes the user and database on an open connection.
- **mysql_character_set_name()**: Returns the default character set name for the current connection.
- **mysql_client_find_plugin()**: Returns a pointer to a plugin.
- **mysql_client_register_plugin()**: Registers a plugin.
- **mysql_close()**: Closes a server connection.
- **mysql_commit()**: Commits the transaction.
- **mysql_connect()**: Connects to a MySQL server. This function is deprecated; use `mysql_real_connect()` instead.
- **mysql_create_db()**: Creates a database. This function is deprecated; use the SQL statement CREATE DATABASE instead.
- **mysql_data_seek()**: Seeks to an arbitrary row number in a query result set.
- **mysql_debug()**: Does a DEBUG_PUSH with the given string.
- **mysql_drop_db()**: Drops a database. This function is deprecated; use the SQL statement DROP DATABASE instead.
- **mysql_dump_debug_info()**: Causes the server to write debug information to the log.
C API Function Overview

- **mysql_eof()**: Determines whether the last row of a result set has been read. This function is deprecated; use mysql_errno() or mysql_error() instead.
- **mysql_errno()**: Returns the error number for the most recently invoked MySQL function.
- **mysql_error()**: Returns the error message for the most recently invoked MySQL function.
- **mysql_escape_string()**: Escapes special characters in a string for use in an SQL statement.
- **mysql_fetch_field()**: Returns the type of the next table field.
- **mysql_fetch_field_direct()**: Returns the type of a table field, given a field number.
- **mysql_fetch_fields()**: Returns an array of all field structures.
- **mysql_fetch_lengths()**: Returns the lengths of all columns in the current row.
- **mysql_fetch_row()**: Fetches the next row from the result set.
- **mysql_field_count()**: Returns the number of result columns for the most recent statement.
- **mysql_field_seek()**: Puts the column cursor on a specified column.
- **mysql_field_tell()**: Returns the position of the field cursor used for the last mysql_fetch_field() call.
- **mysql_free_result()**: Frees memory used by a result set.
- **mysql_get_character_set_info()**: Returns information about default character set.
- **mysql_get_client_info()**: Returns client version information as a string.
- **mysql_get_client_version()**: Returns client version information as an integer.
- **mysql_get_host_info()**: Returns a string describing the connection.
- **mysql_get_proto_info()**: Returns the protocol version used by the connection.
- **mysql_get_server_info()**: Returns the server version number.
- **mysql_get_server_version()**: Returns the server version number as an integer.
- **mysql_get_ssl_cipher()**: Returns the current SSL cipher.
- **mysql_hex_string()**: Encodes a string in hexadecimal format.
- **mysql_info()**: Returns information about the most recently executed query.
- **mysql_init()**: Gets or initializes a MYSQL structure.
- **mysql_insert_id()**: Returns the ID generated for an AUTO_INCREMENT column by the previous query.
- **mysql_kill()**: Kills a given thread.
- **mysql_library_end()**: Finalizes the MySQL C API library.
- **mysql_library_init()**: Initializes the MySQL C API library.
- **mysql_list_dbs()**: Returns database names matching a simple regular expression.
• `mysql_list_fields()`: Returns field names matching a simple regular expression.
• `mysql_list_processes()`: Returns a list of the current server threads.
• `mysql_list_tables()`: Returns table names matching a simple regular expression.
• `mysql_load_plugin()`: Loads a plugin.
• `mysql_load_plugin_v()`: Loads a plugin.
• `mysql_more_results()`: Checks whether any more results exist.
• `mysql_next_result()`: Returns/initiates the next result in multiple-result executions.
• `mysql_num_fields()`: Returns the number of columns in a result set.
• `mysql_num_rows()`: Returns the number of rows in a result set.
• `mysql_options()`: Sets connect options for `mysql_real_connect()`.
• `mysql_ping()`: Checks whether the connection to the server is working, reconnecting as necessary.
• `mysql_plugin_options()`: Sets a plugin option.
• `mysql_query()`: Executes an SQL query specified as a null-terminated string.
• `mysql_real_connect()`: Connects to a MySQL server.
• `mysql_real_escape_string()`: Escapes special characters in a string for use in an SQL statement, taking into account the current character set of the connection.
• `mysql_real_query()`: Executes an SQL query specified as a counted string.
• `mysql_refresh()`: Flashes or resets tables and caches.
• `mysql_reload()`: Tells the server to reload the grant tables.
• `mysql_rollback()`: Rolls back the transaction.
• `mysql_row_seek()`: Seeks to a row offset in a result set, using value returned from `mysql_row_tell()`.
• `mysql_row_tell()`: Returns the row cursor position.
• `mysql_select_db()`: Selects a database.
• `mysql_server_end()`: Finalizes the MySQL C API library.
• `mysql_server_init()`: Initializes the MySQL C API library.
• `mysql_set_character_set()`: Sets the default character set for the current connection.
• `mysql_set_local_infile_default()`: Sets the `LOAD DATA LOCAL` handler callbacks to their default values.
• `mysql_set_local_infile_handler()`: Installs application-specific `LOAD DATA LOCAL` handler callbacks.
• `mysql_set_server_option()`: Sets an option for the connection (like `multi-statements`).
• **mysql_sqlstate():** Returns the SQLSTATE error code for the last error.

• **mysql_shutdown():** Shuts down the database server.

• **mysql_ssl_set():** Prepares to establish an SSL connection to the server.

• **mysql_stat():** Returns the server status as a string.

• **mysql_store_result():** Retrieves a complete result set to the client.

• **mysql_thread_end():** Finalizes a thread handler.

• **mysql_thread_id():** Returns the current thread ID.

• **mysql_thread_init():** Initializes a thread handler.

• **mysql_thread_safe():** Returns 1 if the clients are compiled as thread-safe.

• **mysql_use_result():** Initiates a row-by-row result set retrieval.

• **mysql_warning_count():** Returns the warning count for the previous SQL statement.

Application programs should use this general outline for interacting with MySQL:

1. Initialize the MySQL client library by calling `mysql_library_init()`. This function exists in both the `libmysqlclient` C client library and the `libmysqld` embedded server library, so it is used whether you build a regular client program by linking with the `-libmysqlclient` flag, or an embedded server application by linking with the `-libmysqld` flag.

2. Initialize a connection handler by calling `mysql_init()` and connect to the server by calling `mysql_real_connect()`.

3. Issue SQL statements and process their results. (The following discussion provides more information about how to do this.)

4. Close the connection to the MySQL server by calling `mysql_close()`.

5. End use of the MySQL client library by calling `mysql_library_end()`.

The purpose of calling `mysql_library_init()` and `mysql_library_end()` is to provide proper initialization and finalization of the MySQL client library. For applications that are linked with the client library, they provide improved memory management. If you do not call `mysql_library_end()`, a block of memory remains allocated. (This does not increase the amount of memory used by the application, but some memory leak detectors will complain about it.) For applications that are linked with the embedded server, these calls start and stop the server.

In a nonmultithreaded environment, the call to `mysql_library_init()` may be omitted, because `mysql_init()` will invoke it automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multithreaded environment, and thus neither is `mysql_init()`, which calls `mysql_library_init()`. You must either call `mysql_library_init()` prior to spawning any threads, or else use a mutex to protect the call, whether you invoke `mysql_library_init()` or indirectly through `mysql_init()`. This should be done prior to any other client library call.

To connect to the server, call `mysql_init()` to initialize a connection handler, then call `mysql_real_connect()` with that handler (along with other information such as the host name, user name, and password). Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of 1 in versions of the API older than 5.0.3, or 0 in newer versions. A
C API Function Overview

value of 1 for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the `MYSQL_OPT_RECONNECT` option to `mysql_options()` to control reconnection behavior. When you are done with the connection, call `mysql_close()` to terminate it. Do not use the handler after it has been closed.

While a connection is active, the client may send SQL statements to the server using `mysql_query()` or `mysql_real_query()`. The difference between the two is that `mysql_query()` expects the query to be specified as a null-terminated string whereas `mysql_real_query()` expects a counted string. If the string contains binary data (which may include null bytes), you must use `mysql_real_query()`.

For each non-`SELECT` query (for example, `INSERT`, `UPDATE`, `DELETE`), you can find out how many rows were changed (affected) by calling `mysql_affected_rows()`.

For `SELECT` queries, you retrieve the selected rows as a result set. (Note that some statements are `SELECT`-like in that they return rows. These include `SHOW`, `DESCRIBE`, and `EXPLAIN`. Treat these statements the same way as `SELECT` statements.)

There are two ways for a client to process result sets. One way is to retrieve the entire result set all at once by calling `mysql_store_result()`. This function acquires from the server all the rows returned by the query and stores them in the client. The second way is for the client to initiate a row-by-row result set retrieval by calling `mysql_use_result()`. This function initializes the retrieval, but does not actually get any rows from the server.

In both cases, you access rows by calling `mysql_fetch_row()`. With `mysql_store_result()`, `mysql_fetch_row()` accesses rows that have previously been fetched from the server. With `mysql_use_result()`, `mysql_fetch_row()` actually retrieves the row from the server. Information about the size of the data in each row is available by calling `mysql_fetch_lengths()`.

After you are done with a result set, call `mysql_free_result()` to free the memory used for it.

The two retrieval mechanisms are complementary. Choose the approach that is most appropriate for each client application. In practice, clients tend to use `mysql_store_result()` more commonly.

An advantage of `mysql_store_result()` is that because the rows have all been fetched to the client, you not only can access rows sequentially, you can move back and forth in the result set using `mysql_data_seek()` or `mysql_row_seek()` to change the current row position within the result set. You can also find out how many rows there are by calling `mysql_num_rows()`. On the other hand, the memory requirements for `mysql_store_result()` may be very high for large result sets and you are more likely to encounter out-of-memory conditions.

An advantage of `mysql_use_result()` is that the client requires less memory for the result set because it maintains only one row at a time (and because there is less allocation overhead, `mysql_use_result()` can be faster). Disadvantages are that you must process each row quickly to avoid tying up the server, you do not have random access to rows within the result set (you can only access rows sequentially), and the number of rows in the result set is unknown until you have retrieved them all. Furthermore, you must retrieve all the rows even if you determine in mid-retrieval that you've found the information you were looking for.

The API makes it possible for clients to respond appropriately to statements (retrieving rows only as necessary) without knowing whether the statement is a `SELECT`. You can do this by calling `mysql_store_result()` after each `mysql_query()` (or `mysql_real_query()`). If the result set call succeeds, the statement was a `SELECT` and you can read the rows. If the result set call fails, call `mysql_field_count()` to determine whether a result was actually to be expected. If `mysql_field_count()` returns zero, the statement returned no data (indicating that it was an `INSERT`, `UPDATE`, `DELETE`, and so forth), and was not expected to return rows. If `mysql_field_count()` is nonzero, the statement should have returned rows, but did not. This indicates that the statement was a
SELECT that failed. See the description for mysql_field_count() for an example of how this can be done.

Both mysql_store_result() and mysql_use_result() enable you to obtain information about the fields that make up the result set (the number of fields, their names and types, and so forth). You can access field information sequentially within the row by calling mysql_fetch_field() repeatedly, or by field number within the row by calling mysql_fetch_field_direct(). The current field cursor position may be changed by calling mysql_field_seek(). Setting the field cursor affects subsequent calls to mysql_fetch_field(). You can also get information for fields all at once by calling mysql_fetch_fields().

For detecting and reporting errors, MySQL provides access to error information by means of the mysql_errno() and mysql_error() functions. These return the error code or error message for the most recently invoked function that can succeed or fail, enabling you to determine when an error occurred and what it was.

### 23.7.6 C API Function Descriptions

This section describes C API functions other than those used for prepared statements or the replication stream interface. For information about those, see Section 23.7.10, "C API Prepared Statement Function Descriptions", and C API Binary Log Function Descriptions.

In the descriptions here, a parameter or return value of NULL means NULL in the sense of the C programming language, not a MySQL NULL value.

Functions that return a value generally return a pointer or an integer. Unless specified otherwise, functions returning a pointer return a non-NULL value to indicate success or a NULL value to indicate an error, and functions returning an integer return zero to indicate success or nonzero to indicate an error. Note that “nonzero” means just that. Unless the function description says otherwise, do not test against a value other than zero:

```c
if (result)                   /* correct */
    ... error ...
if (result < 0)               /* incorrect */
    ... error ...
if (result == -1)             /* incorrect */
    ... error ...
```

When a function returns an error, the Errors subsection of the function description lists the possible types of errors. You can find out which of these occurred by calling mysql_errno(). A string representation of the error may be obtained by calling mysql_error().

#### 23.7.6.1 mysql_affected_rows()

```c
my_ulonglong mysql_affected_rows(MYSQL *mysql)
```

**Description**

mysql_affected_rows() may be called immediately after executing a statement with mysql_query() or mysql_real_query(). It returns the number of rows changed, deleted, or inserted by the last statement if it was an UPDATE, DELETE, or INSERT. For SELECT statements, mysql_affected_rows() works like mysql_num_rows().

For UPDATE statements, the affected-rows value by default is the number of rows actually changed. If you specify the CLIENT_FOUND_ROWS flag to mysql_real_connect() when connecting to mysqld, the affected-rows value is the number of rows “found”; that is, matched by the WHERE clause.
For **REPLACE** statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

For **INSERT ... ON DUPLICATE KEY UPDATE** statements, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the **CLIENT_FOUND_ROWS** flag, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

Following a **CALL** statement for a stored procedure, **mysql_affected_rows()** returns the value that it would return for the last statement executed within the procedure, or 0 if that statement would return -1. Within the procedure, you can use **ROW_COUNT()** at the SQL level to obtain the affected-rows value for individual statements.

**mysql_affected_rows()** returns a meaningful value for a wider range of statements. For details, see the description for **ROW_COUNT()** in Section 12.15, “Information Functions”.

**Return Values**

An integer greater than zero indicates the number of rows affected or retrieved. Zero indicates that no records were updated for an **UPDATE** statement, no rows matched the **WHERE** clause in the query or that no query has yet been executed. -1 indicates that the query returned an error or that, for a **SELECT** query, **mysql_affected_rows()** was called prior to calling **mysql_store_result()**.

Because **mysql_affected_rows()** returns an unsigned value, you can check for -1 by comparing the return value to *(my_ulonglong)-1* (or to *(my_ulonglong)~0*, which is equivalent).

**Errors**

None.

**Example**

```c
char *stmt = "UPDATE products SET cost=cost*1.25
    WHERE group=10";
mysql_query(&mysql,stmt);
printf("%ld products updated",
    (long) mysql_affected_rows(&mysql));
```

### 23.7.6.2 mysql_autocommit()

**my_bool mysql_autocommit(MYSQL *mysql, my_bool mode)**

**Description**

Sets autocommit mode on if **mode** is 1, off if **mode** is 0.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

None.

### 23.7.6.3 mysql_change_user()

**my_bool mysql_change_user(MYSQL *mysql, const char *user, const char *password, const char *db)**
Description

Changes the user and causes the database specified by \texttt{db} to become the default (current) database on the connection specified by \texttt{mysql}. In subsequent queries, this database is the default for table references that include no explicit database specifier.

\texttt{mysql\_change\_user()} fails if the connected user cannot be authenticated or does not have permission to use the database. In this case, the user and database are not changed.

Pass a \texttt{db} parameter of \texttt{NULL} if you do not want to have a default database.

This function resets the session state as if one had done a new connect and reauthenticated. (See Section 23.7.19, “C API Automatic Reconnection Control”.) It always performs a \texttt{ROLLBACK} of any active transactions, closes and drops all temporary tables, and unlocks all locked tables. Session system variables are reset to the values of the corresponding global system variables. Prepared statements are released and \texttt{HANDLER} variables are closed. Locks acquired with \texttt{GET\_LOCK()} are released. These effects occur even if the user did not change.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

The same that you can get from \texttt{mysql\_real\_connect()}, plus:

- \texttt{CR\_COMMANDS\_OUT\_OF\_SYNC}
  
  Commands were executed in an improper order.

- \texttt{CR\_SERVER\_GONE\_ERROR}
  
  The MySQL server has gone away.

- \texttt{CR\_SERVER\_LOST}
  
  The connection to the server was lost during the query.

- \texttt{CR\_UNKNOWN\_ERROR}
  
  An unknown error occurred.

- \texttt{ER\_UNKNOWN\_COM\_ERROR}
  
  The MySQL server does not implement this command (probably an old server).

- \texttt{ER\_ACCESS\_DENIED\_ERROR}
  
  The user or password was wrong.

- \texttt{ER\_BAD\_DB\_ERROR}
  
  The database did not exist.

- \texttt{ER\_DBACCESS\_DENIED\_ERROR}
  
  The user did not have access rights to the database.
• **ER_WRONG_DB_NAME**
  
  The database name was too long.

**Example**

```c
if (mysql_change_user(&mysql, "user", "password", "new_database"))
{
    fprintf(stderr, "Failed to change user.  Error: %s\n", mysql_error(&mysql));
}
```

### 23.7.6.4 mysql_character_set_name()

```c
const char *mysql_character_set_name(MYSQL *mysql)
```

**Description**

Returns the default character set name for the current connection.

**Return Values**

The default character set name

**Errors**

None.

### 23.7.6.5 mysql_close()

```c
void mysql_close(MYSQL *mysql)
```

**Description**

Closes a previously opened connection. `mysql_close()` also deallocates the connection handler pointed to by `mysql` if the handler was allocated automatically by `mysql_init()` or `mysql_connect()`. Do not use the handler after it has been closed.

**Return Values**

None.

**Errors**

None.

### 23.7.6.6 mysql_commit()

```c
my_bool mysql_commit(MYSQL *mysql)
```

**Description**

Commits the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is `RELEASE` (or 2), the server performs a release after terminating a
transaction and closes the client connection. Call `mysql_close()` from the client program to close the connection from the client side.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

None.

23.7.6.7 `mysql_connect()`

```c
MYSQL *mysql_connect(MYSQL *mysql, const char *host, const char *user, const char *passwd)
```

**Description**

This function is deprecated. Use `mysql_real_connect()` instead.

`mysql_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_connect()` must complete successfully before you can execute any of the other API functions, with the exception of `mysql_get_client_info()`.

The meanings of the parameters are the same as for the corresponding parameters for `mysql_real_connect()` with the difference that the connection parameter may be `NULL`. In this case, the C API allocates memory for the connection structure automatically and frees it when you call `mysql_close()`. The disadvantage of this approach is that you cannot retrieve an error message if the connection fails. (To get error information from `mysql_errno()` or `mysql_error()`, you must provide a valid `MYSQL` pointer.)

**Return Values**

Same as for `mysql_real_connect()`.

**Errors**

Same as for `mysql_real_connect()`.

23.7.6.8 `mysql_create_db()`

```c
int mysql_create_db(MYSQL *mysql, const char *db)
```

**Description**

Creates the database named by the `db` parameter.

This function is deprecated. Use `mysql_query()` to issue an SQL `CREATE DATABASE` statement instead.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- `CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

**Example**

```c
if(mysql_create_db(&mysql, "my_database"))
{
    fprintf(stderr, "Failed to create new database. Error: %s\n",
            mysql_error(&mysql));
}
```

**23.7.6.9 mysql_data_seek()**

```c
void mysql_data_seek(MYSQL_RES *result, my_ulonglong offset)
```

**Description**

Seeks to an arbitrary row in a query result set. The `offset` value is a row number. Specify a value in the range from 0 to `mysql_num_rows(result) - 1`.

This function requires that the result set structure contains the entire result of the query, so `mysql_data_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

**Return Values**

None.

**Errors**

None.

**23.7.6.10 mysql_debug()**

```c
void mysql_debug(const char *debug)
```

**Description**

Does a `DEBUG_PUSH` with the given string. `mysql_debug()` uses the Fred Fish debug library. To use this function, you must compile the client library to support debugging. See Section 24.5.3, "The DEBUG Package".

**Return Values**

None.
Errors

None.

Example

The call shown here causes the client library to generate a trace file in `/tmp/client.trace` on the client machine:

```c
mysql_debug("d:t:O,/tmp/client.trace");
```

23.7.6.11 mysql_drop_db()

```c
int mysql_drop_db(MYSQL *mysql, const char *db)
```

Description

Drops the database named by the `db` parameter.

This function is deprecated. Use `mysql_query()` to issue an SQL `DROP DATABASE` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.
- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.
- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.
- **CR_UNKNOWN_ERROR**

  An unknown error occurred.

Example

```c
if(mysql_drop_db(&mysql, "my_database"))
    fprintf(stderr, "Failed to drop the database: Error: %s\n",
            mysql_error(&mysql));
```

23.7.6.12 mysql_dump_debug_info()

```c
int mysql_dump_debug_info(MYSQL *mysql)
```

Description

Instructs the server to write debugging information to the error log. The connected user must have the `SUPER` privilege.
Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

### 23.7.6.13 mysql_eof()

```c
my_bool mysql_eof(MYSQL_RES *result)
```

**Description**

This function is deprecated. `mysql_errno()` or `mysql_error()` may be used instead.

`mysql_eof()` determines whether the last row of a result set has been read.

If you acquire a result set from a successful call to `mysql_store_result()`, the client receives the entire set in one operation. In this case, a NULL return from `mysql_fetch_row()` always means the end of the result set has been reached and it is unnecessary to call `mysql_eof()`. When used with `mysql_store_result()`, `mysql_eof()` always returns true.

On the other hand, if you use `mysql_use_result()` to initiate a result set retrieval, the rows of the set are obtained from the server one by one as you call `mysql_fetch_row()` repeatedly. Because an error may occur on the connection during this process, a NULL return value from `mysql_fetch_row()` does not necessarily mean the end of the result set was reached normally. In this case, you can use `mysql_eof()` to determine what happened. `mysql_eof()` returns a nonzero value if the end of the result set was reached and zero if an error occurred.

Historically, `mysql_eof()` predates the standard MySQL error functions `mysql_errno()` and `mysql_error()`. Because those error functions provide the same information, their use is preferred over `mysql_eof()`, which is deprecated. (In fact, they provide more information, because `mysql_eof()` returns only a boolean value whereas the error functions indicate a reason for the error when one occurs.)

**Return Values**

Zero for success. Nonzero if the end of the result set has been reached.

**Errors**

None.
Example

The following example shows how you might use `mysql_eof()`:

```c
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(!mysql_eof(result)) // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

However, you can achieve the same effect with the standard MySQL error functions:

```c
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(mysql_errno(&mysql)) // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

### 23.7.6.14 `mysql_errno()`

**unsigned int mysql_errno(MYSQL *mysql)**

**Description**

For the connection specified by *mysql*, `mysql_errno()` returns the error code for the most recently invoked API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL *errmsg.h* header file. Server error message numbers are listed in *mysqld_error.h*. Errors also are listed at Appendix B, Errors, Error Codes, and Common Problems.

**Note**

Some functions such as `mysql_fetch_row()` do not set `mysql_errno()` if they succeed. A rule of thumb is that all functions that have to ask the server for information reset `mysql_errno()` if they succeed.

MySQL-specific error numbers returned by `mysql_errno()` differ from SQLSTATE values returned by `mysql_sqlstate()`. For example, the `mysql` client program displays errors using the following format, where 1146 is the `mysql_errno()` value and '42S02' is the corresponding `mysql_sqlstate()` value:

```shell
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

**Return Values**

An error code value for the last `mysql_XXX()` call, if it failed. zero means no error occurred.

**Errors**

None.
23.7.6.15 mysql_error()

```
cost char *mysql_error(MYSQL *mysql)
```

**Description**

For the connection specified by `mysql`, `mysql_error()` returns a null-terminated string containing the error message for the most recently invoked API function that failed. If a function did not fail, the return value of `mysql_error()` may be the previous error or an empty string to indicate no error.

A rule of thumb is that all functions that have to ask the server for information reset `mysql_error()` if they succeed.

For functions that reset `mysql_error()`, either of these two tests can be used to check for an error:

```
if(*mysql_error(&mysql))
{
    // an error occurred
}
if(mysql_error(&mysql)[0])
{
    // an error occurred
}
```

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages. See Section 10.12, “Setting the Error Message Language”.

**Return Values**

A null-terminated character string that describes the error. An empty string if no error occurred.

**Errors**

None.

23.7.6.16 mysql_escape_string()

```
Note
This function should not be used. Use mysql_real_escape_string() instead.
```

`mysql_escape_string()` is identical to `mysql_real_escape_string()` except that `mysql_real_escape_string()` takes a connection handler as its first argument and escapes the string according to the current character set. `mysql_escape_string()` does not take a connection argument and does not respect the current character set.

23.7.6.17 mysql_fetch_field()

```
MYSQL_FIELD *mysql_fetch_field(MYSQL_RES *result)
```

**Description**

Returns the definition of one column of a result set as a `MYSQL_FIELD` structure. Call this function repeatedly to retrieve information about all columns in the result set. `mysql_fetch_field()` returns `NULL` when no more fields are left.
mysql_fetch_field() is reset to return information about the first field each time you execute a new SELECT query. The field returned by mysql_fetch_field() is also affected by calls to mysql_field_seek().

If you've called mysql_query() to perform a SELECT on a table but have not called mysql_store_result(), MySQL returns the default blob length (8KB) if you call mysql_fetch_field() to ask for the length of a BLOB field. (The 8KB size is chosen because MySQL does not know the maximum length for the BLOB. This should be made configurable sometime.) Once you've retrieved the result set, field->max_length contains the length of the largest value for this column in the specific query.

**Return Values**

The MYSQL_FIELD structure for the current column. NULL if no columns are left.

**Errors**

None.

**Example**

```c
MYSQL_FIELD *field;
while((field = mysql_fetch_field(result)))
{
    printf("field name %s\n", field->name);
}
```

### 23.7.6.18 mysql_fetch_field_direct()

MYSQL_FIELD *mysql_fetch_field_direct(MYSQL_RES *result, unsigned int fieldnr)

**Description**

Given a field number fieldnr for a column within a result set, returns that column's field definition as a MYSQL_FIELD structure. Use this function to retrieve the definition for an arbitrary column. Specify a value for fieldnr in the range from 0 to mysql_num_fields(result)-1.

**Return Values**

The MYSQL_FIELD structure for the specified column.

**Errors**

None.

**Example**

```c
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *field;
num_fields = mysql_num_fields(result);
for(i = 0; i < num_fields; i++)
{
    field = mysql_fetch_field_direct(result, i);
    printf("Field %u is %s\n", i, field->name);
}
```
23.7.6.19 mysql_fetch_fields()

MySQL_FIELD *mysql_fetch_fields(MYSQL_RES *result)

Description

Returns an array of all MYSQL_FIELD structures for a result set. Each structure provides the field definition for one column of the result set.

Return Values

An array of MYSQL_FIELD structures for all columns of a result set.

Errors

None.

Example

```c
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *fields;

num_fields = mysql_num_fields(result);
fields = mysql_fetch_fields(result);
for(i = 0; i < num_fields; i++)
{
    printf("Field %u is %s\n", i, fields[i].name);
}
```

23.7.6.20 mysql_fetch_lengths()

unsigned long *mysql_fetch_lengths(MYSQL_RES *result)

Description

Returns the lengths of the columns of the current row within a result set. If you plan to copy field values, this length information is also useful for optimization, because you can avoid calling strlen(). In addition, if the result set contains binary data, you must use this function to determine the size of the data, because strlen() returns incorrect results for any field containing null characters.

The length for empty columns and for columns containing NULL values is zero. To see how to distinguish these two cases, see the description for mysql_fetch_row().

Return Values

An array of unsigned long integers representing the size of each column (not including any terminating null bytes). NULL if an error occurred.

Errors

mysql_fetch_lengths() is valid only for the current row of the result set. It returns NULL if you call it before calling mysql_fetch_row() or after retrieving all rows in the result.

Example

```c
MYSQL_ROW row;
unsigned long *lengths;
unsigned int num_fields;
```
unsigned int i;
row = mysql_fetch_row(result);
if (row)
{
    num_fields = mysql_num_fields(result);
    lengths = mysql_fetch_lengths(result);
    for(i = 0; i < num_fields; i++)
    {
        printf("Column \%u is \%lu bytes in length.\n", 
               i, lengths[i]);
    }
}

23.7.6.21 mysql_fetch_row()
MYSQL_ROW mysql_fetch_row(MYSQL_RES *result)

Description
mysql_fetch_row() retrieves the next row of a result set:

• When used after mysql_store_result(), mysql_fetch_row() returns NULL if there are no more rows to retrieve.

• When used after mysql_use_result(), mysql_fetch_row() returns NULL if there are no more rows to retrieve or an error occurred.

The number of values in the row is given by mysql_num_fields(result). If row holds the return value from a call to mysql_fetch_row(), pointers to the values are accessed as row[0] to row[mysql_num_fields(result)-1]. NULL values in the row are indicated by NULL pointers.

The lengths of the field values in the row may be obtained by calling mysql_fetch_lengths(). Empty fields and fields containing NULL both have length 0; you can distinguish these by checking the pointer for the field value. If the pointer is NULL, the field is NULL; otherwise, the field is empty.

Return Values
A MYSQL_ROW structure for the next row, or NULL. The meaning of a NULL return depends on which function was called preceding mysql_fetch_row():

• When used after mysql_store_result(), mysql_fetch_row() returns NULL if there are no more rows to retrieve.

• When used after mysql_use_result(), mysql_fetch_row() returns NULL if there are no more rows to retrieve or an error occurred. To determine whether an error occurred, check whether mysql_error() returns a nonempty string or mysql_errno() returns nonzero.

Errors
Errors are not reset between calls to mysql_fetch_row()

• CR_SERVER_LOST
  The connection to the server was lost during the query.

• CR_UNKNOWN_ERROR
  An unknown error occurred.
23.7.6.22 mysql_field_count()

```
unsigned int mysql_field_count(MYSQL *mysql)
```

**Description**

Returns the number of columns for the most recent query on the connection.

The normal use of this function is when `mysql_store_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”.

**Return Values**

An unsigned integer representing the number of columns in a result set.

**Errors**

None.

**Example**

```c
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result) // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
}```
else // mysql_store_result() returned nothing; should it have? {
   if(mysql_field_count(&mysql) == 0) {
      // query does not return data
      // (it was not a SELECT)
      num_rows = mysql_affected_rows(&mysql);
   }
   else // mysql_store_result() should have returned data
   {  
      fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
   }
}

An alternative is to replace the mysql_field_count(&mysql) call with mysql_errno(&mysql). In this case, you are checking directly for an error from mysql_store_result() rather than inferring from the value of mysql_field_count() whether the statement was a SELECT.

23.7.6.23 mysql_field_seek()

MYSQL_FIELD_OFFSET mysql_field_seek(MYSQL_RES *result, MYSQL_FIELD_OFFSET offset)

Description

Sets the field cursor to the given offset. The next call to mysql_fetch_field() retrieves the field definition of the column associated with that offset.

To seek to the beginning of a row, pass an offset value of zero.

Return Values

The previous value of the field cursor.

Errors

None.

23.7.6.24 mysql_field_tell()

MYSQL_FIELD_OFFSET mysql_field_tell(MYSQL_RES *result)

Description

Returns the position of the field cursor used for the last mysql_fetch_field(). This value can be used as an argument to mysql_field_seek().

Return Values

The current offset of the field cursor.

Errors

None.

23.7.6.25 mysql_free_result()
void mysql_free_result(MYSQL_RES *result)

Description

`mysql_free_result()` frees the memory allocated for a result set by `mysql_store_result()`, `mysql_use_result()`, `mysql_list_dbs()`, and so forth. When you are done with a result set, you must free the memory it uses by calling `mysql_free_result()`.

Do not attempt to access a result set after freeing it.

Return Values

None.

Errors

None.

23.7.6.26 mysql_get_character_set_info()

void mysql_get_character_set_info(MYSQL *mysql, MY_CHARSET_INFO *cs)

Description

This function provides information about the default client character set. The default character set may be changed with the `mysql_set_character_set()` function.

Example

This example shows the fields that are available in the `MY_CHARSET_INFO` structure:

```c
if (!mysql_set_character_set(&mysql, "utf8"))
{
    MY_CHARSET_INFO cs;
    mysql_get_character_set_info(&mysql, &cs);
    printf("character set information:\n");
    printf("character set+collation number: %d\n", cs.number);
    printf("character set name: %s\n", cs.name);
    printf("collation name: %s\n", cs.csname);
    printf("comment: %s\n", cs.comment);
    printf("directory: %s\n", cs.dir);
    printf("multi byte character min. length: %d\n", cs.mbminlen);
    printf("multi byte character max. length: %d\n", cs.mbmaxlen);
}
```

23.7.6.27 mysql_get_client_info()

const char *mysql_get_client_info(void)

Description

Returns a string that represents the MySQL client library version (for example, "5.5.62").

The function value is the MySQL version. For more information, see Section 23.7.3.4, "C API Server Version and Client Library Version".

Return Values

A character string that represents the MySQL client library version.
Errors

None.

23.7.6.28 mysql_get_client_version()

```
unsigned long mysql_get_client_version(void)
```

Description

Returns an integer that represents the MySQL client library version. The value has the format \texttt{XYYZZ} where \texttt{X} is the major version, \texttt{YY} is the release level (or minor version), and \texttt{ZZ} is the sub-version within the release level:

\[
\text{major\_version}\times10000 + \text{release\_level}\times100 + \text{sub\_version}
\]

For example, "5.5.62" is returned as \texttt{50562}.

The function value is the MySQL version. For more information, see Section 23.7.3.4, "C API Server Version and Client Library Version".

Return Values

An integer that represents the MySQL client library version.

Errors

None.

23.7.6.29 mysql_get_host_info()

```
const char *mysql_get_host_info(MYSQL *mysql)
```

Description

Returns a string describing the type of connection in use, including the server host name.

Return Values

A character string representing the server host name and the connection type.

Errors

None.

23.7.6.30 mysql_get_proto_info()

```
unsigned int mysql_get_proto_info(MYSQL *mysql)
```

Description

Returns the protocol version used by current connection.

Return Values

An unsigned integer representing the protocol version used by the current connection.
Errors

None.

23.7.6.31 mysql_get_server_info()

const char *mysql_get_server_info(MYSQL *mysql)

Description

Returns a string that represents the MySQL server version (for example, "5.5.62").

Return Values

A character string that represents the MySQL server version.

Errors

None.

23.7.6.32 mysql_get_server_version()

unsigned long mysql_get_server_version(MYSQL *mysql)

Description

Returns an integer that represents the MySQL server version. The value has the format $XYYZZ$ where $X$ is the major version, $YY$ is the release level (or minor version), and $ZZ$ is the sub-version within the release level:

$major\_version*10000 + release\_level*100 + sub\_version$

For example, "5.5.62" is returned as 50562.

This function is useful in client programs for determining whether some version-specific server capability exists.

Return Values

An integer that represents the MySQL server version.

Errors

None.

23.7.6.33 mysql_get_ssl_cipher()

const char *mysql_get_ssl_cipher(MYSQL *mysql)

Description

mysql_get_ssl_cipher() returns the encryption cipher used for the given connection to the server. mysql is the connection handler returned from mysql_init().

Return Values

A string naming the encryption cipher used for the connection, or NULL if the connection is not encrypted.
23.7.34 mysql_hex_string()

unsigned long mysql_hex_string(char *to, const char *from, unsigned long length)

Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, “String Literals”.

The string in the from argument is encoded in hexadecimal format, with each character encoded as two hexadecimal digits. The result is placed in the to argument, followed by a terminating null byte.

The string pointed to by from must be length bytes long. You must allocate the to buffer to be at least length*2+1 bytes long. When mysql_hex_string() returns, the contents of to is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

The return value can be placed into an SQL statement using either X'value' or 0xvalue format. However, the return value does not include the X'...' or 0x. The caller must supply whichever of those is desired.

Example

```c
char query[1000],*end;
end = strmov(query, "INSERT INTO test_table values(");
end = strmov(end, "X'");
end += mysql_hex_string(end, "What is this", 12);
end = strmov(end, ",X'");
end += mysql_hex_string(end, "binary data: \0\r\n", 16);
end = strmov(end, ")");
if (mysql_real_query(&mysql, query, (unsigned int) (end - query)))
{
    fprintf(stderr, "Failed to insert row, Error: %s\n",
            mysql_error(&mysql));
}
```

The strmov() function used in the example is included in the libmysqlclient library and works like strcpy() but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into to, not including the terminating null character.

Errors

None.

23.7.35 mysql_info()

const char *mysql_info(MYSQL *mysql)

Description

Retrieves a string providing information about the most recently executed statement, but only for the statements listed here. For other statements, mysql_info() returns NULL. The format of the string varies depending on the type of statement, as described here. The numbers are illustrative only; the string contains values appropriate for the statement.
• **INSERT INTO ... SELECT ...**

  String format: Records: 100 Duplicates: 0 Warnings: 0

• **INSERT INTO ... VALUES (...),(...),(...)...**

  String format: Records: 3 Duplicates: 0 Warnings: 0

• **LOAD DATA**

  String format: Records: 1 Deleted: 0 Skipped: 0 Warnings: 0

• **ALTER TABLE**

  String format: Records: 3 Duplicates: 0 Warnings: 0

• **UPDATE**

  String format: Rows matched: 40 Changed: 40 Warnings: 0

  `mysql_info()` returns a non-NULL value for **INSERT ... VALUES** only for the multiple-row form of the statement (that is, only if multiple value lists are specified).

### Return Values

A character string representing additional information about the most recently executed statement. **NULL** if no information is available for the statement.

### Errors

None.

### 23.7.6.36 mysql_init()

**MYSQL *mysql_init(MYSQL *mysql)**

**Description**

Allocates or initializes a **MYSQL** object suitable for **mysql_real_connect()**. If **mysql** is a **NULL** pointer, the function allocates, initializes, and returns a new object. Otherwise, the object is initialized and the address of the object is returned. If **mysql_init()** allocates a new object, it is freed when **mysql_close()** is called to close the connection.

In a nonmultithreaded environment, **mysql_init()** invokes **mysql_library_init()** automatically as necessary. However, **mysql_library_init()** is not thread-safe in a multithreaded environment, and thus neither is **mysql_init()**. Before calling **mysql_init()**, either call **mysql_library_init()** prior to spawning any threads, or use a mutex to protect the **mysql_library_init()** call. This should be done prior to any other client library call.

### Return Values

An initialized **MYSQL** handler. **NULL** if there was insufficient memory to allocate a new object.

### Errors

In case of insufficient memory, **NULL** is returned.
23.7.6.37 mysql_insert_id()

my_ulonglong mysql_insert_id(MYSQL *mysql)

Description

Returns the value generated for an **AUTO_INCREMENT** column by the previous **INSERT** or **UPDATE** statement. Use this function after you have performed an **INSERT** statement into a table that contains an **AUTO_INCREMENT** field, or have used **INSERT** or **UPDATE** to set a column value with **LAST_INSERT_ID(expr)**.

The return value of **mysql_insert_id()** is always zero unless explicitly updated under one of the following conditions:

- **INSERT** statements that store a value into an **AUTO_INCREMENT** column. This is true whether the value is automatically generated by storing the special values **NULL** or **0** into the column, or is an explicit nonspecial value.
- In the case of a multiple-row **INSERT** statement, **mysql_insert_id()** returns the first automatically generated **AUTO_INCREMENT** value that was successfully inserted.
- If no rows are successfully inserted, **mysql_insert_id()** returns 0.
- If an **INSERT ... SELECT** statement is executed, and no automatically generated value is successfully inserted, **mysql_insert_id()** returns the ID of the last inserted row.
- If an **INSERT ... SELECT** statement uses **LAST_INSERT_ID(expr)**, **mysql_insert_id()** returns **expr**.
- **INSERT** statements that generate an **AUTO_INCREMENT** value by inserting **LAST_INSERT_ID(expr)** into any column or by updating any column to **LAST_INSERT_ID(expr)**.
- If the previous statement returned an error, the value of **mysql_insert_id()** is undefined.

The return value of **mysql_insert_id()** can be simplified to the following sequence:

1. If there is an **AUTO_INCREMENT** column, and an automatically generated value was successfully inserted, return the first such value.
2. If **LAST_INSERT_ID(expr)** occurred in the statement, return **expr**, even if there was an **AUTO_INCREMENT** column in the affected table.
3. The return value varies depending on the statement used. When called after an **INSERT** statement:
   - If there is an **AUTO_INCREMENT** column in the table, and there were some explicit values for this column that were successfully inserted into the table, return the last of the explicit values.

   When called after an **INSERT ... ON DUPLICATE KEY UPDATE** statement:
   - If there is an **AUTO_INCREMENT** column in the table and there were some explicit successfully inserted values or some updated values, return the last of the inserted or updated values.

**mysql_insert_id()** returns 0 if the previous statement does not use an **AUTO_INCREMENT** value. If you must save the value for later, be sure to call **mysql_insert_id()** immediately after the statement that generates the value.

The value of **mysql_insert_id()** is affected only by statements issued within the current client connection. It is not affected by statements issued by other clients.
The LAST_INSERT_ID() SQL function will contain the value of the first automatically generated value that was successfully inserted. LAST_INSERT_ID() is not reset between statements because the value of that function is maintained in the server. Another difference from mysql_insert_id() is that LAST_INSERT_ID() is not updated if you set an AUTO_INCREMENT column to a specific nonspecial value. See Section 12.15, “Information Functions”.

mysql_insert_id() returns 0 following a CALL statement for a stored procedure that generates an AUTO_INCREMENT value because in this case mysql_insert_id() applies to CALL and not the statement within the procedure. Within the procedure, you can use LAST_INSERT_ID() at the SQL level to obtain the AUTO_INCREMENT value.

The reason for the differences between LAST_INSERT_ID() and mysql_insert_id() is that LAST_INSERT_ID() is made easy to use in scripts while mysql_insert_id() tries to provide more exact information about what happens to the AUTO_INCREMENT column.

Return Values

Described in the preceding discussion.

Errors

None.

23.7.6.38 mysql_kill()

int mysql_kill(MYSQL *mysql, unsigned long pid)

Description

Asks the server to kill the thread specified by pid.

This function is deprecated. Use mysql_query() to issue an SQL KILL statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC
  Commands were executed in an improper order.
- CR_SERVER_GONE_ERROR
  The MySQL server has gone away.
- CR_SERVER_LOST
  The connection to the server was lost during the query.
- CR_UNKNOWN_ERROR
  An unknown error occurred.

23.7.6.39 mysql_library_end()
**void mysql_library_end(void)**

**Description**

This function finalizes the MySQL library. Call it when you are done using the library (for example, after disconnecting from the server). The action taken by the call depends on whether your application is linked to the MySQL client library or the MySQL embedded server library. For a client program linked against the `libmysqlclient` library by using the `-lmysqlclient` flag, `mysql_library_end()` performs some memory management to clean up. For an embedded server application linked against the `libmysqld` library by using the `-lmysqld` flag, `mysql_library_end()` shuts down the embedded server and then cleans up.

**Note**

To avoid memory leaks after the application is done using the library (for example, after closing the connection to the server), be sure to call `mysql_library_end()` explicitly. This enables memory management to be performed to clean up and free resources used by the library.

For usage information, see Section 23.7.5, “C API Function Overview”, and Section 23.7.6.40, “mysql_library_init()”.

**23.7.6.40 mysql_library_init()**

**int mysql_library_init(int argc, char **argv, char **groups)**

**Description**

Call this function to initialize the MySQL client library before you call any other MySQL function, whether your application is a regular client program or uses the embedded server. If the application uses the embedded server, this call starts the server and initializes any subsystems (`mysys`, `InnoDB`, and so forth) that the server uses.

**Note**

To avoid memory leaks after the application is done using the library (for example, after closing the connection to the server), be sure to call `mysql_library_end()` explicitly. This enables memory management to be performed to clean up and free resources used by the library. See Section 23.7.6.39, “mysql_library_end()”.

The choice of whether the application operates as a regular client or uses the embedded server depends on whether you use the `libmysqlclient` or `libmysqld` library at link time to produce the final executable. For additional information, see Section 23.7.5, “C API Function Overview”.

In a nonmultithreaded environment, the call to `mysql_library_init()` may be omitted, because `mysql_init()` will invoke it automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multithreaded environment, and thus neither is `mysql_init()`, which calls `mysql_library_init()`. You must either call `mysql_library_init()` prior to spawning any threads, or else use a mutex to protect the call, whether you invoke `mysql_library_init()` or indirectly through `mysql_init()`. Do this prior to any other client library call.

The `argc` and `argv` arguments are analogous to the arguments to `main()`, and enable passing of options to the embedded server. For convenience, `argc` may be 0 (zero) if there are no command-line arguments for the server. This is the usual case for applications intended for use only as regular (nonembedded) clients, and the call typically is written as `mysql_library_init(0, NULL, NULL)`.
When arguments are to be passed (argc is greater than 0), the first element of argv is ignored (it typically contains the program name). mysql_library_init() makes a copy of the arguments so it is safe to destroy argv or groups after the call.

For embedded applications, if you want to connect to an external server without starting the embedded server, you have to specify a negative value for argc.

The groups argument is an array of strings that indicate the groups in option files from which to read options. See Section 4.2.2.2, "Using Option Files". Make the final entry in the array NULL. For convenience, if the groups argument itself is NULL, the [server] and [embedded] groups are used by default.

Return Values
Zero for success. Nonzero if an error occurred.

23.7.6.41 mysql_list_dbs()

MYSQL_RES *mysql_list_dbs(MYSQL *mysql, const char *wild)
Description

Returns a result set consisting of database names on the server that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters `%` or `_`, or may be a NULL pointer to match all databases. Calling `mysql_list_dbs()` is similar to executing the query `SHOW DATABASES [LIKE wild].`

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

• `CR_COMMANDS_OUT_OF_SYNC`
  
  Commands were executed in an improper order.

• `CR_OUT_OF_MEMORY`
  
  Out of memory.

• `CR_SERVER_GONE_ERROR`
  
  The MySQL server has gone away.

• `CR_SERVER_LOST`
  
  The connection to the server was lost during the query.

• `CR_UNKNOWN_ERROR`
  
  An unknown error occurred.

23.7.6.42 mysql_list_fields()

```c
MYSQL_RES *mysql_list_fields(MYSQL *mysql, const char *table, const char *wild)
```

Description

Returns an empty result set for which the metadata provides information about the columns in the given table that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters `%` or `_`, or may be a NULL pointer to match all fields. Calling `mysql_list_fields()` is similar to executing the query `SHOW COLUMNS FROM tbl_name [LIKE wild].`

It is preferable to use `SHOW COLUMNS FROM tbl_name` instead of `mysql_list_fields()`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

• `CR_COMMANDS_OUT_OF_SYNC`
Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR
  The MySQL server has gone away.

- CR_SERVER_LOST
  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR
  An unknown error occurred.

Example

```c
int i;
MYSQL_RES *tbl_cols = mysql_list_fields(mysql, "mytbl", "f%");  
unsigned int field_cnt = mysql_num_fields(tbl_cols);
printf("Number of columns: %d\n", field_cnt);
for (i=0; i < field_cnt; ++i)  
{ 
    /* col describes i-th column of the table */
    MYSQL_FIELD *col = mysql_fetch_field_direct(tbl_cols, i);
    printf("Column %d: %s\n", i, col->name);
}
mysql_free_result(tbl_cols);
```

23.7.6.43 mysql_list_processes()

**MYSQL_RES *mysql_list_processes(MYSQL *mysql)**

Description

Returns a result set describing the current server threads. This is the same kind of information as that reported by `mysqladmin processlist` or a `SHOW PROCESSLIST` query.

You must free the result set with `mysql_free_result()`.

Return Values

A **MYSQL_RES** result set for success. **NULL** if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC
  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR
  The MySQL server has gone away.

- CR_SERVER_LOST
  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR
An unknown error occurred.

23.7.6.44 mysql_list_tables()

MYSQL_RES *mysql_list_tables(MYSQL *mysql, const char *wild)

Description

Returns a result set consisting of table names in the current database that match the simple regular expression specified by the \texttt{wild} parameter. \texttt{wild} may contain the wildcard characters \texttt{%} or \texttt{_}, or may be a \texttt{NULL} pointer to match all tables. Calling \texttt{mysql_list_tables()} is similar to executing the query \texttt{SHOW TABLES [LIKE wild]}.

You must free the result set with \texttt{mysql_free_result()}.

Return Values

A \texttt{MYSQL_RES} result set for success. \texttt{NULL} if an error occurred.

Errors

- \texttt{CR_COMMANDS_OUT_OF_SYNC}
  
  Commands were executed in an improper order.

- \texttt{CR_SERVER_GONE_ERROR}
  
  The MySQL server has gone away.

- \texttt{CR_SERVER_LOST}
  
  The connection to the server was lost during the query.

- \texttt{CR_UNKNOWN_ERROR}
  
  An unknown error occurred.

23.7.6.45 mysql_more_results()

my_bool mysql_more_results(MYSQL *mysql)

Description

This function is used when you execute multiple statements specified as a single statement string, or when you execute \texttt{CALL} statements, which can return multiple result sets.

\texttt{mysql_more_results()} \texttt{true} if more results exist from the currently executed statement, in which case the application must call \texttt{mysql_next_result()} to fetch the results.

Return Values

\texttt{TRUE} (1) if more results exist. \texttt{FALSE} (0) if no more results exist.

In most cases, you can call \texttt{mysql_next_result()} instead to test whether more results exist and initiate retrieval if so.
23.7.6.46 mysql_next_result()

int mysql_next_result(MYSQL *mysql)

Description

mysql_next_result() is used when you execute multiple statements specified as a single statement string, or when you use CALL statements to execute stored procedures, which can return multiple result sets.

mysql_next_result() reads the next statement result and returns a status to indicate whether more results exist. If mysql_next_result() returns an error, there are no more results.

Before each call to mysql_next_result(), you must call mysql_free_result() for the current statement if it is a statement that returned a result set (rather than just a result status).

After calling mysql_next_result() the state of the connection is as if you had called mysql_real_query() or mysql_query() for the next statement. This means that you can call mysql_store_result(), mysql_warning_count(), mysql_affected_rows(), and so forth.

If your program uses CALL statements to execute stored procedures, the CLIENT_MULTI_RESULTS flag must be enabled. This is because each CALL returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because CALL can return multiple results, process them using a loop that calls mysql_next_result() to determine whether there are more results.

CLIENT_MULTI_RESULTS can be enabled when you call mysql_real_connect(), either explicitly by passing the CLIENT_MULTI_RESULTS flag itself, or implicitly by passing CLIENT_MULTI_STATEMENTS (which also enables CLIENT_MULTI_RESULTS). CLIENT_MULTI_RESULTS is enabled by default.

It is also possible to test whether there are more results by calling mysql_more_results(). However, this function does not change the connection state, so if it returns true, you must still call mysql_next_result() to advance to the next result.

For an example that shows how to use mysql_next_result(), see Section 23.7.15, “C API Multiple Statement Execution Support”.

Return Values

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Successful and there are more results</td>
</tr>
<tr>
<td>-1</td>
<td>Successful and there are no more results</td>
</tr>
<tr>
<td>&gt;0</td>
<td>An error occurred</td>
</tr>
</tbody>
</table>

Errors

- CR_COMMANDS_OUT_OF_SYNC
Commands were executed in an improper order. For example, if you did not call `mysql_use_result()` for a previous result set.

- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

### 23.7.6.47 mysql_num_fields()

```c
unsigned int mysql_num_fields(MYSQL_RES *result)
```

To pass a `MYSQL*` argument instead, use `unsigned int mysql_field_count(MYSQL *mysql)`.

**Description**

Returns the number of columns in a result set.

You can get the number of columns either from a pointer to a result set or to a connection handler. You would use the connection handler if `mysql_store_result()` or `mysql_use_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT-like`) statement. The example shown here illustrates how this may be done.

See Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”.

**Return Values**

An unsigned integer representing the number of columns in a result set.

**Errors**

None.

**Example**

```c
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result) // there are rows
    {
```
C API Function Descriptions

```c
num_fields = mysql_num_fields(result);
// retrieve rows, then call mysql_free_result(result)
}
else // mysql_store_result() returned nothing; should it have?
{
  if (mysql_errno(&mysql))
  {
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
  }
  else if (mysql_field_count(&mysql) == 0)
  {
    // query does not return data
    // (it was not a SELECT)
    num_rows = mysql_affected_rows(&mysql);
  }
}

An alternative (if you know that your query should have returned a result set) is to replace the
call with a check whether mysql_field_count (&mysql) returns 0. This happens only if something went wrong.

23.7.6.48 mysql_num_rows()

```my_ulonglong``` mysql_num_rows(MYSQL_RES *result)

**Description**

Returns the number of rows in the result set.

The use of ```mysql_num_rows()``` depends on whether you use ```mysql_store_result()``` or ```mysql_use_result()``` to return the result set. If you use ```mysql_store_result()```, ```mysql_num_rows()``` may be called immediately. If you use ```mysql_use_result()```, ```mysql_num_rows()``` does not return the correct value until all the rows in the result set have been retrieved.

```mysql_num_rows()``` is intended for use with statements that return a result set, such as ```SELECT``` For statements such as ```INSERT, UPDATE, or DELETE``` the number of affected rows can be obtained with ```mysql_affected_rows()```.

**Return Values**

The number of rows in the result set.

**Errors**

None.

23.7.6.49 mysql_options()

```int``` mysql_options(MYSQL *mysql, enum mysql_option option, const void *arg)

**Description**

Can be used to set extra connect options and affect behavior for a connection. This function may be called multiple times to set several options.

Call ```mysql_options()``` after ```mysql_init()``` and before ```mysql_connect()``` or ```mysql_real_connect()```. 2868
C API Function Descriptions

The `option` argument is the option that you want to set; the `arg` argument is the value for the option. If the option is an integer, specify a pointer to the value of the integer as the `arg` argument.

Options for information such as SSL certificate and key files are used to establish an encrypted connection if such connections are available, but do not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the technique described in Section 23.7.14, “C API Encrypted Connection Support”.

The following list describes the possible options, their effect, and how `arg` is used for each option. For option descriptions that indicate `arg` is unused, its value is irrelevant; it is conventional to pass 0. Several of the options apply only when the application is linked against the `libmysqld` embedded server library and are unused for applications linked against the `libmysqlclient` client library.

- **MYSQL_DEFAULT_AUTH** (argument type: `char *`)
  
  The name of the authentication plugin to use.

- **MYSQL_ENABLE_CLEARTEXT_PLUGIN** (argument type: `my_bool *`)
  
  Enable the `mysql_clear_password` cleartext authentication plugin. See Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”.

- **MYSQL_INIT_COMMAND** (argument type: `char *`)
  
  SQL statement to execute when connecting to the MySQL server. Automatically re-executed if reconnection occurs.

- **MYSQL_OPT_COMPRESS** (argument: not used)
  
  Compress all information sent between the client and the server if possible. See Section 4.2.5, “Connection Compression Control”.

- **MYSQL_OPT_CONNECT_TIMEOUT** (argument type: `unsigned int *`)
  
  The connect timeout in seconds.

- **MYSQL_OPT_GUESS_CONNECTION** (argument: not used)
  
  For an application linked against the `libmysqld` embedded server library, this option enables the library to guess whether to use the embedded server or a remote server. “Guess” means that if the host name is set and is not `localhost`, it uses a remote server. This behavior is the default. `MYSQL_OPT_USE_EMBEDDED_CONNECTION` and `MYSQL_OPT_USE_REMOTE_CONNECTION` can be used to override it. This option is ignored for applications linked against the `libmysqlclient` client library.

- **MYSQL_OPT_LOCAL_INFILE** (argument type: optional pointer to `unsigned int`)
  
  This option affects client-side `LOCAL` capability for `LOAD DATA` operations. By default, `LOCAL` capability is determined by the default compiled into the MySQL client library (see Section 13.2.6, “LOAD DATA Statement”). To control this capability explicitly, invoke `mysql_options()` to set the `MYSQL_OPT_LOCAL_INFILE` option:

  - `LOCAL` is disabled if the pointer points to an `unsigned int` that has a zero value.
  
  - `LOCAL` is enabled if no pointer is given or if the pointer points to an `unsigned int` that has a nonzero value.

  Successful use of a `LOCAL` load operation by a client also requires that the server permits it.
• **MYSQL_OPT_NAMED_PIPE** (argument: not used)

Use a named pipe to connect to the MySQL server on Windows, if the server permits named-pipe connections.

• **MYSQL_OPT_PROTOCOL** (argument type: `unsigned int *`)

Type of protocol to use. Specify one of the enum values of `mysql_protocol_type` defined in `mysql.h`.

• **MYSQL_OPT_READ_TIMEOUT** (argument type: `unsigned int *`)

The timeout in seconds for each attempt to read from the server. There are retries if necessary, so the total effective timeout value is three times the option value. You can set the value so that a lost connection can be detected earlier than the TCP/IP `Close_Wait_Timeout` value of 10 minutes.

Implementation of this timeout uses mechanisms that may not be available on all platforms. On such a platform, a client that issues a read call might under certain circumstances wait without timing out. For example, a client might not time out if the server is not responding because it is waiting for a “disk full” condition to clear.

• **MYSQL_OPT_RECONNECT** (argument type: `my_bool *`)

Enable or disable automatic reconnection to the server if the connection is found to have been lost. Reconnect is off by default; this option provides a way to set reconnection behavior explicitly. See Section 23.7.19, “C API Automatic Reconnection Control”.

• **MYSQL_OPT_SSL_MODE** (argument type: `unsigned int *`)

The security state to use for the connection to the server. The only permitted arument value is `SSL_MODE_REQUIRED` (require an encrypted connection). If set, this option causes `mysql_real_connect()` to fail if an encrypted connection cannot be obtained, without falling back to an unencrypted connection. Thus, `mysql_real_connect()` returns an error if the server does not support SSL or the client is not configured to use SSL. For more information about the security states, see the description of `--ssl-mode` in Command Options for Encrypted Connections.

To require an encrypted connection in MySQL 5.5, the standard MySQL client programs call `mysql_options()` to set `MYSQL_OPT_SSL_MODE` if the `--ssl-mode=REQUIRED` command-line option was specified. Third-party applications that must be able to require encrypted connections can use the technique described in Section 23.7.14, “C API Encrypted Connection Support”.

This option was added in MySQL 5.5.55.

• **MYSQL_OPT_SSL_VERIFY_SERVER_CERT** (argument type: `my_bool *`)

Enable or disable verification of the server’s Common Name identity in its certificate against the host name used when connecting to the server. The connection is rejected if there is a mismatch. For encrypted connections, this feature can be used to prevent man-in-the-middle attacks. Identity verification is disabled by default.

• **MYSQL_OPT_USE_EMBEDDED_CONNECTION** (argument: not used)

For an application linked against the `libmysqld` embedded server library, this option forces the use of the embedded server for the connection. It is ignored for applications linked against the `libmysqlclient` client library.

• **MYSQL_OPT_USE_REMOTE_CONNECTION** (argument: not used)
For an application linked against the `libmysqld` embedded server library, this option forces the use of a remote server for the connection. It is ignored for applications linked against the `libmysqlclient` client library.

- **MYSQL_OPT_USE_RESULT** (argument: not used)
  This option is unused.

- **MYSQL_OPT_WRITE_TIMEOUT** (argument type: `unsigned int *`)
  The timeout in seconds for each attempt to write to the server. There is a retry if necessary, so the total effective timeout value is two times the option value.

- **MYSQL_PLUGIN_DIR** (argument type: `char *`)
  The directory in which to look for client plugins.

- **MYSQL_READ_DEFAULT_FILE** (argument type: `char *`)
  Read options from the named option file instead of from `my.cnf`.

- **MYSQL_READ_DEFAULT_GROUP** (argument type: `char *`)
  Read options from the named group from `my.cnf` or the file specified with `MYSQL_READ_DEFAULT_FILE`.

- **MYSQL_REPORT_DATA_TRUNCATION** (argument type: `my_bool *`)
  Enable or disable reporting of data truncation errors for prepared statements using the `error` member of `MYSQL_BIND` structures. (Default: enabled.)

- **MYSQL_SECURE_AUTH** (argument type: `my_bool *`)
  Whether to connect to a server that does not support the password hashing used in MySQL 4.1.1 and later.

- **MYSQL_SET_CHARSET_DIR** (argument type: `char *`)
  The path name of the directory that contains character set definition files.

- **MYSQL_SET_CHARSET_NAME** (argument type: `char *`)
  The name of the character set to use as the default character set. The argument can be `MYSQL_AUTODETECT_CHARSET_NAME` to cause the character set to be autodetected based on the operating system setting (see Section 10.4, “Connection Character Sets and Collations”).

- **MYSQL_SET_CLIENT_IP** (argument type: `char *`)
  For an application linked against the `libmysqld` embedded server library (when `libmysqld` is compiled with authentication support), this option means that the user is considered to have connected from the specified IP address (specified as a string) for authentication purposes. It is ignored for applications linked against the `libmysqlclient` client library.

- **MYSQL_SHARED_MEMORY_BASE_NAME** (argument type: `char *`)
  The name of the shared-memory object for communication to the server on Windows, if the server supports shared-memory connections. Specify the same value as used for the `shared_memory_base_name` system variable of the `mysqld` server you want to connect to.
The **client group** is always read if you use `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP`.

The specified group in the option file may contain the following options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>character-sets-dir=dir_name</code></td>
<td>The directory where character sets are installed.</td>
</tr>
<tr>
<td><code>compress</code></td>
<td>Use the compressed client/server protocol.</td>
</tr>
<tr>
<td><code>connect-timeout=seconds</code></td>
<td>The connect timeout in seconds. On Linux this timeout is also used for waiting for the first answer from the server.</td>
</tr>
<tr>
<td><code>database=db_name</code></td>
<td>Connect to this database if no database was specified in the connect command.</td>
</tr>
<tr>
<td><code>debug</code></td>
<td>Debug options.</td>
</tr>
<tr>
<td><code>default-character-set=charset_name</code></td>
<td>The default character set to use.</td>
</tr>
<tr>
<td><code>disable-local-infile</code></td>
<td>Disable use of <code>LOAD DATA LOCAL</code>.</td>
</tr>
<tr>
<td><code>enable-cleartext-plugin</code></td>
<td>Enable the <code>mysql_clear_password</code> cleartext authentication plugin. Added in MySQL 5.5.27.</td>
</tr>
<tr>
<td><code>host=host_name</code></td>
<td>Default host name.</td>
</tr>
<tr>
<td><code>init-command=stmt</code></td>
<td>Statement to execute when connecting to MySQL server. Automatically re-executed if reconnection occurs.</td>
</tr>
<tr>
<td><code>interactive-timeout=seconds</code></td>
<td>Same as specifying <code>CLIENT_INTERACTIVE</code> to <code>mysql_real_connect()</code>. See Section 23.7.6.52, &quot;mysql_real_connect()&quot;.</td>
</tr>
<tr>
<td>`local-infile={0</td>
<td>1}`</td>
</tr>
<tr>
<td><code>max_allowed_packet=bytes</code></td>
<td>Maximum size of packet that client can read from server.</td>
</tr>
<tr>
<td><code>multi-queries,multi-results</code></td>
<td>Enable multiple result sets from multiple-statement executions or stored procedures.</td>
</tr>
<tr>
<td><code>multi-statements</code></td>
<td>Enable the client to send multiple statements in a single string (separated by ; characters).</td>
</tr>
<tr>
<td><code>password=password</code></td>
<td>Default password.</td>
</tr>
<tr>
<td><code>pipe</code></td>
<td>Use named pipes to connect to a MySQL server on Windows.</td>
</tr>
<tr>
<td><code>port=port_num</code></td>
<td>Default port number.</td>
</tr>
<tr>
<td>`protocol={TCP</td>
<td>SOCKET</td>
</tr>
<tr>
<td><code>return-found-rows</code></td>
<td>Tell <code>mysql_info()</code> to return found rows instead of updated rows when using <code>UPDATE</code>.</td>
</tr>
<tr>
<td><code>shared-memory-base-name=name</code></td>
<td>Shared-memory name to use to connect to server.</td>
</tr>
<tr>
<td>`socket={file_name</td>
<td>pipe_name}`</td>
</tr>
<tr>
<td><code>ssl-ca=file_name</code></td>
<td>Certificate Authority file.</td>
</tr>
<tr>
<td><code>ssl-capath=dir_name</code></td>
<td>Certificate Authority directory.</td>
</tr>
<tr>
<td><code>ssl-cert=file_name</code></td>
<td>Certificate file.</td>
</tr>
</tbody>
</table>
Option | Description
---|---
ssl-cipher=cipher_list | Permissible SSL ciphers.
ssl-key=file_name | Key file.
timeout=seconds | Like connect-timeout.
user | Default user.

`timeout` has been replaced by `connect-timeout`, but `timeout` is still supported for backward compatibility.

For more information about option files used by MySQL programs, see Section 4.2.2.2, “Using Option Files”.

**Return Values**

Zero for success. Nonzero if you specify an unknown option.

**Example**

The following `mysql_options()` calls request the use of compression in the client/server protocol, cause options to be read from the `[odbc]` group in option files, and disable transaction autocommit mode:

```c
MYSQL mysql;
mysql_init(&mysql);
mysql_options(&mysql, MYSQL_OPT_COMPRESS, 0);
mysql_options(&mysql, MYSQL_READ_DEFAULT_GROUP, "odbc");
mysql_options(&mysql, MYSQL_INIT_COMMAND, "SET autocommit=0");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
            mysql_error(&mysql));
}
```

### 23.7.6.50 mysql_ping()

```c
int mysql_ping(MYSQL *mysql)
```

**Description**

Checks whether the connection to the server is working. If the connection has gone down and auto-reconnect is enabled an attempt to reconnect is made. If the connection is down and auto-reconnect is disabled, `mysql_ping()` returns an error.

Auto-reconnect is disabled by default. To enable it, call `mysql_options()` with the `MYSQL_OPT_RECONNECT` option. For details, see Section 23.7.6.49, “mysql_options()”.

`mysql_ping()` can be used by clients that remain idle for a long while, to check whether the server has closed the connection and reconnect if necessary.

If `mysql_ping()` does cause a reconnect, there is no explicit indication of it. To determine whether a reconnect occurs, call `mysql_thread_id()` to get the original connection identifier before calling `mysql_ping()`, then call `mysql_thread_id()` again to see whether the identifier has changed.

If reconnect occurs, some characteristics of the connection will have been reset. For details about these characteristics, see Section 23.7.19, “C API Automatic Reconnection Control”.

2873
Return Values

Zero if the connection to the server is active. Nonzero if an error occurred. A nonzero return does not indicate whether the MySQL server itself is down; the connection might be broken for other reasons such as network problems.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  Commands were executed in an improper order.
- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.
- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

23.7.6.51 `mysql_query()`

```c
int mysql_query(MYSQL *mysql, const char *stmt_str)
```

Description

Executes the SQL statement pointed to by the null-terminated string `stmt_str`. Normally, the string must consist of a single SQL statement without a terminating semicolon (\; or \g. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 23.7.15, "C API Multiple Statement Execution Support".

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the \0 character, which `mysql_query()` interprets as the end of the statement string.)

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.7.6.22, "mysql_field_count()".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  Commands were executed in an improper order.
- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.
- **CR_SERVER_LOST**
  The connection to the server was lost during the query.
- **CR_UNKNOWN_ERROR**
C API Function Descriptions

An unknown error occurred.

23.7.6.52 mysql_real_connect()

```c
MYSQL *mysql_real_connect(MYSQL *mysql, const char *host, const char *user, const char *passwd, const char *db, unsigned int port, const char *unix_socket, unsigned long client_flag)
```

**Description**

`mysql_real_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_real_connect()` must complete successfully before you can execute any other API functions that require a valid `MYSQL` connection handler structure.

The parameters are specified as follows:

- For the first parameter, specify the address of an existing `MYSQL` structure. Before calling `mysql_real_connect()`, call `mysql_init()` to initialize the `MYSQL` structure. You can change a lot of connect options with the `mysql_options()` call. See Section 23.7.6.49, “mysql_options()”.

- The value of `host` may be either a host name or an IP address. The client attempts to connect as follows:
  - If `host` is `NULL` or the string "localhost", a connection to the local host is assumed:
    - On Windows, the client connects using a shared-memory connection, if the server has shared-memory connections enabled.
    - On Unix, the client connects using a Unix socket file. The `unix_socket` parameter or the `MYSQL_UNIX_PORT` environment variable may be used to specify the socket name.
  - On Windows, if `host` is ".", or TCP/IP is not enabled and no `unix_socket` is specified or the host is empty, the client connects using a named pipe, if the server has named-pipe connections enabled. If named-pipe connections are not enabled, an error occurs.
  - Otherwise, TCP/IP is used.

You can also influence the type of connection to use with the `MYSQL_OPT_PROTOCOL` or `MYSQL_OPT_NAMED_PIPE` options to `mysql_options()`. The type of connection must be supported by the server.

- The `user` parameter contains the user's MySQL login ID. If `user` is `NULL` or the empty string "", the current user is assumed. Under Unix, this is the current login name. Under Windows ODBC, the current user name must be specified explicitly. See the Connector/ODBC section of Chapter 23, Connectors and APIs.

- The `passwd` parameter contains the password for `user`. If `passwd` is `NULL`, only entries in the `user` table for the user that have a blank (empty) password field are checked for a match. This enables the database administrator to set up the MySQL privilege system in such a way that users get different privileges depending on whether they have specified a password.

**Note**

Do not attempt to encrypt the password before calling `mysql_real_connect()`: password encryption is handled automatically by the client API.
C API Function Descriptions

- The `user` and `passwd` parameters use whatever character set has been configured for the `MYSQL` object. By default, this is `latin1`, but can be changed by calling `mysql_options(mysql, MYSQL_SET_CHARSET_NAME, "charset_name")` prior to connecting.

- `db` is the database name. If `db` is not `NULL`, the connection sets the default database to this value.

- If `port` is not 0, the value is used as the port number for the TCP/IP connection. Note that the `host` parameter determines the type of the connection.

- If `unix_socket` is not `NULL`, the string specifies the socket or named pipe to use. Note that the `host` parameter determines the type of the connection.

- The value of `client_flag` is usually 0, but can be set to a combination of the following flags to enable certain features:
  - `CLIENT_COMPRESS`: Use compression in the client/server protocol.
  - `CLIENT_FOUND_ROWS`: Return the number of found (matched) rows, not the number of changed rows.
  - `CLIENT_IGNORE_SIGPIPE`: Prevents the client library from installing a SIGPIPE signal handler. This can be used to avoid conflicts with a handler that the application has already installed.
  - `CLIENT_IGNORE_SPACE`: Permit spaces after function names. Makes all functions names reserved words.
  - `CLIENT_INTERACTIVE`: Permit `interactive_timeout` seconds of inactivity (rather than `wait_timeout` seconds) before closing the connection. The client's session `wait_timeout` variable is set to the value of the session `interactive_timeout` variable.
  - `CLIENT_LOCAL_FILES`: Enable LOAD DATA LOCAL handling.
  - `CLIENT_MULTI_RESULTS`: Tell the server that the client can handle multiple result sets from multiple-statement executions or stored procedures. This flag is automatically enabled if `CLIENT_MULTI_STATEMENTS` is enabled. See the note following this table for more information about this flag.
  - `CLIENT_MULTI_STATEMENTS`: Tell the server that the client may send multiple statements in a single string (separated by `;` characters). If this flag is not set, multiple-statement execution is disabled. See the note following this table for more information about this flag.
  - `CLIENT_NO_SCHEMA`: Do not permit `db_name.tbl_name.col_name` syntax. This is for ODBC. It causes the parser to generate an error if you use that syntax, which is useful for trapping bugs in some ODBC programs.
  - `CLIENT_ODBC`: Unused.
  - `CLIENT_SSL`: Use SSL (encrypted protocol). Do not set this option within an application program; it is set internally in the client library. Instead, use `mysql_options()` or `mysql_ssl_set()` before calling `mysql_real_connect()`.
  - `CLIENT_REMEMBER_OPTIONS`: Remember options specified by calls to `mysql_options()`. Without this option, if `mysql_real_connect()` fails, you must repeat the `mysql_options()` calls before trying to connect again. With this option, the `mysql_options()` calls need not be repeated.

If your program uses `CALL` statements to execute stored procedures, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because `CALL` can return
multiple results, process them using a loop that calls `mysql_next_result()` to determine whether there are more results.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`). `CLIENT_MULTI_RESULTS` is enabled by default.

If you enable `CLIENT_MULTI_STATEMENTS` or `CLIENT_MULTI_RESULTS`, you should process the result for every call to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.7.15, "C API Multiple Statement Execution Support".

For some parameters, it is possible to have the value taken from an option file rather than from an explicit value in the `mysql_real_connect()` call. To do this, call `mysql_options()` with the `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP` option before calling `mysql_real_connect()`. Then, in the `mysql_real_connect()` call, specify the "no-value" value for each parameter to be read from an option file:

- For `host`, specify a value of `NULL` or the empty string ("").
- For `user`, specify a value of `NULL` or the empty string.
- For `passwd`, specify a value of `NULL`. (For the password, a value of the empty string in the `mysql_real_connect()` call cannot be overridden in an option file, because the empty string indicates explicitly that the MySQL account must have an empty password.)
- For `db`, specify a value of `NULL` or the empty string.
- For `port`, specify a value of 0.
- For `unix_socket`, specify a value of `NULL`.

If no value is found in an option file for a parameter, its default value is used as indicated in the descriptions given earlier in this section.

**Return Values**

A `MYSQL*` connection handler if the connection was successful, `NULL` if the connection was unsuccessful. For a successful connection, the return value is the same as the value of the first parameter.

**Errors**

- `CR_CONN_HOST_ERROR`
  Failed to connect to the MySQL server.
- `CR_CONNECTION_ERROR`
  Failed to connect to the local MySQL server.
- `CR_IPSOCK_ERROR`
  Failed to create an IP socket.
- `CR_OUT_OF_MEMORY`
  Out of memory.
C API Function Descriptions

- **CR_SOCKET_CREATE_ERROR**
  Failed to create a Unix socket.

- **CRUNKNOWN_HOST**
  Failed to find the IP address for the host name.

- **CR_VERSION_ERROR**
  A protocol mismatch resulted from attempting to connect to a server with a client library that uses a different protocol version.

- **CR_NAMEDPIPEOPEN_ERROR**
  Failed to create a named pipe on Windows.

- **CR_NAMEDPIPEWAIT_ERROR**
  Failed to wait for a named pipe on Windows.

- **CR_NAMEDPIPESETSTATE_ERROR**
  Failed to get a pipe handler on Windows.

- **CR_SERVER_LOST**
  If `connect_timeout > 0` and it took longer than `connect_timeout` seconds to connect to the server or if the server died while executing the `init-command`.

- **CR_ALREADY_CONNECTED**
  The `MYSQL` connection handler is already connected.

**Example**

```c
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"your_prog_name");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
            mysql_error(&mysql));
}
```

By using `mysql_options()` the MySQL client library reads the `[client]` and `[your prog name]` sections in the `my.cnf` file which ensures that your program works, even if someone has set up MySQL in some nonstandard way.

Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of 1 in versions of the API older than 5.0.3, or 0 in newer versions. A value of 1 for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the `MYSQL_OPT_RECONNECT` option to `mysql_options()` to control reconnection behavior.

**23.7.6.53 mysql_real_escape_string()**

```c
unsigned long mysql_real_escape_string(MYSQL *mysql, char *to, const char *from, unsigned long length)
```
Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, "String Literals".

The *mysql* argument must be a valid, open connection because character escaping depends on the character set in use by the server.

The string in the *from* argument is encoded to produce an escaped SQL string, taking into account the current character set of the connection. The result is placed in the *to* argument, followed by a terminating null byte.

Characters encoded are \, ', " , NUL (ASCII 0), \n, \r, and Control+Z. Strictly speaking, MySQL requires only that backslash and the quote character used to quote the string in the query be escaped. *mysql_real_escape_string()* quotes the other characters to make them easier to read in log files. For comparison, see the quoting rules for literal strings and the *QUOTE()* SQL function in Section 9.1.1, "String Literals", and Section 12.7, "String Functions and Operators".

The string pointed to by *from* must be length bytes long. You must allocate the *to* buffer to be at least length*2+1 bytes long. (In the worst case, each character may need to be encoded as using two bytes, and there must be room for the terminating null byte.) When *mysql_real_escape_string()* returns, the contents of *to* is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

If you must change the character set of the connection, use the *mysql_set_character_set()* function rather than executing a SET NAMES (or SET CHARACTER SET) statement.

*mysql_set_character_set()* works like SET NAMES but also affects the character set used by *mysql_real_escape_string()* , which SET NAMES does not.

Example

The following example inserts two escaped strings into an INSERT statement, each within single quote characters:

```c
char query[1000], *end;

end = strmov(query, "INSERT INTO test_table VALUES(");
*end++ = \\");
end += mysql_real_escape_string(&mysql, end, "What is this", 12);
*end++ = \\");
*end++ = \\");
end += mysql_real_escape_string(&mysql, end, "binary data: \0\r\n", 16);
*end++ = \\");
*end++ = \\");

if (mysql_real_query(&mysql, query, (unsigned int) (end - query)))
{
    fprintf(stderr, "Failed to insert row, Error: %s\n",
            mysql_error(&mysql));
}
```

The strmov() function used in the example is included in the *libmysqlclient* library and works like strcpy() but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into the *to* argument, not including the terminating null character.
Errors

None.

23.7.6.54 mysql_real_query()

```c
int mysql_real_query(MYSQL *mysql, const char *stmt_str, unsigned long length)
```

Description

`mysql_real_query()` executes the SQL statement pointed to by `stmt_str`, a string `length` bytes long. Normally, the string must consist of a single SQL statement without a terminating semicolon (`;`) or `\g`. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 23.7.15, “C API Multiple Statement Execution Support”.

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the `\0` character, which `mysql_query()` interprets as the end of the statement string.) In addition, `mysql_real_query()` is faster than `mysql_query()` because it does not call `strlen()` on the statement string.

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.7.6.22, “mysql_field_count()”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

23.7.6.55 mysql_refresh()

```c
int mysql_refresh(MYSQL *mysql, unsigned int options)
```

Description

This function flushes tables or caches, or resets replication server information. The connected user must have the RELOAD privilege.

The `options` argument is a bitmask composed from any combination of the following values. Multiple values can be OR'ed together to perform multiple operations with a single call.

- **REFRESH_GRANT**
Refresh the grant tables, like `FLUSH PRIVILEGES`.

- **REFRESH_LOG**
  
  Flush the logs, like `FLUSH LOGS`.

- **REFRESH_TABLES**
  
  Flush the table cache, like `FLUSH TABLES`.

- **REFRESH_HOSTS**
  
  Flush the host cache, like `FLUSH HOSTS`.

- **REFRESH_STATUS**
  
  Reset status variables, like `FLUSH STATUS`.

- **REFRESH_THREADS**
  
  Flush the thread cache.

- **REFRESH_SLAVE**
  
  On a slave replication server, reset the master server information and restart the slave, like `RESET SLAVE`.

- **REFRESH_MASTER**
  
  On a master replication server, remove the binary log files listed in the binary log index and truncate the index file, like `RESET MASTER`.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

**23.7.6.56 mysql_reload()**

```c
int mysql_reload(MYSQL *mysql)
```
**Description**

Asks the MySQL server to reload the grant tables. The connected user must have the `RELOAD` privilege.

This function is deprecated. Use `mysql_query()` to issue an SQL `FLUSH PRIVILEGES` statement instead.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

### 23.7.6.57 mysql_rollback()

```c
my_bool mysql_rollback(MYSQL *mysql)
```

**Description**

Rolls back the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is `RELEASE` (or 2), the server performs a release after terminating a transaction and closes the client connection. Call `mysql_close()` from the client program to close the connection from the client side.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

None.

### 23.7.6.58 mysql_row_seek()

```c
MYSQL_ROW_OFFSET mysql_row_seek(MYSQL_RES *result, MYSQL_ROW_OFFSET offset)
```

**Description**

Sets the row cursor to an arbitrary row in a query result set. The `offset` value is a row offset, typically a value returned from `mysql_row_tell()` or from `mysql_row_seek()`. This value is not a row number; to seek to a row within a result set by number, use `mysql_data_seek()` instead.
This function requires that the result set structure contains the entire result of the query, so `mysql_row_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

**Return Values**

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_row_seek()`.

**Errors**

None.

### 23.7.6.59 mysql_row_tell()

```c
MYSQL_ROW_OFFSET mysql_row_tell(MYSQL_RES *result)
```

**Description**

Returns the current position of the row cursor for the last `mysql_fetch_row()`. This value can be used as an argument to `mysql_row_seek()`.

Use `mysql_row_tell()` only after `mysql_store_result()`, not after `mysql_use_result()`.

**Return Values**

The current offset of the row cursor.

**Errors**

None.

### 23.7.6.60 mysql_select_db()

```c
int mysql_select_db(MYSQL *mysql, const char *db)
```

**Description**

Causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that include no explicit database specifier.

`mysql_select_db()` fails unless the connected user can be authenticated as having permission to use the database or some object within it.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- `CR_COMMANDS_OUT_OF_SYNC`
  
  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`
  
  The MySQL server has gone away.

- `CR_SERVER_LOST`
The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

### 23.7.6.61 mysql_set_character_set()

```c
int mysql_set_character_set(MYSQL *mysql, const char *csname)
```

**Description**

This function is used to set the default character set for the current connection. The string `csname` specifies a valid character set name. The connection collation becomes the default collation of the character set. This function works like the `SET NAMES` statement, but also sets the value of `mysql->charset`, and thus affects the character set used by `mysql_real_escape_string()`.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Example**

```c
MYSQL mysql;
mysql_init(&mysql);
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
            mysql_error(&mysql));
}
if (!mysql_set_character_set(&mysql, "utf8"))
{
    printf("New client character set: %s\n",
            mysql_character_set_name(&mysql));
}
```

### 23.7.6.62 mysql_set_local_infile_default()

```c
void mysql_set_local_infile_default(MYSQL *mysql);
```

**Description**

Sets the `LOAD DATA LOCAL` callback functions to the defaults used internally by the C client library. The library calls this function automatically if `mysql_set_local_infile_handler()` has not been called or does not supply valid functions for each of its callbacks.

**Return Values**

None.

**Errors**

None.

### 23.7.6.63 mysql_set_local_infile_handler()

```c
void mysql_set_local_infile_handler(MYSQL *mysql, int (*local_infile_init)(void **, const char *, void *), int (*local_infile_read)(void *, char *, unsigned
```
Description

This function installs callbacks to be used during the execution of LOAD DATA LOCAL statements. It enables application programs to exert control over local (client-side) data file reading. The arguments are the connection handler, a set of pointers to callback functions, and a pointer to a data area that the callbacks can use to share information.

To use `mysql_set_local_infile_handler()`, you must write the following callback functions:

```c
int local_infile_init(void **ptr, const char *filename, void *userdata);
```

The initialization function. This is called once to do any setup necessary, open the data file, allocate data structures, and so forth. The first `void**` argument is a pointer to a pointer. You can set the pointer (that is, `*ptr`) to a value that will be passed to each of the other callbacks (as a `void*`). The callbacks can use this pointed-to value to maintain state information. The `userdata` argument is the same value that is passed to `mysql_set_local_infile_handler()`.

The initialization function should return zero for success, nonzero for an error.

```c
int local_infile_read(void *ptr, char *buf, unsigned int buf_len);
```

The data-reading function. This is called repeatedly to read the data file. `buf` points to the buffer where the read data is stored, and `buf_len` is the maximum number of bytes that the callback can read and store in the buffer. (It can read fewer bytes, but should not read more.)

The return value is the number of bytes read, or zero when no more data could be read (this indicates EOF). Return a value less than zero if an error occurs.

```c
void local_infile_end(void *ptr)
```

The termination function. This is called once after `local_infile_read()` has returned zero (EOF) or an error. Within this function, deallocate any memory allocated by `local_infile_init()` and perform any other cleanup necessary. It is invoked even if the initialization function returns an error.

```c
int local_infile_error(void *ptr,
    char *error_msg,
    unsigned int error_msg_len);
```

The error-handling function. This is called to get a textual error message to return to the user in case any of your other functions returns an error. `error_msg` points to the buffer into which the message is written, and `error_msg_len` is the length of the buffer. Write the message as a null-terminated string, at most `error_msg_len-1` bytes long.

The return value is the error number.

Typically, the other callbacks store the error message in the data structure pointed to by `ptr`, so that `local_infile_error()` can copy the message from there into `error_msg`.

After calling `mysql_set_local_infile_handler()` in your C code and passing pointers to your callback functions, you can then issue a LOAD DATA LOCAL statement (for example, by using `mysql_query()`). The client library automatically invokes your callbacks. The file name specified in LOAD DATA LOCAL will be passed as the second parameter to the `local_infile_init()` callback.
23.7.6.64 mysql_set_server_option()

```c
int mysql_set_server_option(MYSQL *mysql, enum enum_mysql_set_option option)
```

**Description**

Enables or disables an option for the connection. `option` can have one of the following values.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYSQL_OPTION_MULTI_STATEMENTS_ON</td>
<td>Enable multiple-statement support</td>
</tr>
<tr>
<td>MYSQL_OPTION_MULTI_STATEMENTS_OFF</td>
<td>Disable multiple-statement support</td>
</tr>
</tbody>
</table>

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.7.15, “C API Multiple Statement Execution Support”.

Enabling multiple-statement support with `MYSQL_OPTION_MULTI_STATEMENTS_ON` does not have quite the same effect as enabling it by passing the `CLIENT_MULTI_STATEMENTS` flag to `mysql_real_connect()`; `CLIENT_MULTI_STATEMENTS` also enables `CLIENT_MULTI_RESULTS`. If you are using the `CALL` SQL statement in your programs, multiple-result support must be enabled; this means that `MYSQL_OPTION_MULTI_STATEMENTS_ON` by itself is insufficient to permit the use of `CALL`.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **ER_UNKNOWN_COM_ERROR**
  
  The server did not support `mysql_set_server_option()` (which is the case that the server is older than 4.1.1) or the server did not support the option one tried to set.

23.7.6.65 mysql_shutdown()

```c
int mysql_shutdown(MYSQL *mysql, enum mysql_enum_shutdown_level shutdown_level)
```
Description

Asks the database server to shut down. The connected user must have the `SHUTDOWN` privilege. MySQL servers support only one type of shutdown; `shutdown_level` must be equal to `SHUTDOWN_DEFAULT`. Dynamically linked executables that have been compiled with older versions of the `libmysqlclient` headers and call `mysql_shutdown()` must be used with the old `libmysqlclient` dynamic library.

The shutdown process is described in Section 5.1.14, “The Server Shutdown Process”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

23.7.66 mysql_sqlstate()

```c
const char *mysql_sqlstate(MYSQL *mysql)
```

Description

Returns a null-terminated string containing the SQLSTATE error code for the most recently executed SQL statement. The error code consists of five characters. '00000' means “no error.” The values are specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, Errors, Error Codes, and Common Problems.

SQLSTATE values returned by `mysql_sqlstate()` differ from MySQL-specific error numbers returned by `mysql_errno()`. For example, the `mysql` client program displays errors using the following format, where `1146` is the `mysql_errno()` value and '42S02' is the corresponding `mysql_sqlstate()` value:

```bash
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Not all MySQL error numbers are mapped to SQLSTATE error codes. The value 'HY000' (general error) is used for unmapped error numbers.

If you call `mysql_sqlstate()` after `mysql_real_connect()` fails, `mysql_sqlstate()` might not return a useful value. For example, this happens if a host is blocked by the server and the connection is closed without any SQLSTATE value being sent to the client.

Return Values

A null-terminated character string containing the SQLSTATE error code.
See Also

See Section 23.7.6.14, “mysql_errno()”, Section 23.7.6.15, “mysql_error()”, and Section 23.7.10.27, “mysql_stmt_sqlstate()”.

23.7.6.67 mysql_ssl_set()

my_bool mysql_ssl_set(MYSQL *mysql, const char *key, const char *cert, const char *ca, const char *capath, const char *cipher)

Description

mysql_ssl_set() is used for establishing encrypted connections using SSL. The mysql argument must be a valid connection handler. Any unused SSL arguments may be given as NULL.

If used, mysql_ssl_set() must be called before mysql_real_connect(). mysql_ssl_set() does nothing unless SSL support is enabled in the client library.

mysql_ssl_set() specifies SSL information such as certificate and key files for establishing an encrypted connection if such connections are available, but does not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the technique described in Section 23.7.14, “C API Encrypted Connection Support”.

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended. For details, see Section 23.7.14, “C API Encrypted Connection Support”.

Arguments:

• mysql: The connection handler returned from mysql_init().
• key: The path name of the client private key file.
• cert: The path name of the client public key certificate file.
• ca: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server.
• capath: The path name of the directory that contains trusted SSL CA certificate files.
• cipher: The list of permissible ciphers for SSL encryption.

Return Values

This function always returns 0. If SSL setup is incorrect, a subsequent mysql_real_connect() call returns an error when you attempt to connect.

23.7.6.68 mysql_stat()

const char *mysql_stat(MYSQL *mysql)

Description

Returns a character string containing information similar to that provided by the mysqladmin status command. This includes uptime in seconds and the number of running threads, questions, reloads, and open tables.
Return Values

A character string describing the server status. **NULL** if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

23.7.6.69 **mysql_store_result()**

```c
MYSQL_RES *mysql_store_result(MYSQL *mysql)
```

**Description**

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (SELECT, SHOW, DESCRIBE, EXPLAIN, CHECK TABLE, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

You need not call `mysql_store_result()` or `mysql_use_result()` for other statements, but it does not do any harm or cause any notable performance degradation if you call `mysql_store_result()` in all cases. You can detect whether the statement has a result set by checking whether `mysql_store_result()` returns a nonzero value (more about this later).

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.7.15, “C API Multiple Statement Execution Support”.

If you want to know whether a statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.7.6.22, “mysql_field_count()”.

`mysql_store_result()` reads the entire result of a query to the client, allocates a `MYSQL_RES` structure, and places the result into this structure.

`mysql_store_result()` returns **NULL** if the statement did not return a result set (for example, if it was an INSERT statement), or an error occurred and reading of the result set failed.

An empty result set is returned if there are no rows returned. (An empty result set differs from a null pointer as a return value.)

After you have called `mysql_store_result()` and gotten back a result that is not a null pointer, you can call `mysql_num_rows()` to find out how many rows are in the result set.

You can call `mysql_fetch_row()` to fetch rows from the result set, or `mysql_row_seek()` and `mysql_row_tell()` to obtain or set the current row position within the result set.
See Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”.

Return Values

A pointer to a `MYSQL_RES` result structure with the results. `NULL` if the statement did not return a result set or an error occurred. To determine whether an error occurred, check whether `mysql_error()` returns a nonempty string, `mysql_errno()` returns nonzero, or `mysql_field_count()` returns zero.

Errors

`mysql_store_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- `CR_COMMANDS_OUT_OF_SYNC`
  Commands were executed in an improper order.
- `CR_OUT_OF_MEMORY`
  Out of memory.
- `CR_SERVER_GONE_ERROR`
  The MySQL server has gone away.
- `CR_SERVER_LOST`
  The connection to the server was lost during the query.
- `CR_UNKNOWN_ERROR`
  An unknown error occurred.

23.7.6.70 mysql_thread_id()

```
unsigned long mysql_thread_id(MYSQL *mysql)
```

Description

Returns the thread ID of the current connection. This value can be used as an argument to `mysql_kill()` to kill the thread.

If the connection is lost and you reconnect with `mysql_ping()`, the thread ID changes. This means you should not get the thread ID and store it for later. You should get it when you need it.

Note

This function does not work correctly if thread IDs become larger than 32 bits, which can occur on some systems. To avoid problems with `mysql_thread_id()`, do not use it. To get the connection ID, execute a `SELECT CONNECTION_ID()` query and retrieve the result.

Return Values

The thread ID of the current connection.

Errors

None.
**23.7.6.71 mysql_use_result()**

```c
MYSQL_RES *mysql_use_result(MYSQL *mysql)
```

**Description**

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (SELECT, SHOW, DESCRIBE, EXPLAIN, CHECK TABLE, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

`mysql_use_result()` initiates a result set retrieval but does not actually read the result set into the client like `mysql_store_result()` does. Instead, each row must be retrieved individually by making calls to `mysql_fetch_row()`. This reads the result of a query directly from the server without storing it in a temporary table or local buffer, which is somewhat faster and uses much less memory than `mysql_store_result()`. The client allocates memory only for the current row and a communication buffer that may grow up to `max_allowed_packet` bytes.

On the other hand, you should not use `mysql_use_result()` for locking reads if you are doing a lot of processing for each row on the client side, or if the output is sent to a screen on which the user may type a ^S (stop scroll). This ties up the server and prevent other threads from updating any tables from which the data is being fetched.

When using `mysql_use_result()`, you must execute `mysql_fetch_row()` until a NULL value is returned, otherwise, the unfetched rows are returned as part of the result set for your next query. The C API gives the error **Commands out of sync; you can't run this command now** if you forget to do this!

You may not use `mysql_data_seek()`, `mysql_row_seek()`, `mysql_row_tell()`, `mysql_num_rows()`, or `mysql_affected_rows()` with a result returned from `mysql_use_result()`, nor may you issue other queries until `mysql_use_result()` has finished. (However, after you have fetched all the rows, `mysql_num_rows()` accurately returns the number of rows fetched.)

You must call `mysql_free_result()` once you are done with the result set.

When using the `libmysqld` embedded server, the memory benefits are essentially lost because memory usage incrementally increases with each row retrieved until `mysql_free_result()` is called.

**Return Values**

A `MYSQL_RES` result structure. NULL if an error occurred.

**Errors**

`mysql_use_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_OUT_OF_MEMORY**
  
  Out of memory.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.
23.7.6.72 mysql_warning_count()

```c
unsigned int mysql_warning_count(MYSQL *mysql)
```

**Description**

Returns the number of errors, warnings, and notes generated during execution of the previous SQL statement.

**Return Values**

The warning count.

**Errors**

None.

23.7.7 C API Prepared Statements

The MySQL client/server protocol provides for the use of prepared statements. This capability uses the `MYSQL_STMT` statement handler data structure returned by the `mysql_stmt_init()` initialization function. Prepared execution is an efficient way to execute a statement more than once. The statement is first parsed to prepare it for execution. Then it is executed one or more times at a later time, using the statement handler returned by the initialization function.

Prepared execution is faster than direct execution for statements executed more than once, primarily because the query is parsed only once. In the case of direct execution, the query is parsed every time it is executed. Prepared execution also can provide a reduction of network traffic because for each execution of the prepared statement, it is necessary only to send the data for the parameters.

Prepared statements might not provide a performance increase in some situations. For best results, test your application both with prepared and nonprepared statements and choose whichever yields best performance.

Another advantage of prepared statements is that it uses a binary protocol that makes data transfer between client and server more efficient.

For a list of SQL statements that can be used as prepared statements, see Section 13.5, “Prepared Statements”.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

23.7.8 C API Prepared Statement Data Structures

Prepared statements use several data structures:
C API Prepared Statement Data Structures

- To obtain a statement handler, pass a MySQL connection handler to `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT` data structure. This structure is used for further operations with the statement. To specify the statement to prepare, pass the `MYSQL_STMT` pointer and the statement string to `mysql_stmt_prepare()`.

- To provide input parameters for a prepared statement, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_param()`. To receive output column values, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_result()`.

- The `MYSQL_TIME` structure is used to transfer temporal data in both directions.

The following discussion describes the prepared statement data types in detail. For examples that show how to use them, see Section 23.7.10.10, “mysql_stmt_execute()”, and Section 23.7.10.11, “mysql_stmt_fetch()”.

**MYSQL_STMT**

This structure is a handler for a prepared statement. A handler is created by calling `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT`. The handler is used for all subsequent operations with the statement until you close it with `mysql_stmt_close()`, at which point the handler becomes invalid and should no longer be used.

The `MYSQL_STMT` structure has no members intended for application use. Applications should not try to copy a `MYSQL_STMT` structure. There is no guarantee that such a copy will be usable.

Multiple statement handlers can be associated with a single connection. The limit on the number of handlers depends on the available system resources.

**MYSQL_BIND**

This structure is used both for statement input (data values sent to the server) and output (result values returned from the server):

- For input, use `MYSQL_BIND` structures with `mysql_stmt_bind_param()` to bind parameter data values to buffers for use by `mysql_stmt_execute()`.

- For output, use `MYSQL_BIND` structures with `mysql_stmt_bind_result()` to bind buffers to result set columns, for use in fetching rows with `mysql_stmt_fetch()`.

To use a `MYSQL_BIND` structure, zero its contents to initialize it, then set its members appropriately. For example, to declare and initialize an array of three `MYSQL_BIND` structures, use this code:

```c
MYSQL_BIND bind[3];
memset(bind, 0, sizeof(bind));
```

The `MYSQL_BIND` structure contains the following members for use by application programs. For several of the members, the manner of use depends on whether the structure is used for input or output.

- `enum enum_field_types buffer_type`

  The type of the buffer. This member indicates the data type of the C language variable bound to a statement parameter or result set column. For input, `buffer_type` indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored. For permissible `buffer_type` values, see Section 23.7.8.1, “C API Prepared Statement Type Codes”.

- `void *buffer`
A pointer to the buffer to be used for data transfer. This is the address of a C language variable.

For input, `buffer` is a pointer to the variable in which you store the data value for a statement parameter. When you call `mysql_stmt_execute()`, MySQL use the value stored in the variable in place of the corresponding parameter marker in the statement (specified with `?` in the statement string).

For output, `buffer` is a pointer to the variable in which to return a result set column value. When you call `mysql_stmt_fetch()`, MySQL stores a column value from the current row of the result set in this variable. You can access the value when the call returns.

To minimize the need for MySQL to perform type conversions between C language values on the client side and SQL values on the server side, use C variables that have types similar to those of the corresponding SQL values:

- For numeric data types, `buffer` should point to a variable of the proper numeric C type. For integer variables (which can be `char` for single-byte values or an integer type for larger values), you should also indicate whether the variable has the `unsigned` attribute by setting the `is_unsigned` member, described later.

- For character (nonbinary) and binary string data types, `buffer` should point to a character buffer.

- For date and time data types, `buffer` should point to a `MYSQL_TIME` structure.

For guidelines about mapping between C types and SQL types and notes about type conversions, see Section 23.7.8.1, “C API Prepared Statement Type Codes”, and Section 23.7.8.2, “C API Prepared Statement Type Conversions”.

- `unsigned long buffer_length`

The actual size of `*buffer` in bytes. This indicates the maximum amount of data that can be stored in the buffer. For character and binary C data, the `buffer_length` value specifies the length of `*buffer` when used with `mysql_stmt_bind_param()` to specify input values, or
the maximum number of output data bytes that can be fetched into the buffer when used with `mysql_stmt_bind_result()`.

- `unsigned long *length`

  A pointer to an `unsigned long` variable that indicates the actual number of bytes of data stored in `*buffer`. `length` is used for character or binary C data.

  For input parameter data binding, set `*length` to indicate the actual length of the parameter value stored in `*buffer`. This is used by `mysql_stmt_execute()`.

  For output value binding, MySQL sets `*length` when you call `mysql_stmt_fetch()`. The `mysql_stmt_fetch()` return value determines how to interpret the length:

  - If the return value is 0, `*length` indicates the actual length of the parameter value.
  - If the return value is `MYSQL_DATA_TRUNCATED`, `*length` indicates the nontruncated length of the parameter value. In this case, the minimum of `*length` and `buffer_length` indicates the actual length of the value.

  `length` is ignored for numeric and temporal data types because the `buffer_type` value determines the length of the data value.

  If you must determine the length of a returned value before fetching it, see Section 23.7.10.11, "mysql_stmt_fetch()", for some strategies.

- `my_bool *is_null`

  This member points to a `my_bool` variable that is true if a value is `NULL`, false if it is not `NULL`. For input, set `*is_null` to true to indicate that you are passing a `NULL` value as a statement parameter.

  `is_null` is a `pointer` to a boolean scalar, not a boolean scalar, to provide flexibility in how you specify `NULL` values:

  - If your data values are always `NULL`, use `MYSQL_TYPE_NULL` as the `buffer_type` value when you bind the column. The other `MYSQL_BIND` members, including `is_null`, do not matter.
  - If your data values are always `NOT NULL`, set `is_null = (my_bool*) 0`, and set the other members appropriately for the variable you are binding.
  - In all other cases, set the other members appropriately and set `is_null` to the address of a `my_bool` variable. Set that variable's value to true or false appropriately between executions to indicate whether the corresponding data value is `NULL` or `NOT NULL`, respectively.

  For output, when you fetch a row, MySQL sets the value pointed to by `is_null` to true or false according to whether the result set column value returned from the statement is or is not `NULL`.

- `my_bool is_unsigned`

  This member applies for C variables with data types that can be `unsigned` (char, short int, int, long long int). Set `is_unsigned` to true if the variable pointed to by `buffer` is `unsigned` and false otherwise. For example, if you bind a `signed char` variable to `buffer`, specify a type code of `MYSQL_TYPE_TINY` and set `is_unsigned` to false. If you bind an `unsigned char` instead, the type
code is the same but is_unsigned should be true. (For char, it is not defined whether it is signed or unsigned, so it is best to be explicit about signedness by using signed char or unsigned char.)

is_unsigned applies only to the C language variable on the client side. It indicates nothing about the signedness of the corresponding SQL value on the server side. For example, if you use an int variable to supply a value for a BIGINT UNSIGNED column, is_unsigned should be false because int is a signed type. If you use an unsigned int variable to supply a value for a BIGINT column, is_unsigned should be true because unsigned int is an unsigned type. MySQL performs the proper conversion between signed and unsigned values in both directions, although a warning occurs if truncation results.

• my_bool *error

For output, set this member to point to a my_bool variable to have truncation information for the parameter stored there after a row fetching operation. When truncation reporting is enabled, mysql_stmt_fetch() returns MYSQL_DATA_TRUNCATED and *error is true in the MYSQL_BIND structures for parameters in which truncation occurred. Truncation indicates loss of sign or significant digits, or that a string was too long to fit in a column. Truncation reporting is enabled by default, but can be controlled by calling mysql_options() with the MYSQL_REPORT_DATA_TRUNCATION option.

• MYSQL_TIME

This structure is used to send and receive DATE, TIME, DATETIME, and TIMESTAMP data directly to and from the server. Set the buffer member to point to a MYSQL_TIME structure, and set the buffer_type member of a MYSQL_BIND structure to one of the temporal types (MYSQL_TYPE_TIME, MYSQL_TYPE_DATE, MYSQL_TYPE_DATETIME, MYSQL_TYPE_TIMESTAMP).

The MYSQL_TIME structure contains the members listed in the following table.

<table>
<thead>
<tr>
<th>Member</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsigned int year</td>
<td>The year</td>
</tr>
<tr>
<td>unsigned int month</td>
<td>The month of the year</td>
</tr>
<tr>
<td>unsigned int day</td>
<td>The day of the month</td>
</tr>
<tr>
<td>unsigned int hour</td>
<td>The hour of the day</td>
</tr>
<tr>
<td>unsigned int minute</td>
<td>The minute of the hour</td>
</tr>
<tr>
<td>unsigned int second</td>
<td>The second of the minute</td>
</tr>
<tr>
<td>my_bool neg</td>
<td>A boolean flag indicating whether the time is negative</td>
</tr>
<tr>
<td>unsigned long second_part</td>
<td>The fractional part of the second in microseconds; currently unused</td>
</tr>
</tbody>
</table>

Only those parts of a MYSQL_TIME structure that apply to a given type of temporal value are used. The year, month, and day elements are used for DATE, DATETIME, and TIMESTAMP values. The hour, minute, and second elements are used for TIME, DATETIME, and TIMESTAMP values. See Section 23.7.16, “C API Prepared Statement Handling of Date and Time Values”.

23.7.8.1 C API Prepared Statement Type Codes

The buffer_type member of MYSQL_BIND structures indicates the data type of the C language variable bound to a statement parameter or result set column. For input, buffer_type indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored.
C API Prepared Statement Data Structures

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for input values sent to the server. The table shows the C variable types that you can use, the corresponding type codes, and the SQL data types for which the supplied value can be used without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

<table>
<thead>
<tr>
<th>Input Variable C Type</th>
<th>buffer_type Value</th>
<th>SQL Type of Destination Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>signed char</td>
<td>MYSQL_TYPE_TINY</td>
<td>TINYINT</td>
</tr>
<tr>
<td>short int</td>
<td>MYSQL_TYPE_SHORT</td>
<td>SMALLINT</td>
</tr>
<tr>
<td>int</td>
<td>MYSQL_TYPE_LONG</td>
<td>INT</td>
</tr>
<tr>
<td>long long int</td>
<td>MYSQL_TYPE_LONGLONG</td>
<td>BIGINT</td>
</tr>
<tr>
<td>float</td>
<td>MYSQL_TYPE_FLOAT</td>
<td>FLOAT</td>
</tr>
<tr>
<td>double</td>
<td>MYSQL_TYPE_DOUBLE</td>
<td>DOUBLE</td>
</tr>
<tr>
<td>MYSQL_TIME</td>
<td>MYSQL_TYPE_TIME</td>
<td>TIME</td>
</tr>
<tr>
<td>MYSQL_TIME</td>
<td>MYSQL_TYPE_DATE</td>
<td>DATE</td>
</tr>
<tr>
<td>MYSQL_TIME</td>
<td>MYSQL_TYPE_DATETIME</td>
<td>DATETIME</td>
</tr>
<tr>
<td>MYSQL_TIME</td>
<td>MYSQL_TYPE_TIMESTAMP</td>
<td>TIMESTAMP</td>
</tr>
<tr>
<td>char[]</td>
<td>MYSQL_TYPE_STRING</td>
<td>TEXT, CHAR, VARCHAR</td>
</tr>
<tr>
<td>char[]</td>
<td>MYSQL_TYPE_BLOB</td>
<td>BLOB, BINARY, VARBINARY</td>
</tr>
<tr>
<td></td>
<td>MYSQL_TYPE_NULL</td>
<td>NULL</td>
</tr>
</tbody>
</table>

Use `MYSQL_TYPE_NULL` as indicated in the description for the `is_null` member in Section 23.7.8, “C API Prepared Statement Data Structures”.

For input string data, use `MYSQL_TYPE_STRING` or `MYSQL_TYPE_BLOB` depending on whether the value is a character (nonbinary) or binary string:

- **MYSQL_TYPE_STRING** indicates character input string data. The value is assumed to be in the character set indicated by the `character_set_client` system variable. If the server stores the value into a column with a different character set, it converts the value to that character set.

- **MYSQL_TYPE_BLOB** indicates binary input string data. The value is treated as having the binary character set. That is, it is treated as a byte string and no conversion occurs.

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for output values received from the server. The table shows the SQL types of received values, the corresponding type codes that such values have in result set metadata, and the recommended C language data types to bind to the `MYSQL_BIND` structure to receive the SQL values without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

<table>
<thead>
<tr>
<th>SQL Type of Received Value</th>
<th>buffer_type Value</th>
<th>Output Variable C Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TINYINT</td>
<td>MYSQL_TYPE_TINY</td>
<td>signed char</td>
</tr>
<tr>
<td>SMALLINT</td>
<td>MYSQL_TYPE_SHORT</td>
<td>short int</td>
</tr>
<tr>
<td>MEDIUMINT</td>
<td>MYSQL_TYPE_INT24</td>
<td>int</td>
</tr>
<tr>
<td>INT</td>
<td>MYSQL_TYPE_LONG</td>
<td>int</td>
</tr>
<tr>
<td>BIGINT</td>
<td>MYSQL_TYPE_LONGLONG</td>
<td>long long int</td>
</tr>
</tbody>
</table>
### SQL Type of Received Value

<table>
<thead>
<tr>
<th>SQL Type of Received Value</th>
<th>buffer_type Value</th>
<th>Output Variable C Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOAT</td>
<td>MYSQL_TYPE_FLOAT</td>
<td>float</td>
</tr>
<tr>
<td>DOUBLE</td>
<td>MYSQL_TYPE_DOUBLE</td>
<td>double</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>MYSQL_TYPE_NEWDECIMAL</td>
<td>char[]</td>
</tr>
<tr>
<td>YEAR</td>
<td>MYSQL_TYPE_SHORT</td>
<td>short int</td>
</tr>
<tr>
<td>TIME</td>
<td>MYSQL_TYPE_TIME</td>
<td>MYSQL_TIME</td>
</tr>
<tr>
<td>DATE</td>
<td>MYSQL_TYPE_DATE</td>
<td>MYSQL_TIME</td>
</tr>
<tr>
<td>DATETIME</td>
<td>MYSQL_TYPE_DATETIME</td>
<td>MYSQL_TIME</td>
</tr>
<tr>
<td>TIMESTAMP</td>
<td>MYSQL_TYPE_DATETIME</td>
<td>MYSQL_TIME</td>
</tr>
<tr>
<td>CHAR, BINARY</td>
<td>MYSQL_TYPE_STRING</td>
<td>char[]</td>
</tr>
<tr>
<td>VARCHAR, VARBINARY</td>
<td>MYSQL_TYPE_VAR_STRING</td>
<td>char[]</td>
</tr>
<tr>
<td>TINYBLOB, TINYTEXT</td>
<td>MYSQL_TYPE_TINY_BLOB</td>
<td>char[]</td>
</tr>
<tr>
<td>BLOB, TEXT</td>
<td>MYSQL_TYPE_BLOB</td>
<td>char[]</td>
</tr>
<tr>
<td>MEDIUMBLOB, MEDIUMTEXT</td>
<td>MYSQL_TYPE_MEDIUM_BLOB</td>
<td>char[]</td>
</tr>
<tr>
<td>LONGBLOB, LONGTEXT</td>
<td>MYSQL_TYPE_LONG_BLOB</td>
<td>char[]</td>
</tr>
<tr>
<td>BIT</td>
<td>MYSQL_TYPE_BIT</td>
<td>char[]</td>
</tr>
</tbody>
</table>

### 23.7.8.2 C API Prepared Statement Type Conversions

Prepared statements transmit data between the client and server using C language variables on the client side that correspond to SQL values on the server side. If there is a mismatch between the C variable type on the client side and the corresponding SQL value type on the server side, MySQL performs implicit type conversions in both directions.

MySQL knows the type code for the SQL value on the server side. The buffer_type value in the MYSQL_BIND structure indicates the type code of the C variable that holds the value on the client side. The two codes together tell MySQL what conversion must be performed, if any. Here are some examples:

- If you use MYSQL_TYPE_LONG with an int variable to pass an integer value to the server that is to be stored into a FLOAT column, MySQL converts the value to floating-point format before storing it.
- If you fetch an SQL MEDIUMINT column value, but specify a buffer_type value of MYSQL_TYPE_LONGLONG and use a C variable of type long long int as the destination buffer, MySQL converts the MEDIUMINT value (which requires less than 8 bytes) for storage into the long long int (an 8-byte variable).
- If you fetch a numeric column with a value of 255 into a char[4] character array and specify a buffer_type value of MYSQL_TYPE_STRING, the resulting value in the array is a 4-byte string '255\0'.
- MySQL returns DECIMAL values as the string representation of the original server-side value, which is why the corresponding C type is char[]. For example, 12.345 is returned to the client as '12.345'. If you specify MYSQL_TYPE_NEWDECIMAL and bind a string buffer to the MYSQL_BIND structure, mysql_stmt_fetch() stores the value in the buffer as a string without conversion. If instead you specify a numeric variable and type code, mysql_stmt_fetch() converts the string-format DECIMAL value to numeric form.
- For the MYSQL_TYPE_BIT type code, BIT values are returned into a string buffer, which is why the corresponding C type is char[]. The value represents a bit string that requires interpretation on the
To return the value as a type that is easier to deal with, you can cause the value to be cast to integer using either of the following types of expressions:

```
SELECT bit_col + 0 FROM t
SELECT CAST(bit_col AS UNSIGNED) FROM t
```

To retrieve the value, bind an integer variable large enough to hold the value and specify the appropriate corresponding integer type code.

Before binding variables to the `MYSQL_BIND` structures that are to be used for fetching column values, you can check the type codes for each column of the result set. This might be desirable if you want to determine which variable types would be best to use to avoid type conversions. To get the type codes, call `mysql_stmt_result_metadata()` after executing the prepared statement with `mysql_stmt_execute()`. The metadata provides access to the type codes for the result set as described in Section 23.7.10.23, “mysql_stmt_result_metadata()”, and Section 23.7.4, “C API Data Structures”.

To determine whether output string values in a result set returned from the server contain binary or nonbinary data, check whether the `charsetnr` value of the result set metadata is 63 (see Section 23.7.4, “C API Data Structures”). If so, the character set is `binary`, which indicates binary rather than nonbinary data. This enables you to distinguish `BINARY` from `CHAR`, `VARBINARY` from `VARCHAR`, and the `BLOB` types from the `TEXT` types.

If you cause the `max_length` member of the `MYSQL_FIELD` column metadata structures to be set (by calling `mysql_stmt_attr_set()`), be aware that the `max_length` values for the result set indicate the lengths of the longest string representation of the result values, not the lengths of the binary representation. That is, `max_length` does not necessarily correspond to the size of the buffers needed to fetch the values with the binary protocol used for prepared statements. Choose the size of the buffers according to the types of the variables into which you fetch the values. For example, a `TINYINT` column containing the value -128 might have a `max_length` value of 4. But the binary representation of any `TINYINT` value requires only 1 byte for storage, so you can supply a `signed char` variable in which to store the value and set `is_unsigned` to indicate that values are signed.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

### 23.7.9 C API Prepared Statement Function Overview

The following list summarizes the functions available for prepared statement processing. For greater detail, see the descriptions in Section 23.7.10, “C API Prepared Statement Function Descriptions”.

- `mysql_stmt_affected_rows()`: Returns the number of rows changed, deleted, or inserted by prepared `UPDATE`, `DELETE`, or `INSERT` statement.
- `mysql_stmt_attr_get()`: Gets the value of an attribute for a prepared statement.
- `mysql_stmt_attr_set()`: Sets an attribute for a prepared statement.
- `mysql_stmt_bind_param()`: Associates application data buffers with the parameter markers in a prepared SQL statement.
- `mysql_stmt_bind_result()`: Associates application data buffers with columns in a result set.
- `mysql_stmt_close()`: Frees memory used by a prepared statement.
- `mysql_stmt_data_seek()`: Seeks to an arbitrary row number in a statement result set.
C API Prepared Statement Function Overview

- `mysql_stmt_errno()`: Returns the error number for the last statement execution.
- `mysql_stmt_error()`: Returns the error message for the last statement execution.
- `mysql_stmt_execute()`: Executes a prepared statement.
- `mysql_stmt_fetch()`: Fetches the next row of data from a result set and returns data for all bound columns.
- `mysql_stmt_fetch_column()`: Fetches data for one column of the current row of a result set.
- `mysql_stmt_field_count()`: Returns the number of result columns for the most recent statement.
- `mysql_stmt_free_result()`: Frees the resources allocated to a statement handler.
- `mysql_stmt_init()`: Allocates memory for a `MYSQL_STMT` structure and initializes it.
- `mysql_stmt_insert_id()`: Returns the ID generated for an `AUTO_INCREMENT` column by a prepared statement.
- `mysql_stmt_next_result()`: Returns/initiates the next result in a multiple-result execution.
- `mysql_stmt_num_rows()`: Returns the row count from a buffered statement result set.
- `mysql_stmt_param_count()`: Returns the number of parameters in a prepared statement.
- `mysql_stmt_param_metadata()`: Returns parameter metadata in the form of a result set. (This function actually does nothing.)
- `mysql_stmt_prepare()`: Prepares an SQL statement string for execution.
- `mysql_stmt_reset()`: Resets the statement buffers in the server.
- `mysql_stmt_result_metadata()`: Returns prepared statement metadata in the form of a result set.
- `mysql_stmt_row_seek()`: Seeks to a row offset in a statement result set, using value returned from `mysql_stmt_row_tell()`.
- `mysql_stmt_row_tell()`: Returns the statement row cursor position.
- `mysql_stmt_send_long_data()`: Sends long data in chunks to server.
- `mysql_stmt_sqlstate()`: Returns the SQLSTATE error code for the last statement execution.
- `mysql_stmt_store_result()`: Retrieves a complete result set to the client.

Call `mysql_stmt_init()` to create a statement handler, then `mysql_stmt_prepare()` to prepare the statement string, `mysql_stmt_bind_param()` to supply the parameter data, and `mysql_stmt_execute()` to execute the statement. You can repeat the `mysql_stmt_execute()` by changing parameter values in the respective buffers supplied through `mysql_stmt_bind_param()`.

You can send text or binary data in chunks to server using `mysql_stmt_send_long_data()`. See Section 23.7.10.26, “mysql_stmt_send_long_data()”.

If the statement is a `SELECT` or any other statement that produces a result set, `mysql_stmt_prepare()` also returns the result set metadata information in the form of a `MYSQL_RES` result set through `mysql_stmt_result_metadata()`.

You can supply the result buffers using `mysql_stmt_bind_result()`, so that the `mysql_stmt_fetch()` automatically returns data to these buffers. This is row-by-row fetching.
When statement execution has been completed, close the statement handler using `mysql_stmt_close()` so that all resources associated with it can be freed. At that point the handler becomes invalid and should no longer be used.

If you obtained a SELECT statement's result set metadata by calling `mysql_stmt_result_metadata()`, you should also free the metadata using `mysql_free_result()`.

**Execution Steps**

To prepare and execute a statement, an application follows these steps:

1. Create a prepared statement handler with `mysql_stmt_init()`. To prepare the statement on the server, call `mysql_stmt_prepare()` and pass it a string containing the SQL statement.

2. If the statement will produce a result set, call `mysql_stmt_result_metadata()` to obtain the result set metadata. This metadata is itself in the form of result set, albeit a separate one from the one that contains the rows returned by the query. The metadata result set indicates how many columns are in the result and contains information about each column.

3. Set the values of any parameters using `mysql_stmt_bind_param()`. All parameters must be set. Otherwise, statement execution returns an error or produces unexpected results.

4. Call `mysql_stmt_execute()` to execute the statement.

5. If the statement produces a result set, bind the data buffers to use for retrieving the row values by calling `mysql_stmt_bind_result()`.

6. Fetch the data into the buffers row by row by calling `mysql_stmt_fetch()` repeatedly until no more rows are found.

7. Repeat steps 3 through 6 as necessary, by changing the parameter values and re-executing the statement.

When `mysql_stmt_prepare()` is called, the MySQL client/server protocol performs these actions:

- The server parses the statement and sends the okay status back to the client by assigning a statement ID. It also sends total number of parameters, a column count, and its metadata if it is a result set oriented statement. All syntax and semantics of the statement are checked by the server during this call.

- The client uses this statement ID for the further operations, so that the server can identify the statement from among its pool of statements.

When `mysql_stmt_execute()` is called, the MySQL client/server protocol performs these actions:

- The client uses the statement handler and sends the parameter data to the server.

- The server identifies the statement using the ID provided by the client, replaces the parameter markers with the newly supplied data, and executes the statement. If the statement produces a result set, the server sends the data back to the client. Otherwise, it sends an okay status and the number of rows changed, deleted, or inserted.

When `mysql_stmt_fetch()` is called, the MySQL client/server protocol performs these actions:

- The client reads the data from the current row of the result set and places it into the application data buffers by doing the necessary conversions. If the application buffer type is same as that of the field type returned from the server, the conversions are straightforward.

If an error occurs, you can get the statement error number, error message, and SQLSTATE code using `mysql_stmt_errno()`, `mysql_stmt_error()`, and `mysql_stmt_sqlstate()`, respectively.
Prepared Statement Logging

For prepared statements that are executed with the `mysql_stmt_prepare()` and `mysql_stmt_execute()` C API functions, the server writes `Prepare` and `Execute` lines to the general query log so that you can tell when statements are prepared and executed.

Suppose that you prepare and execute a statement as follows:

1. Call `mysql_stmt_prepare()` to prepare the statement string "SELECT ?".
2. Call `mysql_stmt_bind_param()` to bind the value 3 to the parameter in the prepared statement.
3. Call `mysql_stmt_execute()` to execute the prepared statement.

As a result of the preceding calls, the server writes the following lines to the general query log:

<table>
<thead>
<tr>
<th>Prepare</th>
<th>Execute</th>
</tr>
</thead>
</table>

Each `Prepare` and `Execute` line in the log is tagged with a `[N]` statement identifier so that you can keep track of which prepared statement is being logged. `N` is a positive integer. If there are multiple prepared statements active simultaneously for the client, `N` may be greater than 1. Each `Execute` lines shows a prepared statement after substitution of data values for `?` parameters.

23.7.10 C API Prepared Statement Function Descriptions

To prepare and execute queries, use the functions described in detail in the following sections.

All functions that operate with a `MYSQL_STMT` structure begin with the prefix `mysql_stmt_`.

To create a `MYSQL_STMT` handler, use the `mysql_stmt_init()` function.

23.7.10.1 `mysql_stmt_affected_rows()`

```c
my_ulonglong mysql_stmt_affected_rows(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_affected_rows()` may be called immediately after executing a statement with `mysql_stmt_execute()`. It is like `mysql_affected_rows()` but for prepared statements. For a description of what the affected-rows value returned by this function means, See Section 23.7.6.1, "mysql_affected_rows()".

Errors

None.

Example

See the Example in Section 23.7.10.10, "mysql_stmt_execute()".

23.7.10.2 `mysql_stmt_attr_get()`

```c
my_bool mysql_stmt_attr_get(MYSQL_STMT *stmt, enum enum_stmt_attr_type option, void *arg)
```

Description

Can be used to get the current value for a statement attribute.
The `option` argument is the option that you want to get; the `arg` should point to a variable that should contain the option value. If the option is an integer, `arg` should point to the value of the integer.

See Section 23.7.10.3, "mysql_stmt_attr_set()", for a list of options and option types.

**Return Values**

Zero for success. Nonzero if `option` is unknown.

**Errors**

None.

23.7.10.3 mysql_stmt_attr_set()

```c
my_bool mysql_stmt_attr_set(MYSQL_STMT *stmt, enum enum_stmt_attr_type option, const void *arg)
```

**Description**

Can be used to affect behavior for a prepared statement. This function may be called multiple times to set several options.

The `option` argument is the option that you want to set. The `arg` argument is the value for the option. `arg` should point to a variable that is set to the desired attribute value. The variable type is as indicated in the following table.

The following table shows the possible `option` values.

<table>
<thead>
<tr>
<th>Option</th>
<th>Argument Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>STMT_ATTR_UPDATE_MAX_LENGTH</td>
<td><code>my_bool *</code></td>
<td>If set to 1, causes <code>mysql_stmt_store_result()</code> to update the metadata <code>MYSQL_FIELD-&gt;max_length</code> value.</td>
</tr>
<tr>
<td>STMT_ATTR_CURSOR_TYPE</td>
<td><code>unsigned long *</code></td>
<td>Type of cursor to open for statement when <code>mysql_stmt_execute()</code> is invoked. <code>*arg</code> can be <code>CURSOR_TYPE_NO_CURSOR</code> (the default) or <code>CURSOR_TYPE_READ_ONLY</code>.</td>
</tr>
<tr>
<td>STMT_ATTR_PREFETCH_ROWS</td>
<td><code>unsigned long *</code></td>
<td>Number of rows to fetch from server at a time when using a cursor. <code>*arg</code> can be in the range from 1 to the maximum value of <code>unsigned long</code>. The default is 1.</td>
</tr>
</tbody>
</table>

If you use the `STMT_ATTR_CURSOR_TYPE` option with `CURSOR_TYPE_READ_ONLY`, a cursor is opened for the statement when you invoke `mysql_stmt_execute()`. If there is already an open cursor from a previous `mysql_stmt_execute()` call, it closes the cursor before opening a new one. `mysql_stmt_reset()` also closes any open cursor before preparing the statement for re-execution. `mysql_stmt_free_result()` closes any open cursor.

If you open a cursor for a prepared statement, `mysql_stmt_store_result()` is unnecessary, because that function causes the result set to be buffered on the client side.
Return Values

Zero for success. Nonzero if option is unknown.

Errors

None.

Example

The following example opens a cursor for a prepared statement and sets the number of rows to fetch at a time to 5:

```c
MYSQL_STMT *stmt;
int rc;
unsigned long type;
unsigned long prefetch_rows = 5;
stmt = mysql_stmt_init(mysql);
type = (unsigned long) CURSOR_TYPE_READ_ONLY;
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_CURSOR_TYPE, (void*) &type);
/* ... check return value ... */
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_PREFETCH_ROWS,
(void*) &prefetch_rows);
/* ... check return value ... */
```

23.7.10.4 mysql_stmt_bind_param()

```
my_bool mysql_stmt_bind_param(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

mysql_stmt_bind_param() is used to bind input data for the parameter markers in the SQL statement that was passed to mysql_stmt_prepare(). It uses MYSQL_BIND structures to supply the data. bind is the address of an array of MYSQL_BIND structures. The client library expects the array to contain one element for each ? parameter marker that is present in the query.

Suppose that you prepare the following statement:

```
INSERT INTO mytbl VALUES(?,?,?)
```

When you bind the parameters, the array of MYSQL_BIND structures must contain three elements, and can be declared like this:

```c
MYSQL_BIND bind[3];
```

Section 23.7.8, “C API Prepared Statement Data Structures”, describes the members of each MYSQL_BIND element and how they should be set to provide input values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_UNSUPPORTED_PARAM_TYPE**

  The conversion is not supported. Possibly the buffer_type value is invalid or is not one of the supported types.
• CR_OUT_OF_MEMORY
  Out of memory.

• CR_UNKNOWN_ERROR
  An unknown error occurred.

Example

See the Example in Section 23.7.10, “mysql_stmt_execute()”.

23.7.10.5 mysql_stmt_bind_result()

my_bool mysql_stmt_bind_result(MYSQL_STMT *stmt, MYSQL_BIND *bind)

Description

mysql_stmt_bind_result() is used to associate (that is, bind) output columns in the result set to data buffers and length buffers. When mysql_stmt_fetch() is called to fetch data, the MySQL client/server protocol places the data for the bound columns into the specified buffers.

All columns must be bound to buffers prior to calling mysql_stmt_fetch(). bind is the address of an array of MYSQL_BIND structures. The client library expects the array to contain one element for each column of the result set. If you do not bind columns to MYSQL_BIND structures, mysql_stmt_fetch() simply ignores the data fetch. The buffers should be large enough to hold the data values, because the protocol does not return data values in chunks.

A column can be bound or rebound at any time, even after a result set has been partially retrieved. The new binding takes effect the next time mysql_stmt_fetch() is called. Suppose that an application binds the columns in a result set and calls mysql_stmt_fetch(). The client/server protocol returns data in the bound buffers. Then suppose that the application binds the columns to a different set of buffers. The protocol places data into the newly bound buffers when the next call to mysql_stmt_fetch() occurs.

To bind a column, an application calls mysql_stmt_bind_result() and passes the type, address, and length of the output buffer into which the value should be stored. Section 23.7.8, “C API Prepared Statement Data Structures”, describes the members of each MYSQL_BIND element and how they should be set to receive output values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

• CR_UNSUPPORTED_PARAM_TYPE
  The conversion is not supported. Possibly the buffer_type value is invalid or is not one of the supported types.

• CR_OUT_OF_MEMORY
  Out of memory.

• CR_UNKNOWN_ERROR
  An unknown error occurred.
Example

See the Example in Section 23.7.10.11, “mysql_stmt_fetch()”.

23.7.10.6 mysql_stmt_close()

```c
my_bool mysql_stmt_close(MYSQL_STMT *stmt)
```

**Description**

Closes the prepared statement. `mysql_stmt_close()` also deallocates the statement handler pointed to by `stmt`, which at that point becomes invalid and should no longer be used. For a failed `mysql_stmt_close()` call, do not call `mysql_stmt_error()`, or `mysql_stmt_errno()`, or `mysql_stmt_sqlstate()` to obtain error information because `mysql_stmt_close()` makes the statement handler invalid. Call `mysql_error()`, `mysql_errno()`, or `mysql_sqlstate()` instead.

If the current statement has pending or unread results, this function cancels them so that the next query can be executed.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

Example

See the Example in Section 23.7.10.10, “mysql_stmt_execute()”.

23.7.10.7 mysql_stmt_data_seek()

```c
void mysql_stmt_data_seek(MYSQL_STMT *stmt, my_ulonglong offset)
```

**Description**

Seeks to an arbitrary row in a statement result set. The `offset` value is a row number and should be in the range from 0 to `mysql_stmt_num_rows(stmt)-1`.

This function requires that the statement result set structure contains the entire result of the last executed query, so `mysql_stmt_data_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

**Return Values**

None.

**Errors**

None.

23.7.10.8 mysql_stmt_errno()
unsigned int mysql_stmt_errno(MYSQL_STMT *stmt)

Description

For the statement specified by stmt, mysql_stmt_errno() returns the error code for the most recently invoked statement API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL errmsg.h header file. Server error message numbers are listed in mysql_error.h. Errors also are listed at Appendix B, Errors, Error Codes, and Common Problems.

If the failed statement API function was mysql_stmt_close(), do not call or mysql_stmt_errno() to obtain error information because mysql_stmt_close() makes the statement handler invalid. Call mysql_errno() instead.

Return Values

An error code value. Zero if no error occurred.

Errors

None.

23.7.10.9 mysql_stmt_error()

const char *mysql_stmt_error(MYSQL_STMT *stmt)

Description

For the statement specified by stmt, mysql_stmt_error() returns a null-terminated string containing the error message for the most recently invoked statement API function that can succeed or fail. An empty string ("") is returned if no error occurred. Either of these two tests can be used to check for an error:

```c
if(*mysql_stmt_errno(stmt))
{
    // an error occurred
}
if (mysql_stmt_error(stmt)[0])
{
    // an error occurred
}
```

If the failed statement API function was mysql_stmt_close(), do not call mysql_stmt_error() to obtain error information because mysql_stmt_close() makes the statement handler invalid. Call mysql_error() instead.

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages.

Return Values

A character string that describes the error. An empty string if no error occurred.

Errors

None.

23.7.10.10 mysql_stmt_execute()
Description

`mysql_stmt_execute()` executes the prepared query associated with the statement handler. The currently bound parameter marker values are sent to server during this call, and the server replaces the markers with this newly supplied data.

Statement processing following `mysql_stmt_execute()` depends on the type of statement:

- For an `UPDATE`, `DELETE`, or `INSERT`, the number of changed, deleted, or inserted rows can be found by calling `mysql_stmt_affected_rows()`.

- For a statement such as `SELECT` that generates a result set, you must call `mysql_stmt_fetch()` to fetch the data prior to calling any other functions that result in query processing. For more information on how to fetch the results, refer to Section 23.7.10.11, “mysql_stmt_fetch()”.

Do not following invocation of `mysql_stmt_execute()` with a call to `mysql_store_result()` or `mysql_use_result()`. Those functions are not intended for processing results from prepared statements.

For statements that generate a result set, you can request that `mysql_stmt_execute()` open a cursor for the statement by calling `mysql_stmt_attr_set()` before executing the statement. If you execute a statement multiple times, `mysql_stmt_execute()` closes any open cursor before opening a new one.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_OUT_OF_MEMORY**
  
  Out of memory.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

Example

The following example demonstrates how to create and populate a table using `mysql_stmt_init()`, `mysql_stmt_prepare()`, `mysql_stmt_param_count()`, `mysql_stmt_bind_param()`, `mysql_stmt_execute()`, and `mysql_stmt_affected_rows()`. The `mysql` variable is assumed to
be a valid connection handler. For an example that shows how to retrieve data, see Section 23.7.10.11, "mysql_stmt_fetch()".

```c
#define STRING_SIZE 50
#define DROP_SAMPLE_TABLE "DROP TABLE IF EXISTS test_table"
#define CREATE_SAMPLE_TABLE "CREATE TABLE test_table(col1 INT,\n                        col2 VARCHAR(40),\n                        col3 SMALLINT,\n                        col4 TIMESTAMP)"
#define INSERT_SAMPLE "INSERT INTO \n                      test_table(col1,col2,col3) \n                      VALUES(?,?,?)"

MYSQL_STMT *stmt;
MYSQL_BIND bind[3];
my_ulonglong affected_rows;
int param_count;
short small_data;
int int_data;
char str_data[STRING_SIZE];
unsigned long str_length;
my_bool is_null;

if (mysql_query(mysql, DROP_SAMPLE_TABLE))
    {fprintf(stderr, " DROP TABLE failed\n");
      fprintf(stderr, " %s\n", mysql_error(mysql));
      exit(0);
    }

if (mysql_query(mysql, CREATE_SAMPLE_TABLE))
    {fprintf(stderr, " CREATE TABLE failed\n");
      fprintf(stderr, " %s\n", mysql_error(mysql));
      exit(0);
    }

    /* Prepare an INSERT query with 3 parameters */
    /* (the TIMESTAMP column is not named; the server */
    /* sets it to the current date and time) */
    stmt = mysql_stmt_init(mysql);
    if (!stmt)
        {fprintf(stderr, " mysql_stmt_init(), out of memory\n");
          exit(0);
        }
    if (mysql_stmt_prepare(stmt, INSERT_SAMPLE, strlen(INSERT_SAMPLE)))
        {fprintf(stderr, " mysql_stmt_prepare(), INSERT failed\n");
          fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
          exit(0);
        }
    fprintf(stdout, " prepare, INSERT successful\n");

    /* Get the parameter count from the statement */
    param_count= mysql_stmt_param_count(stmt);
    if (param_count != 3) /* validate parameter count */
        {fprintf(stderr, " invalid parameter count returned by MySQL\n");
          exit(0);
        }

    /* Bind the data for all 3 parameters */
```
memset(bind, 0, sizeof(bind));

/* INTEGER PARAM */
/* This is a number type, so there is no need
 to specify buffer_length */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= 0;
bind[0].length= 0;

/* STRING PARAM */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= 0;
bind[1].length= &str_length;

/* SMALLINT PARAM */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null;
bind[2].length= 0;

/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{
    fprintf(stderr, " mysql_stmt_bind_param() failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Specify the data values for the first row */
int_data= 10;             /* integer */
strcpy(str_data, "MySQL", STRING_SIZE); /* string */
str_length= strlen(str_data);

/* INSERT SMALLINT data as NULL */
is_null= 1;

/* Execute the INSERT statement - 1*/
if (mysql_stmt_execute(stmt))
{
    fprintf(stderr, " mysql_stmt_execute() failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Get the number of affected rows */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 1): %lu\n",
(ulong) affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
    fprintf(stderr, " invalid affected rows by MySQL\n");
    exit(0);
}

/* Specify data values for second row,
 then re-execute the statement */
int_data= 1000;
strcpy(str_data, "The most popular Open Source database",
STRING_SIZE);
str_length= strlen(str_data);
small_data= 1000;         /* smallint */
is_null= 0;               /* reset */
/* Execute the INSERT statement - 2*/
if (mysql_stmt_execute(stmt))
{
    fprintf(stderr, " mysql_stmt_execute, 2 failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Get the total rows affected */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 2): %lu\n",
    (unsigned long) affected_rows);
if (affected_rows != 1) /* validate affected rows */
{
    fprintf(stderr, " invalid affected rows by MySQL\n");
    exit(0);
}

/* Close the statement */
if (mysql_stmt_close(stmt))
{
    /* mysql_stmt_close() invalidates stmt, so call */
    /* mysql_error(mysql) rather than mysql_stmt_error(stmt) */
    fprintf(stderr, " failed while closing the statement\n"");
    fprintf(stderr, " %s\n", mysql_error(mysql));
    exit(0);
}

Note
For complete examples on the use of prepared statement functions, refer to the file
tests/mysql_client_test.c. This file can be obtained from a MySQL source
distribution or from the source repository (see Section 2.9, "Installing MySQL from
Source").

23.7.10.11 mysql_stmt_fetch()

    int mysql_stmt_fetch(MYSQL_STMT *stmt)

Description

mysql_stmt_fetch() returns the next row in the result set. It can be called only while the result set
exists; that is, after a call to mysql_stmt_execute() for a statement such as SELECT that produces a
result set.

mysql_stmt_fetch() returns row data using the buffers bound by mysql_stmt_bind_result(). It
returns the data in those buffers for all the columns in the current row set and the lengths are returned to
the length pointer. All columns must be bound by the application before it calls mysql_stmt_fetch().

mysql_stmt_fetch() typically occurs within a loop, to ensure that all result set rows are fetched. For
example:

    int status;
    while (1)
    {
        status = mysql_stmt_fetch(stmt);
        if (status == 1 || status == MYSQL_NO_DATA)
            break;
/* handle current row here */
}
/* if desired, handle status == 1 case and display error here */

By default, result sets are fetched unbuffered a row at a time from the server. To buffer the entire result set on the client, call `mysql_stmt_store_result()` after binding the data buffers and before calling `mysql_stmt_fetch()`.

If a fetched data value is a NULL value, the `*is_null` value of the corresponding `MYSQL_BIND` structure contains TRUE (1). Otherwise, the data and its length are returned in the `*buffer` and `*length` elements based on the buffer type specified by the application. Each numeric and temporal type has a fixed length, as listed in the following table. The length of the string types depends on the length of the actual data value, as indicated by `data_length`.

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYSQL_TYPE_TINY</td>
<td>1</td>
</tr>
<tr>
<td>MYSQL_TYPE_SHORT</td>
<td>2</td>
</tr>
<tr>
<td>MYSQL_TYPE_LONG</td>
<td>4</td>
</tr>
<tr>
<td>MYSQL_TYPE_LONGLONG</td>
<td>8</td>
</tr>
<tr>
<td>MYSQL_TYPE_FLOAT</td>
<td>4</td>
</tr>
<tr>
<td>MYSQL_TYPE_DOUBLE</td>
<td>8</td>
</tr>
<tr>
<td>MYSQL_TYPE_TIME</td>
<td><code>sizeof(MYSQL_TIME)</code></td>
</tr>
<tr>
<td>MYSQL_TYPE_DATE</td>
<td><code>sizeof(MYSQL_TIME)</code></td>
</tr>
<tr>
<td>MYSQL_TYPE_DATETIME</td>
<td><code>sizeof(MYSQL_TIME)</code></td>
</tr>
<tr>
<td>MYSQL_TYPE_STRING</td>
<td><code>data_length</code></td>
</tr>
<tr>
<td>MYSQL_TYPE_BLOB</td>
<td><code>data_length</code></td>
</tr>
</tbody>
</table>

In some cases, you might want to determine the length of a column value before fetching it with `mysql_stmt_fetch()`. For example, the value might be a long string or `BLOB` value for which you want to know how much space must be allocated. To accomplish this, use one of these strategies:

- **Before invoking `mysql_stmt_fetch()` to retrieve individual rows**, pass `STMT_ATTR_UPDATE_MAX_LENGTH` to `mysql_stmt_attr_set()`, then invoke `mysql_stmt_store_result()` to buffer the entire result on the client side. Setting the `STMT_ATTR_UPDATE_MAX_LENGTH` attribute causes the maximal length of column values to be indicated by the `max_length` member of the result set metadata returned by `mysql_stmt_result_metadata()`.

- **Invoke `mysql_stmt_fetch()` with a zero-length buffer** for the column in question and a pointer in which the real length can be stored. Then use the real length with `mysql_stmt_fetch_column()`.

```c
real_length= 0;
bind[0].buffer= 0;
bind[0].buffer_length= 0;
bind[0].length= &real_length
mysql_stmt_bind_result(stmt, bind);
mysql_stmt_fetch(stmt);
if (real_length > 0)
{
  data= malloc(real_length);
  bind[0].buffer= data;
```
Return Values

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Success, the data has been fetched to application data buffers.</td>
</tr>
<tr>
<td>1</td>
<td>Error occurred. Error code and message can be obtained by calling mysql_stmt_errno() and mysql_stmt_error().</td>
</tr>
<tr>
<td>MYSQL_NO_DATA</td>
<td>Success, no more data exists</td>
</tr>
<tr>
<td>MYSQL_DATA_TRUNCATED</td>
<td>Data truncation occurred</td>
</tr>
</tbody>
</table>

MYSQL_DATA_TRUNCATED is returned when truncation reporting is enabled. To determine which column values were truncated when this value is returned, check the error members of the MYSQL_BIND structures used for fetching values. Truncation reporting is enabled by default, but can be controlled by calling mysql_options() with the MYSQL_REPORT_DATA_TRUNCATION option.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**

  Commands were executed in an improper order.

  Although mysql_stmt_fetch() can produce this error, it is more likely to occur for the following C API call if mysql_stmt_fetch() is not called enough times to read the entire result set (that is, enough times to return MYSQL_NO_DATA).

- **CR_OUT_OF_MEMORY**

  Out of memory.

- **CR_SERVER_GONE_ERROR**

  The MySQL server has gone away.

- **CR_SERVER_LOST**

  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**

  An unknown error occurred.

- **CR_UNSUPPORTED_PARAM_TYPE**

  The buffer type is MYSQL_TYPE_DATE, MYSQL_TYPE_TIME, MYSQL_TYPE_DATETIME, or MYSQL_TYPE_TIMESTAMP, but the data type is not DATE, TIME, DATETIME, or TIMESTAMP.

  All other unsupported conversion errors are returned from mysql_stmt_bind_result().

Example

The following example demonstrates how to fetch data from a table using mysql_stmt_result_metadata(), mysql_stmt_bind_result(), and mysql_stmt_fetch().
(This example expects to retrieve the two rows inserted by the example shown in Section 23.7.10.10, “mysql_stmt_execute()”). The mysql variable is assumed to be a valid connection handler.

```
#define STRING_SIZE 50

#define SELECT_SAMPLE "SELECT col1, col2, col3, col4 \n  FROM test_table"

MYSQL_STMT  *stmt;
MYSQL_BIND    bind[4];
MYSQL_RES     *prepare_meta_result;
MYSQL_TIME    ts;
unsigned long length[4];
int           param_count, column_count, row_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
my_bool       is_null[4];
my_bool       error[4];

/* Prepare a SELECT query to fetch data from test_table */
stmt = mysql_stmt_init(mysql);
if (!stmt)
  {
    fprintf(stderr, " mysql_stmt_init(), out of memory\n");
    exit(0);
  }
if (mysql_stmt_prepare(stmt, SELECT_SAMPLE, strlen(SELECT_SAMPLE)))
  {
    fprintf(stderr, " mysql_stmt_prepare(), SELECT failed\n"
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
  }
fprintf(stdout, " prepare, SELECT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_stmt_param_count(stmt);
fprintf(stdout, " total parameters in SELECT: %d\n", param_count);
if (param_count != 0) /* validate parameter count */
  {
    fprintf(stderr, " invalid parameter count returned by MySQL\n");
    exit(0);
  }

/* Fetch result set meta information */
prepare_meta_result = mysql_stmt_result_metadata(stmt);
if (!prepare_meta_result)
  {
    fprintf(stderr,
      " mysql_stmt_result_metadata(), \n    returned no meta information\n";
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
  }

/* Get total columns in the query */
column_count= mysql_num_fields(prepare_meta_result);
fprintf(stdout,
      " total columns in SELECT statement: %d\n", column_count);
if (column_count != 4) /* validate column count */
  {
    fprintf(stderr, " invalid column count returned by MySQL\n";
    exit(0);
  }```

/* Execute the SELECT query */
if (mysql_stmt_execute(stmt))
{
    fprintf(stderr, " mysql_stmt_execute(), failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Bind the result buffers for all 4 columns before fetching them */
memset(bind, 0, sizeof(bind));

/* INTEGER COLUMN */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *) &int_data;
bind[0].is_null= &is_null[0];
bind[0].length= &length[0];
bind[0].error= &error[0];

/* STRING COLUMN */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *) str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= &is_null[1];
bind[1].length= &length[1];
bind[1].error= &error[1];

/* SMALLINT COLUMN */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *) &small_data;
bind[2].is_null= &is_null[2];
bind[2].length= &length[2];
bind[2].error= &error[2];

/* TIMESTAMP COLUMN */
bind[3].buffer_type= MYSQL_TYPE_TIMESTAMP;
bind[3].buffer= (char *) &ts;
bind[3].is_null= &is_null[3];
bind[3].length= &length[3];
bind[3].error= &error[3];

/* Bind the result buffers */
if (mysql_stmt_bind_result(stmt, bind))
{
    fprintf(stderr, " mysql_stmt_bind_result() failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Now buffer all results to client (optional step) */
if (mysql_stmt_store_result(stmt))
{
    fprintf(stderr, " mysql_stmt_store_result() failed\n");
    fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
    exit(0);
}

/* Fetch all rows */
row_count= 0;
fprintf(stdout, "Fetching results ...
");
while (!mysql_stmt_fetch(stmt))
{
    row_count++;
    fprintf(stdout, " row %d\n", row_count);
    /* column 1 */
fprintf(stdout, "   column1 (integer)  : ");
if (is_null[0])
  fprintf(stdout, " NULL\n");
else
  fprintf(stdout, " %d(%ld), int_data, length[0]);
/* column 2 */
fprintf(stdout, "   column2 (string)   : ");
if (is_null[1])
  fprintf(stdout, " NULL\n");
else
  fprintf(stdout, " %s(%ld), str_data, length[1]);
/* column 3 */
fprintf(stdout, "   column3 (smallint) : ");
if (is_null[2])
  fprintf(stdout, " NULL\n");
else
  fprintf(stdout, " %d(%ld), small_data, length[2]);
/* column 4 */
fprintf(stdout, "   column4 (timestamp): ");
if (is_null[3])
  fprintf(stdout, " NULL\n");
else
  fprintf(stdout, " %04d-%02d-%02d %02d:%02d:%02d (%ld),
  ts.year, ts.month, ts.day,
  ts.hour, ts.minute, ts.second,
  length[3]);
fprintf(stdout, "\n");
/* Validate rows fetched */
fprintf(stdout, " total rows fetched: %d\n", row_count);
if (row_count != 2)
{
  fprintf(stderr, " MySQL failed to return all rows\n");
  exit(0);
}
/* Free the prepared result metadata */
mysql_free_result(prepare_meta_result);

/* Close the statement */
if (mysql_stmt_close(stmt))
{
  /* mysql_stmt_close() invalidates stmt, so call */
  /* mysql_error(mysql) rather than mysql_stmt_error(stmt) */
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

23.7.10.12 mysql_stmt_fetch_column()

int mysql_stmt_fetch_column(MYSQL_STMT *stmt, MYSQL_BIND *bind, unsigned int
column, unsigned long offset)

Description

Fetches one column from the current result set row. bind provides the buffer where data should be
placed. It should be set up the same way as for mysql_stmt_bind_result(). column indicates which
column to fetch. The first column is numbered 0. offset is the offset within the data value at which to
begin retrieving data. This can be used for fetching the data value in pieces. The beginning of the value is offset 0.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_INVALID_PARAMETER_NO**
  Invalid column number.

- **CR_NO_DATA**
  The end of the result set has already been reached.

### 23.7.10.13 `mysql_stmt_field_count()`

```c
unsigned int mysql_stmt_field_count(MYSQL_STMT *stmt)
```

**Description**

Returns the number of columns for the most recent statement for the statement handler. This value is zero for statements such as `INSERT` or `DELETE` that do not produce result sets.

`mysql_stmt_field_count()` can be called after you have prepared a statement by invoking `mysql_stmt_prepare()`.

**Return Values**

An unsigned integer representing the number of columns in a result set.

**Errors**

None.

### 23.7.10.14 `mysql_stmt_free_result()`

```c
my_bool mysql_stmt_free_result(MYSQL_STMT *stmt)
```

**Description**

Releases memory associated with the result set produced by execution of the prepared statement. If there is a cursor open for the statement, `mysql_stmt_free_result()` closes it.

**Return Values**

Zero for success. Nonzero if an error occurred.

### 23.7.10.15 `mysql_stmt_init()`

```c
MYSQL_STMT *mysql_stmt_init(MYSQL *mysql)
```

**Description**

Creates and returns a `MYSQL_STMT` handler. The handler should be freed with `mysql_stmt_close()`, at which point the handler becomes invalid and should no longer be used.
C API Prepared Statement Function Descriptions

See also Section 23.7.8, “C API Prepared Statement Data Structures”, for more information.

Return Values

A pointer to a MYSQL_STMT structure in case of success. NULL if out of memory.

Errors

• CR_OUT_OF_MEMORY
  Out of memory.

23.7.10.16 mysql_stmt_insert_id()

my_ulonglong mysql_stmt_insert_id(MYSQL_STMT *stmt)

Description

Returns the value generated for an AUTO_INCREMENT column by the prepared INSERT or UPDATE statement. Use this function after you have executed a prepared INSERT statement on a table which contains an AUTO_INCREMENT field.

See Section 23.7.6.37, “mysql_insert_id()”, for more information.

Return Values

Value for AUTO_INCREMENT column which was automatically generated or explicitly set during execution of prepared statement, or value generated by LAST_INSERT_ID(expr) function. Return value is undefined if statement does not set AUTO_INCREMENT value.

Errors

None.

23.7.10.17 mysql_stmt_next_result()

int mysql_stmt_next_result(MYSQL_STMT *mysql)

Description

This function is used when you use prepared CALL statements to execute stored procedures, which can return multiple result sets. Use a loop that calls mysql_stmt_next_result() to determine whether there are more results. If a procedure has OUT or INOUT parameters, their values will be returned as a single-row result set following any other result sets. The values will appear in the order in which they are declared in the procedure parameter list.

For information about the effect of unhandled conditions on procedure parameters, see Section 13.6.7.5, “Condition Handling and OUT or INOUT Parameters”.

mysql_stmt_next_result() returns a status to indicate whether more results exist. If mysql_stmt_next_result() returns an error, there are no more results.

Before each call to mysql_stmt_next_result(), you must call mysql_stmt_free_result() for the current result if it produced a result set (rather than just a result status).

After calling mysql_stmt_next_result() the state of the connection is as if you had called mysql_stmt_execute(). This means that you can call mysql_stmt_bind_result(), mysql_stmt_affected_rows(), and so forth.
It is also possible to test whether there are more results by calling `mysql_more_results()`. However, this function does not change the connection state, so if it returns true, you must still call `mysql_stmt_next_result()` to advance to the next result.

For an example that shows how to use `mysql_stmt_next_result()`, see Section 23.7.17, "C API Prepared CALL Statement Support".

### Return Values

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Successful and there are more results</td>
</tr>
<tr>
<td>-1</td>
<td>Successful and there are no more results</td>
</tr>
<tr>
<td>&gt;0</td>
<td>An error occurred</td>
</tr>
</tbody>
</table>

### Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query.

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

### 23.7.10.18 mysql_stmt_num_rows()

```c
my_ulonglong mysql_stmt_num_rows(MYSQL_STMT *stmt)
```

#### Description

Returns the number of rows in the result set.

The use of `mysql_stmt_num_rows()` depends on whether you used `mysql_stmt_store_result()` to buffer the entire result set in the statement handler. If you use `mysql_stmt_store_result()`, `mysql_stmt_num_rows()` may be called immediately. Otherwise, the row count is unavailable unless you count the rows as you fetch them.

`mysql_stmt_num_rows()` is intended for use with statements that return a result set, such as `SELECT`. For statements such as `INSERT`, `UPDATE`, or `DELETE`, the number of affected rows can be obtained with `mysql_stmt_affected_rows()`.

#### Return Values

The number of rows in the result set.

#### Errors

None.
23.7.19 mysql_stmt_param_count()

    unsigned long mysql_stmt_param_count(MYSQL_STMT *stmt)

Description

Returns the number of parameter markers present in the prepared statement.

Return Values

An unsigned long integer representing the number of parameters in a statement.

Errors

None.

Example

See the Example in Section 23.7.10, "mysql_stmt_execute()".

23.7.20 mysql_stmt_param_metadata()

    MYSQL_RES *mysql_stmt_param_metadata(MYSQL_STMT *stmt)

This function currently does nothing.

23.7.21 mysql_stmt_prepare()

    int mysql_stmt_prepare(MYSQL_STMT *stmt, const char *stmt_str, unsigned long length)

Description

Given the statement handler returned by mysql_stmt_init(), prepares the SQL statement pointed to by the string stmt_str and returns a status value. The string length should be given by the length argument. The string must consist of a single SQL statement. You should not add a terminating semicolon (;) or \g to the statement.

The application can include one or more parameter markers in the SQL statement by embedding question mark (?) characters into the SQL string at the appropriate positions.

The markers are legal only in certain places in SQL statements. For example, they are permitted in the VALUES() list of an INSERT statement (to specify column values for a row), or in a comparison with a column in a WHERE clause to specify a comparison value. However, they are not permitted for identifiers (such as table or column names), or to specify both operands of a binary operator such as the = equal sign. The latter restriction is necessary because it would be impossible to determine the parameter type. In general, parameters are legal only in Data Manipulation Language (DML) statements, and not in Data Definition Language (DDL) statements.

The parameter markers must be bound to application variables using mysql_stmt_bind_param() before executing the statement.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation".
Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_OUT_OF_MEMORY**
  
  Out of memory.

- **CR_SERVER_GONE_ERROR**
  
  The MySQL server has gone away.

- **CR_SERVER_LOST**
  
  The connection to the server was lost during the query

- **CR_UNKNOWN_ERROR**
  
  An unknown error occurred.

If the prepare operation was unsuccessful (that is, `mysql_stmt_prepare()` returns nonzero), the error message can be obtained by calling `mysql_stmt_error()`.

Example

See the Example in Section 23.7.10.10, "mysql_stmt_execute()".

### 23.7.10.22 `mysql_stmt_reset()`

```c
my_bool mysql_stmt_reset(MYSQL_STMT *stmt)
```

Description

Resets a prepared statement on client and server to state after prepare. It resets the statement on the server, data sent using `mysql_stmt_send_long_data()`, unbuffered result sets and current errors. It does not clear bindings or stored result sets. Stored result sets will be cleared when executing the prepared statement (or closing it).

To re-prepare the statement with another query, use `mysql_stmt_prepare()`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- **CR_COMMANDS_OUT_OF_SYNC**
  
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
C API Prepared Statement Function Descriptions

The MySQL server has gone away.

- **CR_SERVER_LOST**
  The connection to the server was lost during the query

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

### 23.7.10.23 mysql_stmt_result_metadata()

```c
MYSQL_RES *mysql_stmt_result_metadata(MYSQL_STMT *stmt)
```

**Description**

If a statement passed to `mysql_stmt_prepare()` is one that produces a result set, `mysql_stmt_result_metadata()` returns the result set metadata in the form of a pointer to a `MYSQL_RES` structure that can be used to process the meta information such as number of fields and individual field information. This result set pointer can be passed as an argument to any of the field-based API functions that process result set metadata, such as:

- `mysql_num_fields()`
- `mysql_fetch_field()`
- `mysql_fetch_field_direct()`
- `mysql_fetch_fields()`
- `mysql_field_count()`
- `mysql_field_seek()`
- `mysql_field_tell()`
- `mysql_free_result()`

The result set structure should be freed when you are done with it, which you can do by passing it to `mysql_free_result()`. This is similar to the way you free a result set obtained from a call to `mysql_store_result()`.

The result set returned by `mysql_stmt_result_metadata()` contains only metadata. It does not contain any row results. The rows are obtained by using the statement handler with `mysql_stmt_fetch()`.

**Return Values**

A `MYSQL_RES` result structure. **NULL** if no meta information exists for the prepared query.

**Errors**

- **CR_OUT_OF_MEMORY**
  Out of memory.
- **CR_UNKNOWN_ERROR**
An unknown error occurred.

Example

See the Example in Section 23.7.10.11, “mysql_stmt_fetch()”.

23.7.10.24 mysql_stmt_row_seek()

MYSQL_ROW_OFFSET mysql_stmt_row_seek(MYSQL_STMT *stmt, MYSQL_ROW_OFFSET offset)

Description

Sets the row cursor to an arbitrary row in a statement result set. The offset value is a row offset that should be a value returned from mysql_stmt_row_tell() or from mysql_stmt_row_seek(). This value is not a row number; if you want to seek to a row within a result set by number, use mysql_stmt_data_seek() instead.

This function requires that the result set structure contains the entire result of the query, so mysql_stmt_row_seek() may be used only in conjunction with mysql_stmt_store_result().

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to mysql_stmt_row_seek().

Errors

None.

23.7.10.25 mysql_stmt_row_tell()

MYSQL_ROW_OFFSET mysql_stmt_row_tell(MYSQL_STMT *stmt)

Description

Returns the current position of the row cursor for the last mysql_stmt_fetch(). This value can be used as an argument to mysql_stmt_row_seek().

You should use mysql_stmt_row_tell() only after mysql_stmt_store_result().

Return Values

The current offset of the row cursor.

Errors

None.

23.7.10.26 mysql_stmt_send_long_data()

my_bool mysql_stmt_send_long_data(MYSQL_STMT *stmt, unsigned int parameter_number, const char *data, unsigned long length)

Description

Enables an application to send parameter data to the server in pieces (or “chunks”). Call this function after mysql_stmt_bind_param() and before mysql_stmt_execute(). It can be called multiple times to
send the parts of a character or binary data value for a column, which must be one of the **TEXT** or **BLOB** data types.

`parameter_number` indicates which parameter to associate the data with. Parameters are numbered beginning with 0. `data` is a pointer to a buffer containing data to be sent, and `length` indicates the number of bytes in the buffer.

**Note**

The next `mysql_stmt_execute()` call ignores the bind buffer for all parameters that have been used with `mysql_stmt_send_long_data()` since last `mysql_stmt_execute()` or `mysql_stmt_reset()`.

If you want to reset/forget the sent data, you can do it with `mysql_stmt_reset()`. See Section 23.7.10.22, "mysql_stmt_reset()".

As of MySQL 5.5.11, the `max_long_data_size` system variable controls the maximum size of parameter values that can be sent with `mysql_stmt_send_long_data()`. If this variable not set at server startup, the default is the value of the `max_allowed_packet` system variable. `max_long_data_size` is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_INVALID_BUFFER_USE**
  The parameter does not have a string or binary type.

- **CR_INVALID_PARAMETER_NO**
  Invalid parameter number.

- **CR_COMMANDS_OUT_OF_SYNC**
  Commands were executed in an improper order.

- **CR_SERVER_GONE_ERROR**
  The MySQL server has gone away.

- **CR_OUT_OF_MEMORY**
  Out of memory.

- **CR_UNKNOWN_ERROR**
  An unknown error occurred.

**Example**

The following example demonstrates how to send the data for a **TEXT** column in chunks. It inserts the data value 'MySQL - The most popular Open Source database' into the **text_column** column. The `mysql` variable is assumed to be a valid connection handler.
#define INSERT_QUERY "INSERT INTO \n   test_long_data(text_column) VALUES(?)"

MYSQL_BIND bind[1];
long       length;
stmt = mysql_stmt_init(mysql);
if (!stmt)
{    
    fprintf(stderr, " mysql_stmt_init(), out of memory\n");    
    exit(0);    
}
if (mysql_stmt_prepare(stmt, INSERT_QUERY, strlen(INSERT_QUERY)))
{    
    fprintf(stderr, " \n mysql_stmt_prepare(), INSERT failed\n");    
    fprintf(stderr, " %s", mysql_stmt_error(stmt));    
    exit(0);    
}
memset(bind, 0, sizeof(bind));
bind[0].buffer_type= MYSQL_TYPE_STRING;
bind[0].length= &length;
bind[0].is_null= 0;
/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{    
    fprintf(stderr, "\n param bind failed\n");    
    fprintf(stderr, " %s", mysql_stmt_error(stmt));    
    exit(0);    
}
/* Supply data in chunks to server */
if (mysql_stmt_send_long_data(stmt,0,"MySQL",5))
{    
    fprintf(stderr, "\n send_long_data failed\n");    
    fprintf(stderr, " %s", mysql_stmt_error(stmt));    
    exit(0);    
}
/* Supply the next piece of data */
if (mysql_stmt_send_long_data(stmt,0," - The most popular Open Source database",40))
{    
    fprintf(stderr, "\n send_long_data failed\n");    
    fprintf(stderr, " %s", mysql_stmt_error(stmt));    
    exit(0);    
}
/* Now, execute the query */
if (mysql_stmt_execute(stmt))
{    
    fprintf(stderr, "\n mysql_stmt_execute failed\n");    
    fprintf(stderr, " %s", mysql_stmt_error(stmt));    
    exit(0);    
}

23.7.10.27 mysql_stmt_sqlstate()

    const char *mysql_stmt_sqlstate(MYSQL_STMT *stmt)

Description

For the statement specified by stmt, mysql_stmt_sqlstate() returns a null-terminated string containing the SQLSTATE error code for the most recently invoked prepared statement API function that can succeed or fail. The error code consists of five characters. "00000" means “no error.” The values are
Specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, Errors, Error Codes, and Common Problems.

Not all MySQL errors are mapped to SQLSTATE codes. The value "HY000" (general error) is used for unmapped errors.

If the failed statement API function was mysql_stmt_close(), do not call mysql_stmt_sqlstate() to obtain error information because mysql_stmt_close() makes the statement handler invalid. Call mysql_sqlstate() instead.

**Return Values**

A null-terminated character string containing the SQLSTATE error code.

### 23.7.10.28 mysql_stmt_store_result()

```c
int mysql_stmt_store_result(MYSQL_STMT *stmt)
```

**Description**

Result sets are produced by calling `mysql_stmt_execute()` to executed prepared statements for SQL statements such as `SELECT`, `SHOW`, `DESCRIBE`, and `EXPLAIN`. By default, result sets for successfully executed prepared statements are not buffered on the client and `mysql_stmt_fetch()` fetches them one at a time from the server. To cause the complete result set to be buffered on the client, call `mysql_stmt_store_result()` after binding data buffers with `mysql_stmt_bind_result()` and before calling `mysql_stmt_fetch()` to fetch rows. (For an example, see Section 23.7.10.11, `mysql_stmt_fetch()`.)

`mysql_stmt_store_result()` is optional for result set processing, unless you will call `mysql_stmt_data_seek()`, `mysql_stmt_row_seek()`, or `mysql_stmt_row_tell()`. Those functions require a seekable result set.

It is unnecessary to call `mysql_stmt_store_result()` after executing an SQL statement that does not produce a result set, but if you do, it does not harm or cause any notable performance problem. You can detect whether the statement produced a result set by checking if `mysql_stmt_result_metadata()` returns `NULL`. For more information, refer to Section 23.7.10.23, "mysql_stmt_result_metadata()."

**Note**

MySQL does not by default calculate `MYSQL_FIELD->max_length` for all columns in `mysql_stmt_store_result()` because calculating this would slow down `mysql_stmt_store_result()` considerably and most applications do not need `max_length`. If you want `max_length` to be updated, you can call `mysql_stmt_attr_set(MYSQL_STMT, STMT_ATTR_UPDATE_MAX_LENGTH, &flag)` to enable this. See Section 23.7.10.3, "mysql_stmt_attr_set()."

**Return Values**

Zero for success. Nonzero if an error occurred.

**Errors**

- **CR_COMMANDS_OUT_OF_SYNC**

  Commands were executed in an improper order.

- **CR_OUT_OF_MEMORY**
23.7.11 C API Threaded Function Descriptions

To create a threaded client, use the functions described in the following sections. See also Section 23.7.3.2, “Writing C API Threaded Client Programs”.

23.7.11.1 my_init()

```c
void my_init(void)
```

Description

`my_init()` initializes some global variables that MySQL needs. It also calls `mysql_thread_init()` for this thread.

It is necessary for `my_init()` to be called early in the initialization phase of a program’s use of the MySQL client library. However, `my_init()` is automatically called by `mysql_init()`, `mysql_library_init()`, `mysql_server_init()`, and `mysql_connect()`. If you ensure that your program invokes one of those functions before any other MySQL calls, there is no need to invoke `my_init()` explicitly.

To access the prototype for `my_init()`, your program should include these header files:

```c
#include <my_global.h>
#include <my_sys.h>
```

Return Values

None.

23.7.11.2 mysql_thread_end()

```c
void mysql_thread_end(void)
```

Description

Call this function before calling `pthread_exit()` to free memory allocated by `mysql_thread_init()`. `mysql_thread_end()` is not invoked automatically by the client library. It must be called explicitly to avoid a memory leak.

Return Values

None.
23.7.11.3 mysql_thread_init()

my_bool mysql_thread_init(void)

Description

This function must be called early within each created thread to initialize thread-specific variables. However, it may be unnecessarily to invoke it explicitly. Calling mysql_thread_init() is automatically handled my_init(), which itself is called by mysql_init(), mysql_library_init(), mysql_server_init(), and mysql_connect(). If you invoke any of those functions, mysql_thread_init() is called for you.

Return Values

Zero for success. Nonzero if an error occurred.

23.7.11.4 mysql_thread_safe()

unsigned int mysql_thread_safe(void)

Description

This function indicates whether the client library is compiled as thread-safe.

Return Values

1 if the client library is thread-safe, 0 otherwise.

23.7.12 C API Embedded Server Function Descriptions

MySQL applications can be written to use an embedded server. See Section 23.6, "libmysqld, the Embedded MySQL Server Library". To write such an application, you must link it against the libmysqld library by using the -lmysql flag rather than linking it against the libmysqlclient client library by using the -lmysqlclient flag. However, the calls to initialize and finalize the library are the same whether you write a client application or one that uses the embedded server: Call mysql_library_init() to initialize the library and mysql_library_end() when you are done with it. See Section 23.7.5, "C API Function Overview".

23.7.12.1 mysql_server_end()

void mysql_server_end(void)

Description

This function finalizes the MySQL library, which should be done when you are done using the library. However, mysql_server_end() is deprecated and mysql_library_end() should be used instead. See Section 23.7.6.39, "mysql_library_end()".

Note

To avoid memory leaks after the application is done using the library (for example, after closing the connection to the server), be sure to call mysql_server_end() (or mysql_library_end()) explicitly. This enables memory management to be performed to clean up and free resources used by the library.
Return Values

None.

23.7.12.2 mysql_server_init()

```c
int mysql_server_init(int argc, char **argv, char **groups)
```

Description

This function initializes the MySQL client library, which must be done before you call any other MySQL function. However, `mysql_server_init()` is deprecated and you should call `mysql_library_init()` instead. See Section 23.7.6.40, “mysql_library_init()”.

Note

To avoid memory leaks after the application is done using the library (for example, after closing the connection to the server), be sure to call `mysql_server_end()` (or `mysql_library_end()`) explicitly. This enables memory management to be performed to clean up and free resources used by the library. See Section 23.7.6.39, “mysql_library_end()”.

Return Values

Zero for success. Nonzero if an error occurred.

23.7.13 C API Client Plugin Functions

This section describes functions used for the client-side plugin API. They enable management of client plugins. For a description of the `st_mysql_client_plugin` structure used by these functions, see Client Plugin Descriptors.

It is unlikely that a client program needs to call the functions in this section. For example, a client that supports the use of authentication plugins normally causes a plugin to be loaded by calling `mysql_options()` to set the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options:

```c
char *plugin_dir = "path_to_plugin_dir";
char *default_auth = "plugin_name";
/* ... process command-line options ... */
mysql_options(&mysql, MYSQL_PLUGIN_DIR, plugin_dir);
mysql_options(&mysql, MYSQL_DEFAULT_AUTH, default_auth);
```

Typically, the program will also accept `--plugin-dir` and `--default-auth` options that enable users to override the default values.

23.7.13.1 mysql_client_find_plugin()

```c
struct st_mysql_client_plugin *mysql_client_find_plugin(MYSQL *mysql, const char *name, int type)
```

Description

Returns a pointer to a loaded plugin, loading the plugin first if necessary. An error occurs if the type is invalid or the plugin cannot be found or loaded.
Specify the parameters as follows:

- **mysql**: A pointer to a `MYSQL` structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.

- **name**: The plugin name.

- **type**: The plugin type.

**Return Values**

A pointer to the plugin for success. `NULL` if an error occurred.

**Errors**

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.7.6.15, “mysql_error()”, and Section 23.7.6.14, “mysql_errno()”.

**Example**

```c
MYSQL mysql;
struct st_mysql_client_plugin *p;

if (p = mysql_client_find_plugin(&mysql, "myplugin", MYSQL_CLIENT_AUTHENTICATION_PLUGIN, 0))
{
    printf("Plugin version: %d.%d.%d\n", p->version[0], p->version[1], p->version[2]);
}
```

23.7.13.2 `mysql_client_register_plugin()`

```c
struct st_mysql_client_plugin *mysql_client_register_plugin(MYSQL *mysql, struct st_mysql_client_plugin *plugin)
```

**Description**

Adds a plugin structure to the list of loaded plugins. An error occurs if the plugin is already loaded.

Specify the parameters as follows:

- **mysql**: A pointer to a `MYSQL` structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.

- **plugin**: A pointer to the plugin structure.

**Return Values**

A pointer to the plugin for success. `NULL` if an error occurred.

**Errors**

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.7.6.15, “mysql_error()”, and Section 23.7.6.14, “mysql_errno()”.

23.7.13.3 `mysql_load_plugin()`
struct st_mysql_client_plugin *mysql_load_plugin(MYSQL *mysql, const char *name, int type, int argc, ...)  

Description  

Loads a MySQL client plugin, specified by name and type. An error occurs if the type is invalid or the plugin cannot be loaded.

It is not possible to load multiple plugins of the same type. An error occurs if you try to load a plugin of a type already loaded.

Specify the parameters as follows:

• **mysql**: A pointer to a MYSQL structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.

• **name**: The name of the plugin to load.

• **type**: The type of plugin to load, or -1 to disable type checking. If type is not -1, only plugins matching the type are considered for loading.

• **argc**: The number of following arguments (0 if there are none). Interpretation of any following arguments depends on the plugin type.

Another way to cause plugins to be loaded is to set the LIBMYSQL_PLUGINS environment variable to a list of semicolon-separated plugin names. For example:

```bash  
export LIBMYSQL_PLUGINS="myplugin1;myplugin2"  
```

Plugins named by LIBMYSQL_PLUGINS are loaded when the client program calls `mysql_library_init()`. No error is reported if problems occur loading these plugins.

Return Values  

A pointer to the plugin if it was loaded successfully. NULL if an error occurred.

Errors  

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.7.15, "mysql_error()", and Section 23.7.14, "mysql_errno()".

Example  

```c  
MYSQL mysql;  
if(!mysql_load_plugin(&mysql, "myplugin",  
                         MYSQL_CLIENT_AUTHENTICATION_PLUGIN, 0))  
{  
  fprintf(stderr, "Error: %s\n", mysql_error(&mysql));  
  exit(-1);  
}  
```

See Also  

See also Section 23.7.13.3, "mysql_load_plugin()", Section 23.7.15, "mysql_error()", Section 23.7.14, "mysql_errno()".
23.7.13.4 mysql_load_plugin_v()

```
struct st_mysql_client_plugin *mysql_load_plugin_v(MYSQL *mysql, const char *name, int type, int argc, va_list args)
```

**Description**

This function is equivalent to `mysql_load_plugin()`, but it accepts a `va_list` instead of a variable list of parameters.

**See Also**

See also Section 23.7.13.3, "mysql_load_plugin()".

23.7.13.5 mysql_plugin_options()

```
int mysql_plugin_options(struct st_mysql_client_plugin *plugin, const char *option, const void *value)
```

**Description**

Passes an option type and value to a plugin. This function can be called multiple times to set several options. If the plugin does not have an option handler, an error occurs.

Specify the parameters as follows:

- **plugin**: A pointer to the plugin structure.
- **option**: The option to be set.
- **value**: A pointer to the option value.

**Return Values**

Zero for success, 1 if an error occurred. If the plugin has an option handler, that handler should also return zero for success and 1 if an error occurred.

23.7.14 C API Encrypted Connection Support

For applications that require control over how encrypted connections are established, the C API provides these capabilities:

- The `mysql_ssl_set()` and `mysql_options()` functions enable applications to set the appropriate SSL/TLS options before calling `mysql_real_connect()`. For example, to require the use of an encrypted connection, see Enforcing an Encrypted Connection.

- The `mysql_get_ssl_cipher()` function enables applications to determine, after a connection has been established, whether the connection uses encryption. A NULL return value indicates that encryption is not being used. A non-NULL return value indicates an encrypted connection and names the encryption cipher. See Section 23.7.6.33, "mysql_get_ssl_cipher()".

- C API Options for Encrypted Connections

- Enforcing an Encrypted Connection
C API Encrypted Connection Support

• Improving Security of Encrypted Connections

C API Options for Encrypted Connections

mysql_ssl_set() takes the following arguments for control over use of encrypted connections. For more information, see Section 23.7.6.67, “mysql_ssl_set()”.

- key: The path name of the client private key file.
- cert: The path name of the client public key certificate file.
- ca: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server.
- capath: The path name of the directory that contains trusted SSL CA certificate files.
- cipher: The list of permissible ciphers for SSL encryption.

mysql_options() provides the following options for control over use of encrypted connections. For option details, see Section 23.7.6.49, “mysql_options()”.

- MYSQL_OPT_SSL_MODE: The connection security state.
- MYSQL_OPT_SSL_VERIFY_SERVER_CERT: Whether to perform host name identity verification of the server certificate Common Name value.

Enforcing an Encrypted Connection

mysql_ssl_set() options for information such as SSL certificate and key files are used to establish an encrypted connection if such connections are available, but do not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the following technique:

1. Call mysql_ssl_set() and mysql_options() as necessary to supply the appropriate SSL parameters (certificate and key files, encryption ciphers, and so forth).

2. For MySQL 5.5.55 and higher, MYSQL_OPT_SSL_MODE is available, so call mysql_options() to pass the MYSQL_OPT_SSL_MODE option with a value of SSL_MODE_REQUIRED.

Important

In MySQL 5.5, the minor C API version number was not incremented for the addition of MYSQL_OPT_SSL_MODE in MySQL 5.5.55. Application programs compiled for MySQL 5.5 that require MYSQL_OPT_SSL_MODE may fail to operate properly if the dynamic loader provides an older client library that does not include MYSQL_OPT_SSL_MODE. Such applications must be written to handle this possibility by checking whether the mysql_options() call succeeds or fails.

3. Call mysql_real_connect() to connect to the server. As of MySQL 5.5.55, the call fails if an encrypted connection cannot be obtained; exit with an error. Prior to 5.5.55 (before MYSQL_OPT_SSL_MODE is available), clients are required to check for themselves, after calling mysql_real_connect(), whether the connection is encrypted. To do this if mysql_real_connect() succeeds, call mysql_get_ssl_cipher() to check whether the resulting connection is encrypted. If not, exit with an error.

MySQL clients implement this technique using a wrapper function named mysql_connect_ssl_check() to establish and check the connection, rather than calling
mysql_real_connect() directly. To see how this works, look in the client directory of a MySQL source distribution at the source for any of the standard MySQL clients, as well as the client_priv.h file that contains the mysql_connect_ssl_check() wrapper function implementation. A call to mysql_connect_ssl_check() takes arguments like the arguments to mysql_real_connect(), plus an extra argument indicating whether to require an encrypted connection:

```c
if (!mysql_connect_ssl_check(&mysql, host, user, pass, db,
    port, sock, flags,
    opt_ssl_required))
{
    /* failure: connection not obtained, or not encrypted if required to be */
}
else
{
    /* success: connection obtained, encrypted if required to be */
}
```

Version notes:

- In MySQL 5.5.49, the --ssl-mode=REQUIRED command-line option was backported from MySQL 5.7 to MySQL 5.5. Clients can check for this option and use it to determine whether to require an encrypted connection. If so, clients must check for themselves, after calling mysql_real_connect(), whether the connection is encrypted, and fail if not. To do this, call mysql_get_ssl_cipher() and check the return value.

- In MySQL 5.5.55, the MYSQL_OPT_SSL_MODE option for mysql_options() was backported from MySQL 5.7 to MySQL 5.5. A call to mysql_options() to set the MYSQL_OPT_SSL_MODE option to value of SSL_MODE_REQUIRED suffices to cause mysql_real_connect() to fail if the connection is not encrypted. mysql_get_ssl_cipher() can still be called after connecting, although it is not necessary to do so.

### Improving Security of Encrypted Connections

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended:

- To specify the CA certificate, call mysql_ssl_set() to pass the ca (or capath) argument.

- To enable host name identity verification, call mysql_options() to enable the MYSQL_OPT_SSL_VERIFY_SERVER_CERT option.

- To require an encrypted connection, call mysql_options() to pass the MYSQL_OPT_SSL_MODE option with a value of SSL_MODE_REQUIRED. (For details about SSL_MODE_REQUIRED, see Enforcing an Encrypted Connection.)

### 23.7.15 C API Multiple Statement Execution Support

By default, mysql_query() and mysql_real_query() interpret their statement string argument as a single statement to be executed, and you process the result according to whether the statement produces a result set (a set of rows, as for SELECT) or an affected-rows count (as for INSERT, UPDATE, and so forth).

MySQL also supports the execution of a string containing multiple statements separated by semicolon (;) characters. This capability is enabled by special options that are specified either when you connect to the server with mysql_real_connect() or after connecting by calling mysql_set_server_option().
Executing a multiple-statement string can produce multiple result sets or row-count indicators. Processing these results involves a different approach than for the single-statement case: After handling the result from the first statement, it is necessary to check whether more results exist and process them in turn if so. To support multiple-result processing, the C API includes the `mysql_more_results()` and `mysql_next_result()` functions. These functions are used at the end of a loop that iterates as long as more results are available. *Failure to process the result this way may result in a dropped connection to the server.*

Multiple-result processing also is required if you execute `CALL` statements for stored procedures. Results from a stored procedure have these characteristics:

- Statements within the procedure may produce result sets (for example, if it executes `SELECT` statements). These result sets are returned in the order that they are produced as the procedure executes.

  In general, the caller cannot know how many result sets a procedure will return. Procedure execution may depend on loops or conditional statements that cause the execution path to differ from one call to the next. Therefore, you must be prepared to retrieve multiple results.

- The final result from the procedure is a status result that includes no result set. The status indicates whether the procedure succeeded or an error occurred.

The multiple statement and result capabilities can be used only with `mysql_query()` or `mysql_real_query()`. They cannot be used with the prepared statement interface. Prepared statement handlers are defined to work only with strings that contain a single statement. See Section 23.7.7, "C API Prepared Statements".

To enable multiple-statement execution and result processing, the following options may be used:

- The `mysql_real_connect()` function has a `flags` argument for which two option values are relevant:

  - `CLIENT_MULTI_RESULTS` enables the client program to process multiple results. This option must be enabled if you execute `CALL` statements for stored procedures that produce result sets. Otherwise, such procedures result in an error Error 1312 (0A000): PROCEDURE proc_name can't return a result set in the given context. `CLIENT_MULTI_RESULTS` is enabled by default.

  - `CLIENT_MULTI_STATEMENTS` enables `mysql_query()` and `mysql_real_query()` to execute statement strings containing multiple statements separated by semicolons. This option also enables `CLIENT_MULTI_RESULTS` implicitly, so a `flags` argument of `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()` is equivalent to an argument of `CLIENT_MULTI_STATEMENTS | CLIENT_MULTI_RESULTS`. That is, `CLIENT_MULTI_STATEMENTS` is sufficient to enable multiple-statement execution and all multiple-result processing.

- After the connection to the server has been established, you can use the `mysql_set_server_option()` function to enable or disable multiple-statement execution by passing it an argument of `MYSQL_OPTION_MULTI_STATEMENTS_ON` or `MYSQL_OPTION_MULTI_STATEMENTS_OFF`. Enabling multiple-statement execution with this function also enables processing of "simple" results for a multiple-statement string where each statement produces a single result, but is *not* sufficient to permit processing of stored procedures that produce result sets.

The following procedure outlines a suggested strategy for handling multiple statements:

1. Pass `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()`, to fully enable multiple-statement execution and multiple-result processing.
2. After calling `mysql_query()` or `mysql_real_query()` and verifying that it succeeds, enter a loop within which you process statement results.

3. For each iteration of the loop, handle the current statement result, retrieving either a result set or an affected-rows count. If an error occurs, exit the loop.

4. At the end of the loop, call `mysql_next_result()` to check whether another result exists and initiate retrieval for it if so. If no more results are available, exit the loop.

One possible implementation of the preceding strategy is shown following. The final part of the loop can be reduced to a simple test of whether `mysql_next_result()` returns nonzero. The code as written distinguishes between no more results and an error, which enables a message to be printed for the latter occurrence.

```c
/* connect to server with the CLIENT_MULTI_STATEMENTS option */
if (mysql_real_connect (mysql, host_name, user_name, password,
     db_name, port_num, socket_name, CLIENT_MULTI_STATEMENTS) == NULL)
{
    printf("mysql_real_connect() failed\n");
    mysql_close(mysql);
    exit(1);
}
/* execute multiple statements */
status = mysql_query(mysql,
    "DROP TABLE IF EXISTS test_table;
    CREATE TABLE test_table(id INT);
    INSERT INTO test_table VALUES(10);
    UPDATE test_table SET id=20 WHERE id=10;
    SELECT * FROM test_table;
    DROP TABLE test_table");
if (status)
{
    printf("Could not execute statement(s)\n");
    mysql_close(mysql);
    exit(0);
}
/* process each statement result */
do {
    /* did current statement return data? */
    result = mysql_store_result(mysql);
    if (result)
    {
        /* yes; process rows and free the result set */
        process_result_set(mysql, result);
        mysql_free_result(result);
    }
    else          /* no result set or error */
    {
        if (mysql_field_count(mysql) == 0)
        {
            printf("0 rows affected\n",
                  mysql_affected_rows(mysql));
        }
        else   /* some error occurred */
        {
            printf("Could not retrieve result set\n");
            break;
        }
    }
    /* more results? -1 = no, >0 = error, 0 = yes (keep looping) */
    if ((status = mysql_next_result(mysql)) > 0)
        printf("Could not execute statement\n");
}while (status == 0);
```
23.7.16 C API Prepared Statement Handling of Date and Time Values

The binary (prepared statement) protocol enables you to send and receive date and time values (\texttt{DATE}, \texttt{TIME}, \texttt{DATETIME}, and \texttt{TIMESTAMP}), using the \texttt{MYSQL_TIME} structure. The members of this structure are described in Section 23.7.8, “C API Prepared Statement Data Structures”.

To send temporal data values, create a prepared statement using \texttt{mysql_stmt_prepare()}. Then, before calling \texttt{mysql_stmt_execute()} to execute the statement, use the following procedure to set up each temporal parameter:

1. In the \texttt{MYSQL_BIND} structure associated with the data value, set the \texttt{buffer_type} member to the type that indicates what kind of temporal value you’re sending. For \texttt{DATE}, \texttt{TIME}, \texttt{DATETIME}, or \texttt{TIMESTAMP} values, set \texttt{buffer_type} to \texttt{MYSQL_TYPE_DATE}, \texttt{MYSQL_TYPE_TIME}, \texttt{MYSQL_TYPE_DATETIME}, or \texttt{MYSQL_TYPE_TIMESTAMP}, respectively.

2. Set the \texttt{buffer} member of the \texttt{MYSQL_BIND} structure to the address of the \texttt{MYSQL_TIME} structure in which you pass the temporal value.

3. Fill in the members of the \texttt{MYSQL_TIME} structure that are appropriate for the type of temporal value to pass.

Use \texttt{mysql_stmt_bind_param()} to bind the parameter data to the statement. Then you can call \texttt{mysql_stmt_execute()}.

To retrieve temporal values, the procedure is similar, except that you set the \texttt{buffer_type} member to the type of value you expect to receive, and the \texttt{buffer} member to the address of a \texttt{MYSQL_TIME} structure into which the returned value should be placed. Use \texttt{mysql_stmt_bind_result()} to bind the buffers to the statement after calling \texttt{mysql_stmt_execute()} and before fetching the results.

Here is a simple example that inserts \texttt{DATE}, \texttt{TIME}, and \texttt{TIMESTAMP} data. The \texttt{mysql} variable is assumed to be a valid connection handler.

```c
MYSQL_TIME ts;
MYSQL_BIND bind[3];
MYSQL_STMT *stmt;

strmov(query, "INSERT INTO test_table(date_field, time_field, \
    timestamp_field) VALUES(?,?,?);

stmt = mysql_stmt_init(mysql);
if (!stmt)
    {fprintf(stderr, " mysql_stmt_init(), out of memory\n");
     exit(0);
    }
if (mysql_stmt_prepare(mysql, query, strlen(query)))
    {fprintf(stderr, " mysql_stmt_prepare(), INSERT failed\n"
     fprintf(stderr, " %s", mysql_stmt_error(stmt));
     exit(0);
    }
/* set up input buffers for all 3 parameters */
bind[0].buffer_type= MYSQL_TYPE_DATE;
bind[0].buffer= (char *)&ts;
bind[0].is_null= 0;
bind[0].length= 0;
...
bind[1]= bind[2]= bind[0];
...
mysql_stmt_bind_param(stmt, bind);

/* supply the data to be sent in the ts structure */
ts.year= 2002;
ts.month= 02;
ts.day= 03;

ts.hour= 10;
ts.minute= 45;
ts.second= 20;

mysql_stmt_execute(stmt);

23.7.17 C API Prepared CALL Statement Support

This section describes prepared-statement support in the C API for stored procedures executed using CALL statements:

Stored procedures executed using prepared CALL statements can be used in the following ways:

• A stored procedure can produce any number of result sets. The number of columns and the data types of the columns need not be the same for all result sets.

• The final values of OUT and INOUT parameters are available to the calling application after the procedure returns. These parameters are returned as an extra single-row result set following any result sets produced by the procedure itself. The row contains the values of the OUT and INOUT parameters in the order in which they are declared in the procedure parameter list.

For information about the effect of unhandled conditions on procedure parameters, see Section 13.6.7.5, "Condition Handling and OUT or INOUT Parameters".

The following discussion shows how to use these capabilities through the C API for prepared statements. To use prepared CALL statements through the PREPARE and EXECUTE statements, see Section 13.2.1, "CALL Statement".

An application that executes a prepared CALL statement should use a loop that fetches a result and then invokes mysql_stmt_next_result() to determine whether there are more results. The results consist of any result sets produced by the stored procedure followed by a final status value that indicates whether the procedure terminated successfully.

If the procedure has OUT or INOUT parameters, the result set preceding the final status value contains their values. To determine whether a result set contains parameter values, test whether the SERVER_PS_OUT_PARAMS bit is set in the server_status member of the MYSQL connection handler:

mysql->server_status & SERVER_PS_OUT_PARAMS

The following example uses a prepared CALL statement to execute a stored procedure that produces multiple result sets and that provides parameter values back to the caller by means of OUT and INOUT parameters. The procedure takes parameters of all three types (IN, OUT, INOUT), displays their initial values, assigns new values, displays the updated values, and returns. The expected return information from the procedure therefore consists of multiple result sets and a final status:

• One result set from a SELECT that displays the initial parameter values: 10, NULL, 30. (The OUT parameter is assigned a value by the caller, but this assignment is expected to be ineffective: OUT parameters are seen as NULL within a procedure until assigned a value within the procedure.)

• One result set from a SELECT that displays the modified parameter values: 100, 200, 300.
• One result set containing the final OUT and INOUT parameter values: 200, 300.

• A final status packet.

The code to execute the procedure:

```c
MYSQL_STMT *stmt;
MYSQL_BIND ps_params[3]; /* input parameter buffers */
int int_data[3]; /* input/output values */
my_bool is_null[3]; /* output value nullability */
int status;

/* set up stored procedure */
status = mysql_query(mysql, "DROP PROCEDURE IF EXISTS p1");
test_error(mysql, status);
status = mysql_query(mysql, 
"CREATE PROCEDURE p1(
  IN p_in INT, 
  OUT p_out INT, 
  INOUT p_inout INT) 
BEGIN 
  SELECT p_in, p_out, p_inout; 
  SET p_in = 100, p_out = 200, p_inout = 300; 
  SELECT p_in, p_out, p_inout; 
END");
test_error(mysql, status);

/* initialize and prepare CALL statement with parameter placeholders */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  printf("Could not initialize statement\n");
  exit(1);
}

status = mysql_stmt_prepare(stmt, "CALL p1(?, ?, ?)", 16);
test_stmt_error(stmt, status);

/* initialize parameters: p_in, p_out, p_inout (all INT) */
memset(ps_params, 0, sizeof (ps_params));

ps_params[0].buffer_type = MYSQL_TYPE_LONG;
ps_params[0].buffer = (char *) &int_data[0];
ps_params[0].length = 0;
ps_params[0].is_null = 0;

ps_params[1].buffer_type = MYSQL_TYPE_LONG;
ps_params[1].buffer = (char *) &int_data[1];
ps_params[1].length = 0;
ps_params[1].is_null = 0;

ps_params[2].buffer_type = MYSQL_TYPE_LONG;
ps_params[2].buffer = (char *) &int_data[2];
ps_params[2].length = 0;
ps_params[2].is_null = 0;

/* bind parameters */
status = mysql_stmt_bind_param(stmt, ps_params);
test_stmt_error(stmt, status);

/* assign values to parameters and execute statement */
int_data[0]= 10; /* p_in */
int_data[1]= 20; /* p_out */
int_data[2]= 30; /* p_inout */

status = mysql_stmt_execute(stmt);
test_stmt_error(stmt, status);
```
C API Prepared CALL Statement Support

/* process results until there are no more */
do {
  int i;
  int num_fields; /* number of columns in result */
  MYSQL_FIELD *fields; /* for result set metadata */
  MYSQL_BIND *rs_bind; /* for output buffers */

  /* the column count is > 0 if there is a result set */
  /* 0 if the result is only the final status packet */
  num_fields = mysql_stmt_field_count(stmt);

  if (num_fields > 0)
  {
    /* there is a result set to fetch */
    printf("Number of columns in result: %d\n", (int) num_fields);

    /* what kind of result set is this? */
    printf("Data: ");
    if(mysql->server_status & SERVER_PS_OUT_PARAMS)
      printf("this result set contains OUT/INOUT parameters\n");
    else
      printf("this result set is produced by the procedure\n");

    MYSQL_RES *rs_metadata = mysql_stmt_result_metadata(stmt);
    test_stmt_error(stmt, rs_metadata == NULL);
    fields = mysql_fetch_fields(rs_metadata);
    rs_bind = (MYSQL_BIND *) malloc(sizeof (MYSQL_BIND) * num_fields);
    if (!rs_bind)
    {
      printf("Cannot allocate output buffers\n");
      exit(1);
    }
    memset(rs_bind, 0, sizeof (MYSQL_BIND) * num_fields);

    /* set up and bind result set output buffers */
    for (i = 0; i < num_fields; ++i)
    {
      rs_bind[i].buffer_type = fields[i].type;
      rs_bind[i].is_null = &is_null[i];

      switch (fields[i].type)
      {
      case MYSQL_TYPE_LONG:
        rs_bind[i].buffer = (char *) &(int_data[i]);
        rs_bind[i].buffer_length = sizeof (int_data);
        break;

      default:
        fprintf(stderr, "ERROR: unexpected type: %d.\n", fields[i].type);
        exit(1);
      }
    }

    status = mysql_stmt_bind_result(stmt, rs_bind);
    test_stmt_error(stmt, status);

    /* fetch and display result set rows */
    while (1)
    {
      status = mysql_stmt_fetch(stmt);

      if (status == 1 || status == MYSQL_NO_DATA)
        break;
  }
}
for (i = 0; i < num_fields; ++i)
{
    switch (rs_bind[i].buffer_type)
    {
        case MYSQL_TYPE_LONG:
            if (*rs_bind[i].is_null)
                printf(" val[%d] = NULL;", i);
            else
                printf(" val[%d] = %ld;",
                        i, (long) *((int *) rs_bind[i].buffer));
            break;
        default:
            printf(" unexpected type (%d)\n",
                    rs_bind[i].buffer_type);
    }
    printf("\n");
}

mysql_free_result(rs_metadata); /* free metadata */
free(rs_bind);                  /* free output buffers */
}
else
{
    /* no columns = final status packet */
    printf("End of procedure output\n");
}

/* more results? -1 = no, >0 = error, 0 = yes (keep looking) */
status = mysql_stmt_next_result(stmt);
if (status > 0)
test_stmt_error(stmt, status);
} while (status == 0);

mysql_stmt_close(stmt);

Execution of the procedure should produce the following output:

Number of columns in result: 3
Data: this result set is produced by the procedure
Number of columns in result: 3
Data: this result set is produced by the procedure
    val[0] = 100; val[1] = 200; val[2] = 300;
Number of columns in result: 2
Data: this result set contains OUT/INOUT parameters
    val[0] = 200; val[1] = 300;
End of procedure output

The code uses two utility routines, test_error() and test_stmt_error(), to check for errors and terminate after printing diagnostic information if an error occurred:

static void test_error(MYSQL *mysql, int status)
{
    if (status)
    {
        fprintf(stderr, "Error: %s (errno: %d)\n",
                mysql_error(mysql), mysql_errno(mysql));
        exit(1);
    }
}

static void test_stmt_error(MYSQL_STMT *stmt, int status)
{
    if (status)
    {

23.7.18 C API Prepared Statement Problems

Here follows a list of the currently known problems with prepared statements:

- TIME, TIMESTAMP, and DATETIME do not support parts of seconds (for example, from DATE_FORMAT()).

- When converting an integer to string, ZEROFILL is honored with prepared statements in some cases where the MySQL server does not print the leading zeros. (For example, with MIN(number-with-zero-fill)).

- When converting a floating-point number to a string in the client, the rightmost digits of the converted value may differ slightly from those of the original value.

- Prepared statements use the query cache under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.

- Prepared statements do not support multi-statements (that is, multiple statements within a single string separated by ; characters).

- The capabilities of prepared CALL statements are described in Section 23.7.17, “C API Prepared CALL Statement Support”.

23.7.19 C API Automatic Reconnection Control

The MySQL client library can perform an automatic reconnection to the server if it finds that the connection is down when you attempt to send a statement to the server to be executed. If auto-reconnect is enabled, the library tries once to reconnect to the server and send the statement again.

Auto-reconnect is disabled by default.

If it is important for your application to know that the connection has been dropped (so that it can exit or take action to adjust for the loss of state information), be sure that auto-reconnect is disabled. To ensure this, call mysql_options() with the MYSQL_OPT_RECONNECT option:

```c
my_bool reconnect = 0;
mysql_options(&mysql, MYSQL_OPT_RECONNECT, &reconnect);
```

If the connection has gone down, the effect of mysql_ping() depends on the auto-reconnect state. If auto-reconnect is enabled, mysql_ping() performs a reconnect. Otherwise, it returns an error.

Some client programs might provide the capability of controlling automatic reconnection. For example, mysql reconnects by default, but the --skip-reconnect option can be used to suppress this behavior.

If an automatic reconnection does occur (for example, as a result of calling mysql_ping()), there is no explicit indication of it. To check for reconnection, call mysql_thread_id() to get the original connection identifier before calling mysql_ping(), then call mysql_thread_id() again to see whether the identifier changed.

Automatic reconnection can be convenient because you need not implement your own reconnect code, but if a reconnection does occur, several aspects of the connection state are reset on the server side and your application will not be notified.
The connection-related state is affected as follows:

- Any active transactions are rolled back and autocommit mode is reset.
- All table locks are released.
- All TEMPORARY tables are closed (and dropped).
- Session system variables are reinitialized to the values of the corresponding global system variables, including system variables that are set implicitly by statements such as `SET NAMES`.
- User variable settings are lost.
- Prepared statements are released.
- HANDLER variables are closed.
- The value of `LAST_INSERT_ID()` is reset to 0.
- Locks acquired with `GET_LOCK()` are released.

If reconnection occurs, any SQL statement specified by calling `mysql_options()` with the `MYSQL_INIT_COMMAND` option is re-executed.

If the connection drops, it is possible that the session associated with the connection on the server side will still be running if the server has not yet detected that the client is no longer connected. In this case, any locks held by the original connection still belong to that session, so you may want to kill it by calling `mysql_kill()`.

### 23.7.20 C API Common Issues

#### 23.7.20.1 Why `mysql_store_result()` Sometimes Returns NULL After `mysql_query()` Returns Success

It is possible for `mysql_store_result()` to return NULL following a successful call to `mysql_query()`. When this happens, it means one of the following conditions occurred:

- There was a `malloc()` failure (for example, if the result set was too large).
- The data could not be read (an error occurred on the connection).
- The query returned no data (for example, it was an INSERT, UPDATE, or DELETE).

You can always check whether the statement should have produced a nonempty result by calling `mysql_field_count()`. If `mysql_field_count()` returns zero, the result is empty and the last query was a statement that does not return values (for example, an INSERT or a DELETE). If `mysql_field_count()` returns a nonzero value, the statement should have produced a nonempty result. See the description of the `mysql_field_count()` function for an example.

You can test for an error by calling `mysql_error()` or `mysql_errno()`.

#### 23.7.20.2 What Results You Can Get from a Query

In addition to the result set returned by a query, you can also get the following information:

- `mysql_affected_rows()` returns the number of rows affected by the last query when doing an INSERT, UPDATE, or DELETE.
For a fast re-create, use `TRUNCATE TABLE`.

- `mysql_num_rows()` returns the number of rows in a result set. With `mysql_store_result()`, `mysql_num_rows()` may be called as soon as `mysql_store_result()` returns. With `mysql_use_result()`, `mysql_num_rows()` may be called only after you have fetched all the rows with `mysql_fetch_row()`.

- `mysql_insert_id()` returns the ID generated by the last query that inserted a row into a table with an `AUTO_INCREMENT` index. See Section 23.7.6.37, “`mysql_insert_id()`”.

- Some queries (LOAD DATA, INSERT INTO ... SELECT, UPDATE) return additional information. The result is returned by `mysql_info()`. See the description for `mysql_info()` for the format of the string that it returns. `mysql_info()` returns a `NULL` pointer if there is no additional information.

### 23.7.20.3 How to Get the Unique ID for the Last Inserted Row

If you insert a record into a table that contains an `AUTO_INCREMENT` column, you can obtain the value stored into that column by calling the `mysql_insert_id()` function.

You can check from your C applications whether a value was stored in an `AUTO_INCREMENT` column by executing the following code (which assumes that you've checked that the statement succeeded). It determines whether the query was an `INSERT` with an `AUTO_INCREMENT` index:

```c
if ((result = mysql_store_result(&mysql)) == 0 &&
    mysql_field_count(&mysql) == 0 &&
    mysql_insert_id(&mysql) != 0)
{
    used_id = mysql_insert_id(&mysql);
}
```

When a new `AUTO_INCREMENT` value has been generated, you can also obtain it by executing a `SELECT LAST_INSERT_ID()` statement with `mysql_query()` and retrieving the value from the result set returned by the statement.

When inserting multiple values, the last automatically incremented value is returned.

For `LAST_INSERT_ID()`, the most recently generated ID is maintained in the server on a per-connection basis. It is not changed by another client. It is not even changed if you update another `AUTO_INCREMENT` column with a nonmagic value (that is, a value that is not `NULL` and not `0`). Using `LAST_INSERT_ID()` and `AUTO_INCREMENT` columns simultaneously from multiple clients is perfectly valid. Each client will receive the last inserted ID for the last statement that client executed.

If you want to use the ID that was generated for one table and insert it into a second table, you can use SQL statements like this:

```sql
INSERT INTO foo (auto,text)
VALUES(NULL,'text');         # generate ID by inserting NULL
INSERT INTO foo2 (id,text)
VALUES(LAST_INSERT_ID(),'text');  # use ID in second table
```

`mysql_insert_id()` returns the value stored into an `AUTO_INCREMENT` column, whether that value is automatically generated by storing `NULL` or `0` or was specified as an explicit value. `LAST_INSERT_ID()` returns only automatically generated `AUTO_INCREMENT` values. If you store an explicit value other than `NULL` or `0`, it does not affect the value returned by `LAST_INSERT_ID()`.

For more information on obtaining the last ID in an `AUTO_INCREMENT` column:

- For information on `LAST_INSERT_ID()`, which can be used within an SQL statement, see Section 12.15, “Information Functions”.

2944
MySQL PHP API

- For information on `mysql_insert_id()`, the function you use from within the C API, see Section 23.7.6.37, "mysql_insert_id()".
- For information on obtaining the auto-incremented value when using Connector/J, see Retrieving AUTO_INCREMENT Column Values through JDBC.
- For information on obtaining the auto-incremented value when using Connector/ODBC, see Obtaining Auto-Increment Values.

23.8 MySQL PHP API

The MySQL PHP API manual is now published in standalone form, not as part of the MySQL Reference Manual. See MySQL and PHP.

23.9 MySQL Perl API

The Perl DBI module provides a generic interface for database access. You can write a DBI script that works with many different database engines without change. To use DBI with MySQL, install the following:

1. The DBI module.
2. The DBD::mysql module. This is the DataBase Driver (DBD) module for Perl.
3. Optionally, the DBD module for any other type of database server you want to access.

Perl DBI is the recommended Perl interface. It replaces an older interface called mysqlperl, which should be considered obsolete.

These sections contain information about using Perl with MySQL and writing MySQL applications in Perl:

- For installation instructions for Perl DBI support, see Section 2.13, "Perl Installation Notes".
- For an example of reading options from option files, see Section 5.7.4, "Using Client Programs in a Multiple-Server Environment".
- For secure coding tips, see Section 6.1.1, "Security Guidelines".
- For debugging tips, see Section 24.5.1.4, "Debugging mysqld under gdb".
- For some Perl-specific environment variables, see Section 4.9, "Environment Variables".
- For considerations for running on macOS, see Section 2.4, "Installing MySQL on OS X".
- For ways to quote string literals, see Section 9.1.1, "String Literals".

DBI information is available at the command line, online, or in printed form:

- Once you have the DBI and DBD::mysql modules installed, you can get information about them at the command line with the perl documentation:
  
  shell> perl -d DBI
  shell> perl -d DBI::FAQ
  shell> perl -d DBD::mysql

  You can also use pod2man, pod2html, and so on to translate this information into other formats.
- For online information about Perl DBI, visit the DBI website, http://dbi.perl.org/. That site hosts a general DBI mailing list.
• For printed information, the official DBI book is *Programming the Perl DBI* (Alligator Descartes and Tim Bunce, O'Reilly & Associates, 2000). Information about the book is available at the DBI website, http://dbi.perl.org/.

### 23.10 MySQL Python API

MySQLdb is a third-party driver that provides MySQL support for Python, compliant with the Python DB API version 2.0. It can be found at http://sourceforge.net/projects/mysql-python/.

The new MySQL Connector/Python component provides an interface to the same Python API, and is built into the MySQL Server and supported by Oracle. See MySQL Connector/Python Developer Guide for details on the Connector, as well as coding guidelines for Python applications and sample Python code.

### 23.11 MySQL Ruby APIs

Two APIs are available for Ruby programmers developing MySQL applications:

- The MySQL/Ruby API is based on the *libmysqlclient* API library. For information on installing and using the MySQL/Ruby API, see Section 23.11.1, "The MySQL/Ruby API".

- The Ruby/MySQL API is written to use the native MySQL network protocol (a native driver). For information on installing and using the Ruby/MySQL API, see Section 23.11.2, "The Ruby/MySQL API".

For background and syntax information about the Ruby language, see Ruby Programming Language.

#### 23.11.1 The MySQL/Ruby API

The MySQL/Ruby module provides access to MySQL databases using Ruby through *libmysqlclient*.

For information on installing the module, and the functions exposed, see MySQL/Ruby.

#### 23.11.2 The Ruby/MySQL API

The Ruby/MySQL module provides access to MySQL databases using Ruby through a native driver interface using the MySQL network protocol.

For information on installing the module, and the functions exposed, see Ruby/MySQL.

### 23.12 MySQL Tcl API

MySQLtcl is a simple API for accessing a MySQL database server from the Tcl programming language. It can be found at http://www.xdobry.de/mysqltcl/.

### 23.13 MySQL Eiffel Wrapper

Eiffel MySQL is an interface to the MySQL database server using the Eiffel programming language, written by Michael Ravits. It can be found at http://efsa.sourceforge.net/archive/ravits/mysql.htm.
Chapter 24 Extending MySQL

Table of Contents

24.1 MySQL Internals ................................................................. 2947
  24.1.1 MySQL Threads ......................................................... 2947
  24.1.2 The MySQL Test Suite ............................................... 2948
24.2 The MySQL Plugin API .................................................... 2949
  24.2.1 Types of Plugins ....................................................... 2949
  24.2.2 Plugin API Characteristics ........................................... 2952
  24.2.3 Plugin API Components .............................................. 2953
  24.2.4 Writing Plugins ........................................................ 2954
24.3 MySQL Services for Plugins .............................................. 2954
24.4 Adding Functions to MySQL .............................................. 2995
  24.4.1 Features of the User-Defined Function Interface .............. 2997
  24.4.2 Adding a User-Defined Function .................................... 2997
  24.4.3 Adding a Native Function .......................................... 3007
24.5 Debugging and Porting MySQL .......................................... 3009
  24.5.1 Debugging a MySQL Server ........................................... 3009
  24.5.2 Debugging a MySQL Client ......................................... 3016
  24.5.3 The DBUG Package ..................................................... 3017

24.1 MySQL Internals

This chapter describes what you need to know when working on the MySQL code. To track or contribute to MySQL development, follow the instructions in Section 2.9.5, “Installing MySQL Using a Development Source Tree”. If you are interested in MySQL internals, you should also join the MySQL Community Slack. Feel free to ask questions about the code and to send patches that you would like to contribute to the MySQL project!

24.1.1 MySQL Threads

The MySQL server creates the following threads:

• Connection manager threads handle client connection requests on the network interfaces that the server listens to. On all platforms, one manager thread handles TCP/IP connection requests. On Unix, this manager thread also handles Unix socket file connection requests. On Windows, a manager thread handles shared-memory connection requests, and another handles named-pipe connection requests. The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

• Connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

For information about tuning the parameters that control thread resources, see Section 8.12.5.1, “How MySQL Handles Client Connections”.

• On a master replication server, connections from slave servers are handled like client connections: there is one thread per connected slave.
• On a slave replication server, an I/O thread is started to connect to the master server and read updates from it. An SQL thread is started to apply updates read from the master. These two threads run independently and can be started and stopped independently.

• A signal thread handles all signals. This thread also normally handles alarms and calls `process_alarm()` to force timeouts on connections that have been idle too long.

• If InnoDB is used, there will be additional read and write threads by default. The number of these are controlled by the `innodb_read_io_threads` and `innodb_write_io_threads` parameters. See Section 14.17, “InnoDB Startup Options and System Variables”.

• If `mysqld` is compiled with `-DUSE_ALARM_THREAD`, a dedicated thread that handles alarms is created. This is only used on some systems where there are problems with `sigwait()` or if you want to use the `thr_alarm()` code in your application without a dedicated signal handling thread.

• If the server is started with the `--flush_time=val` option, a dedicated thread is created to flush all tables every `val` seconds.

• Each table for which `INSERT DELAYED` statements are issued gets its own thread. See Section 13.2.5.3, “INSERT DELAYED Statement”.

• If the event scheduler is active, there is one thread for the scheduler, and a thread for each event currently running. See Section 20.4.1, “Event Scheduler Overview”.

  `mysqladmin processlist` only shows the connection, `INSERT DELAYED`, replication, and event threads.

### 24.1.2 The MySQL Test Suite

The test system that is included in Unix source and binary distributions makes it possible for users and developers to perform regression tests on the MySQL code. These tests can be run on Unix.

You can also write your own test cases. For information, including system requirements, see The MySQL Test Framework in the MySQL Server Doxygen documentation, available at https://dev.mysql.com/doc/index-other.html.

The current set of test cases does not test everything in MySQL, but it should catch most obvious bugs in the SQL processing code, operating system or library issues, and is quite thorough in testing replication. Our goal is to have the tests cover 100% of the code. We welcome contributions to our test suite. You may especially want to contribute tests that examine the functionality critical to your system because this ensures that all future MySQL releases work well with your applications.

The test system consists of a test language interpreter (`mysqltest`), a Perl script to run all tests (`mysql-test-run.pl`), the actual test cases written in a special test language, and their expected results. To run the test suite on your system after a build, type `make test` from the source root directory, or change location to the `mysql-test` directory and type `./mysql-test-run.pl`. If you have installed a binary distribution, change location to the `mysql-test` directory under the installation root directory (for example, `/usr/local/mysql/mysql-test`), and run `./mysql-test-run.pl`. All tests should succeed. If any do not, feel free to try to find out why and report the problem if it indicates a bug in MySQL. See Section 1.6, “How to Report Bugs or Problems”.

If one test fails, you should run `mysql-test-run.pl` with the `--force` option to check whether any other tests fail.

If you have a copy of `mysqld` running on the machine where you want to run the test suite, you do not have to stop it, as long as it is not using ports 9306 or 9307. If either of those ports is taken, you should
set the `MTR_BUILD_THREAD` environment variable to an appropriate value, and the test suite will use a different set of ports for master, slave, and NDB. For example:

```
shell> export MTR_BUILD_THREAD=31
shell> ./mysql-test-run.pl [options] [test_name]
```

In the `mysql-test` directory, you can run an individual test case with `./mysql-test-run.pl test_name`.

If you have a question about the test suite, or have a test case to contribute, join the MySQL Community Slack.

## 24.2 The MySQL Plugin API

MySQL supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The API is generic and does not specify what plugins can do. The components supported by this interface include, but are not limited to, storage engines, full-text parser plugins, and server extensions.

For example, full-text parser plugins can be used to replace or augment the built-in full-text parser. A plugin can parse text into words using rules that differ from those used by the built-in parser. This can be useful if you need to parse text with characteristics different from those expected by the built-in parser.

The plugin interface is more general than the older user-defined function (UDF) interface.

The plugin interface uses the `plugin` table in the `mysql` database to record information about plugins that have been installed permanently with the `INSTALL PLUGIN` statement. This table is created as part of the MySQL installation process. Plugins can also be installed for a single server invocation with the `--plugin-load` option. Plugins installed this way are not recorded in the `plugin` table. See Section 5.5.1, “Installing and Uninstalling Plugins”.

MySQL supports an API for client plugins in addition to that for server plugins. This is used, for example, by authentication plugins where a server-side plugin and a client-side plugin cooperate to enable clients to connect to the server through a variety of authentication methods.

### Additional Resources

The book *MySQL 5.1 Plugin Development* by Sergei Golubchik and Andrew Hutchings provides a wealth of detail about the plugin API. Despite the fact that the book's title refers to MySQL Server 5.1, most of the information in it applies to later versions as well.

### 24.2.1 Types of Plugins

The plugin API enables creation of plugins that implement several capabilities:

- Storage engines
- Full-text parsers
- Daemons
- `INFORMATION_SCHEMA` tables
- Semisynchronous replication
- Auditing
Types of Plugins

- Authentication

The following sections provide an overview of these plugin types.

- Storage Engine Plugins
- Full-Text Parser Plugins
- Daemon Plugins
- INFORMATION_SCHEMA Plugins
- Semisynchronous Replication Plugins
- Audit Plugins
- Authentication Plugins

Storage Engine Plugins

The pluggable storage engine architecture used by MySQL Server enables storage engines to be written as plugins and loaded into and unloaded from a running server. For a description of this architecture, see Section 15.2, “Overview of MySQL Storage Engine Architecture”.

For information on how to use the plugin API to write storage engines, see MySQL Internals: Writing a Custom Storage Engine.

Full-Text Parser Plugins

MySQL has a built-in parser that it uses by default for full-text operations (parsing text to be indexed, or parsing a query string to determine the terms to be used for a search). For full-text processing, “parsing” means extracting words from text or a query string based on rules that define which character sequences make up a word and where word boundaries lie.

When parsing for indexing purposes, the parser passes each word to the server, which adds it to a full-text index. When parsing a query string, the parser passes each word to the server, which accumulates the words for use in a search.

The parsing properties of the built-in full-text parser are described in Section 12.9, “Full-Text Search Functions”. These properties include rules for determining how to extract words from text. The parser is influenced by certain system variables such as `ft_min_word_len` and `ft_max_word_len` that cause words shorter or longer to be excluded, and by the stopword list that identifies common words to be ignored.

The plugin API enables you to provide a full-text parser of your own so that you have control over the basic duties of a parser. A parser plugin can operate in either of two roles:

- The plugin can replace the built-in parser. In this role, the plugin reads the input to be parsed, splits it up into words, and passes the words to the server (either for indexing or for word accumulation).

  One reason to use a parser this way is that you need to use different rules from those of the built-in parser for determining how to split up input into words. For example, the built-in parser considers the text “case-sensitive” to consist of two words “case” and “sensitive,” whereas an application might need to treat the text as a single word.

- The plugin can act in conjunction with the built-in parser by serving as a front end for it. In this role, the plugin extracts text from the input and passes the text to the parser, which splits up the text into words.
Types of Plugins

using its normal parsing rules. In particular, this parsing will be affected by the `ft_xxx` system variables and the stopword list.

One reason to use a parser this way is that you need to index content such as PDF documents, XML documents, or `.doc` files. The built-in parser is not intended for those types of input but a plugin can pull out the text from these input sources and pass it to the built-in parser.

It is also possible for a parser plugin to operate in both roles. That is, it could extract text from noncleartext input (the front end role), and also parse the text into words (thus replacing the built-in parser).

A full-text plugin is associated with full-text indexes on a per-index basis. That is, when you install a parser plugin initially, that does not cause it to be used for any full-text operations. It simply becomes available. For example, a full-text parser plugin becomes available to be named in a `WITH PARSER` clause when creating individual `FULLTEXT` indexes. To create such an index at table-creation time, do this:

```sql
CREATE TABLE t
(
    doc CHAR(255),
    FULLTEXT INDEX (doc) WITH PARSER my_parser
) ENGINE=MyISAM;
```

Or you can add the index after the table has been created:

```sql
ALTER TABLE t ADD FULLTEXT INDEX (doc) WITH PARSER my_parser;
```

The only SQL change for associating the parser with the index is the `WITH PARSER` clause. Searches are specified as before, with no changes needed for queries.

When you associate a parser plugin with a `FULLTEXT` index, the plugin is required for using the index. If the parser plugin is dropped, any index associated with it becomes unusable. Any attempt to use a table for which a plugin is not available results in an error, although `DROP TABLE` is still possible.

For more information about full-text plugins, see Section 24.2.4.4, “Writing Full-Text Parser Plugins”.

MySQL 5.5 only supports full-text plugins with `MyISAM`.

Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. MySQL distributions include an example daemon plugin that writes periodic heartbeat messages to a file.

For more information about daemon plugins, see Section 24.2.4.5, “Writing Daemon Plugins”.

INFORMATION_SCHEMA Plugins

`INFORMATION_SCHEMA` plugins enable the creation of tables containing server metadata that are exposed to users through the `INFORMATION_SCHEMA` database. For example, InnoDB uses `INFORMATION_SCHEMA` plugins to provide tables that contain information about current transactions and locks.

For more information about `INFORMATION_SCHEMA` plugins, see Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”.

Semisynchronous Replication Plugins

MySQL replication is asynchronous by default. With semisynchronous replication, a commit performed on the master side blocks before returning to the session that performed the transaction until at least one
slave acknowledges that it has received and logged the events for the transaction. Semisynchronous replication is implemented through complementary master and client plugins. See Section 17.3.8, “Semisynchronous Replication”.

For more information about semisynchronous replication plugins, see Section 24.2.4.7, “Writing Semisynchronous Replication Plugins”.

**Audit Plugins**

The server provides a pluggable audit interface that enables information about server operations to be reported to interested parties. Audit notification occurs for these operations (although the interface is general and the server could be modified to report others):

- Write a message to the general query log (if the log is enabled)
- Write a message to the error log
- Send a query result to a client

Audit plugins may register with the audit interface to receive notification about server operations. When an auditable event occurs within the server, the server determines whether notification is needed. For each registered audit plugin, the server checks the event against those event classes in which the plugin is interested and passes the event to the plugin if there is a match.

This interface enables audit plugins to receive notifications only about operations in event classes they consider significant and to ignore others. The interface provides for categorization of operations into event classes and further division into event subclasses within each class.

When an audit plugin is notified of an auditable event, it receives a pointer to the current THD structure and a pointer to a structure that contains information about the event. The plugin can examine the event and perform whatever auditing actions are appropriate. For example, the plugin can see what statement produced a result set or was logged, the number of rows in a result, who the current user was for an operation, or the error code for failed operations.

For more information about audit plugins, see Section 24.2.4.8, “Writing Audit Plugins”.

**Authentication Plugins**

MySQL supports pluggable authentication. Authentication plugins exist on both the server and client sides. Plugins on the server side implement authentication methods for use by clients when they connect to the server. A plugin on the client side communicates with a server-side plugin to provide the authentication information that it requires. A client-side plugin may interact with the user, performing tasks such as soliciting a password or other authentication credentials to be sent to the server. See Section 6.2.10, “Pluggable Authentication”.

Pluggable authentication also enables proxy user capability, in which one user takes the identity of another user. A server-side authentication plugin can return to the server the name of the user whose identity the connecting user should have. See Section 6.2.11, “Proxy Users”.

For more information about authentication plugins, see Section 24.2.4.9, “Writing Authentication Plugins”.

**24.2.2 Plugin API Characteristics**

The server plugin API has these characteristics:

- All plugins have several things in common.
Each plugin has a name that it can be referred to in SQL statements, as well as other metadata such as an author and a description that provide other information. This information can be examined in the `INFORMATION_SCHEMA.PLUGINS` table or using the `SHOW PLUGINS` statement.

- The plugin framework is extendable to accommodate different kinds of plugins.

Although some aspects of the plugin API are common to all types of plugins, the API also permits type-specific interface elements so that different types of plugins can be created. A plugin with one purpose can have an interface most appropriate to its own requirements and not the requirements of some other plugin type.

Interfaces for several types of plugins exist, such as storage engines, full-text parser, and `INFORMATION_SCHEMA` tables. Others can be added.

- Plugins can expose information to users.

A plugin can implement system and status variables that are available through the `SHOW VARIABLES` and `SHOW STATUS` statements.

- The plugin API includes versioning information.

The version information included in the plugin API enables a plugin library and each plugin that it contains to be self-identifying with respect to the API version that was used to build the library. If the API changes over time, the version numbers will change, but a server can examine a given plugin library's version information to determine whether it supports the plugins in the library.

There are two types of version numbers. The first is the version for the general plugin framework itself. Each plugin library includes this kind of version number. The second type of version applies to individual plugins. Each specific type of plugin has a version for its interface, so each plugin in a library has a type-specific version number. For example, a library containing a full-text parser plugin has a general plugin API version number, and the plugin has a version number specific to the full-text plugin interface.

- The plugin API implements security restrictions.

A plugin library must be installed in a specific dedicated directory for which the location is controlled by the server and cannot be changed at runtime. Also, the library must contain specific symbols that identify it as a plugin library. The server will not load something as a plugin if it was not built as a plugin.

- Plugins have access to server services.

The services interface exposes server functionality that plugins can access using ordinary function calls. For details, see Section 24.3, “MySQL Services for Plugins”.

In some respects, the server plugin API is similar to the older user-defined function (UDF) API that it supersedes, but the plugin API has several advantages over the older interface. For example, UDFs had no versioning information. Also, the newer plugin interface eliminates the security issues of the older UDF interface. The older interface for writing nonplugin UDFs permitted libraries to be loaded from any directory searched by the system's dynamic linker, and the symbols that identified the UDF library were relatively nonspecific.

The client plugin API has similar architectural characteristics, but client plugins have no direct access to the server the way server plugins do.

### 24.2.3 Plugin API Components

The server plugin implementation comprises several components.
Writing Plugins

SQL statements:

- `INSTALL PLUGIN` registers a plugin in the `mysql.plugin` table and loads the plugin code.
- `UNINSTALL PLUGIN` unregisters a plugin from the `mysql.plugin` table and unloads the plugin code.
- The `WITH PARSER` clause for full-text index creation associates a full-text parser plugin with a given `FULLTEXT` index.
- `SHOW PLUGINS` displays information about server plugins.

Command-line options and system variables:

- The `--plugin-load` option enables plugins to be loaded at server startup time.
- The `plugin_dir` system variable indicates the location of the directory where all plugins must be installed. The value of this variable can be specified at server startup with a `--plugin_dir=dir_name` option. `mysql_config --plugindir` displays the default plugin directory path name.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

Plugin-related tables:

- The `INFORMATION_SCHEMA.PLUGINS` table contains plugin information.
- The `mysql.plugin` table lists each plugin that was installed with `INSTALL PLUGIN` and is required for plugin use. For new MySQL installations, this table is created during the installation process.

The client plugin implementation is simpler:

- For the `mysql_options()` C API function, the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options enable client programs to load authentication plugins.
- There are C API functions that enable management of client plugins.

To examine how MySQL implements plugins, consult the following source files in a MySQL source distribution:

- In the `include/mysql` directory, `plugin.h` exposes the public plugin API. This file should be examined by anyone who wants to write a plugin library. `plugin_xxx.h` files provide additional information that pertains to specific types of plugins. `client_plugin.h` contains information specific to client plugins.
- In the `sql` directory, `sql_plugin.h` and `sql_plugin.cc` comprise the internal plugin implementation. `sql_acl.cc` is where the server uses authentication plugins. These files need not be consulted by plugin developers. They may be of interest for those who want to know more about how the server handles plugins.
- In the `sql-common` directory, `client_plugin.h` implements the C API client plugin functions, and `client.c` implements client authentication support. These files need not be consulted by plugin developers. They may be of interest for those who want to know more about how the server handles plugins.

**24.2.4 Writing Plugins**

To create a plugin library, you must provide the required descriptor information that indicates what plugins the library file contains, and write the interface functions for each plugin.
Every server plugin must have a general descriptor that provides information to the plugin API, and a type-specific descriptor that provides information about the plugin interface for a given type of plugin. The structure of the general descriptor is the same for all plugin types. The structure of the type-specific descriptor varies among plugin types and is determined by the requirements of what the plugin needs to do. The server plugin interface also enables plugins to expose status and system variables. These variables become visible through the `SHOW STATUS` and `SHOW VARIABLES` statements and the corresponding `INFORMATION_SCHEMA` tables.

For client-side plugins, the architecture is a bit different. Each plugin must have a descriptor, but there is no division into separate general and type-specific descriptors. Instead, the descriptor begins with a fixed set of members common to all client plugin types, and the common members are followed by any additional members required to implement the specific plugin type.

You can write plugins in C or C++ (or another language that can use C calling conventions). Plugins are loaded and unloaded dynamically, so your operating system must support dynamic loading and you must have compiled the calling application dynamically (not statically). For server plugins, this means that `mysqld` must be linked dynamically.

A server plugin contains code that becomes part of the running server, so when you write the plugin, you are bound by any and all constraints that otherwise apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to plugins originally written for older servers. For information about these constraints, see Section 2.9.7, “MySQL Source-Configuration Options”, and Section 2.9.8, “Dealing with Problems Compiling MySQL”.

Client plugin writers should avoid dependencies on what symbols the calling application has because you cannot be sure what applications will use the plugin.

### 24.2.4.1 Overview of Plugin Writing

The following procedure provides an overview of the steps needed to create a plugin library. The next sections provide additional details on setting plugin data structures and writing specific types of plugins.

1. In the plugin source file, include the header files that the plugin library needs. The `plugin.h` file is required, and the library might require other files as well. For example:

   ```
   #include <stdlib.h>
   #include <ctype.h>
   #include <mysql/plugin.h>
   ```

2. Set up the descriptor information for the plugin library file. For server plugins, write the library descriptor, which must contain the general plugin descriptor for each server plugin in the file. For more information, see Server Plugin Library and Plugin Descriptors. In addition, set up the type-specific descriptor for each server plugin in the library. Each plugin's general descriptor points to its type-specific descriptor.

   For client plugins, write the client descriptor. For more information, see Client Plugin Descriptors.

3. Write the plugin interface functions for each plugin. For example, each plugin's general plugin descriptor points to the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. The plugin's type-specific description may also point to interface functions.

4. For server plugins, set up the status and system variables, if there are any.

5. Compile the plugin library as a shared library and install it in the plugin directory. For more information, see Section 24.2.4.3, “Compiling and Installing Plugin Libraries”.

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2955
6. For server plugins, register the plugin with the server. For more information, see Section 5.5.1, “Installing and Uninstalling Plugins”.

7. Test the plugin to verify that it works properly.

### 24.2.4.2 Plugin Data Structures

A plugin library file includes descriptor information to indicate what plugins it contains.

If the plugin library contains any server plugins, it must include the following descriptor information:

- A library descriptor indicates the general server plugin API version number used by the library and contains a general plugin descriptor for each server plugin in the library. To provide the framework for this descriptor, invoke two macros from the `plugin.h` header file:

```c
mysql_declare_plugin(name)
... one or more server plugin descriptors here ...
mysql_declare_plugin_end;
```

The macros expand to provide a declaration for the API version automatically. You must provide the plugin descriptors.

- Within the library descriptor, each general server plugin is described by a `st_mysql_plugin` structure. This plugin descriptor structure contains information that is common to every type of server plugin: a value that indicates the plugin type; the plugin name, author, description, and license type; pointers to the initialization and deinitialization functions that the server invokes when it loads and unloads the plugin, and pointers to any status or system variables the plugin implements.

- Each general server plugin descriptor within the library descriptor also contains a pointer to a type-specific plugin descriptor. The structure of the type-specific descriptors varies from one plugin type to another because each type of plugin can have its own API. A type-specific plugin descriptor contains a type-specific API version number and pointers to the functions that are needed to implement that plugin type. For example, a full-text parser plugin has initialization and deinitialization functions, and a main parsing function. The server invokes these functions when it uses the plugin to parse text.

The plugin library also contains the interface functions that are referenced by the general and type-specific descriptors for each plugin in the library.

If the plugin library contains a client plugin, it must include a descriptor for the plugin. The descriptor begins with a fixed set of members common to all client plugins, followed by any members specific to the plugin type. To provide the descriptor framework, invoke two macros from the `client_plugin.h` header file:

```c
mysql_declare_client_plugin(plugin_type)
... members common to all client plugins ...
... type-specific extra members ...
mysql_end_client_plugin;
```

The plugin library also contains any interface functions referenced by the client descriptor.

The `mysql_declare_plugin()` and `mysql_declare_client_plugin()` macros differ somewhat in how they can be invoked, which has implications for the contents of plugin libraries. The following guidelines summarize the rules:

- `mysql_declare_plugin()` and `mysql_declare_client_plugin()` can both be used in the same source file, which means that a plugin library can contain both server and client plugins. However, each of `mysql_declare_plugin()` and `mysql_declare_client_plugin()` can be used at most once.

- `mysql_declare_plugin()` permits multiple server plugin declarations, so a plugin library can contain multiple server plugins.
• `mysql_declare_client_plugin()` permits only a single client plugin declaration. To create multiple client plugins, separate plugin libraries must be used.

When a client program looks for a client plugin that is in a plugin library and not built into `libmysqlclient`, it looks for a file with a base name that is the same as the plugin name. For example, if a program needs to use a client authentication plugin named `auth_xxx` on a system that uses `.so` as the library suffix, it looks in the file named `auth_xxx.so`. (On macOS, the program looks first for `auth_xxx.dylib`, then for `auth_xxx.so`.) For this reason, if a plugin library contains a client plugin, the library must have the same base name as that plugin.

The same is not true for a library that contains server plugins. The `--plugin-load` option and the `INSTALL PLUGIN` statement provide the library file name explicitly, so there need be no explicit relationship between the library name and the name of any server plugins it contains.

Server Plugin Library and Plugin Descriptors

Every plugin library that contains server plugins must include a library descriptor that contains the general plugin descriptor for each server plugin in the file. This section discusses how to write the library and general descriptors for server plugins.

The library descriptor must define two symbols:

• `_mysql_plugin_interface_version_` specifies the version number of the general plugin framework. This is given by the `MYSQL_PLUGIN_INTERFACE_VERSION` symbol, which is defined in the `plugin.h` file.

• `_mysql_plugin_declarations_` defines an array of plugin declarations, terminated by a declaration with all members set to 0. Each declaration is an instance of the `st_mysql_plugin` structure (also defined in `plugin.h`). There must be one of these for each server plugin in the library.

If the server does not find those two symbols in a library, it does not accept it as a legal plugin library and rejects it with an error. This prevents use of a library for plugin purposes unless it was built specifically as a plugin library.

The conventional way to define the two required symbols is by using the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros from the `plugin.h` file:

```c
mysql_declare_plugin(name)
  ... one or more server plugin descriptors here ...
mysql_declare_plugin_end;
```

Each server plugin must have a general descriptor that provides information to the server plugin API. The general descriptor has the same structure for all plugin types. The `st_mysql_plugin` structure in the `plugin.h` file defines this descriptor:

```c
struct st_mysql_plugin
{
  int type;       /* the plugin type (a MYSQL_XXX_PLUGIN value) */
  void *info;     /* pointer to type-specific plugin descriptor */
  const char *name; /* plugin name */
  const char *author; /* plugin author (for I_S.PLUGINS) */
  const char *descr; /* general descriptive text (for I_S.PLUGINS) */
  int license;    /* the plugin license (PLUGIN_LICENSE_XXX) */
  int (*init)(void *);  /* the function to invoke when plugin is loaded */
  int (*deinit)(void *);/* the function to invoke when plugin is unloaded */
  unsigned int version; /* plugin version (for I_S.PLUGINS) */
  struct st_mysql_show_var *status_vars;
  struct st_mysql_sys_var **system_vars;
  void * __reserved1;   /* reserved for dependency checking */
  unsigned long flags;  /* flags for plugin */
};
```
The `st_mysql_plugin` descriptor structure members are used as follows. `char *` members should be specified as null-terminated strings.

- **type**: The plugin type. This must be one of the plugin-type values from `plugin.h`:

```c
/*
 * The allowable types of plugins
 */
#define MYSQL_UDF_PLUGIN    0  /* User-defined function */
#define MYSQL_STORAGE_ENGINE_PLUGIN 1  /* Storage Engine */
#define MYSQL_FTPARSER_PLUGIN 2  /* Full-text parser plugin */
#define MYSQL_DAEMON_PLUGIN  3  /* The daemon/raw plugin type */
#define MYSQL_INFORMATION_SCHEMA_PLUGIN 4  /* The I_S plugin type */
#define MYSQL_AUDIT_PLUGIN   5  /* The Audit plugin type */
#define MYSQL_REPLICATION_PLUGIN 6  /* The replication plugin type */
#define MYSQL_AUTHENTICATION_PLUGIN 7  /* The authentication plugin type */
...```

For example, for a full-text parser plugin, the `type` value is `MYSQL_FTPARSER_PLUGIN`.

- **info**: A pointer to the type-specific descriptor for the plugin. This descriptor’s structure depends on the particular type of plugin, unlike that of the general plugin descriptor structure. For version-control purposes, the first member of the type-specific descriptor for every plugin type is expected to be the interface version for the type. This enables the server to check the type-specific version for every plugin no matter its type. Following the version number, the descriptor includes any other members needed, such as callback functions and other information needed by the server to invoke the plugin properly. Later sections on writing particular types of server plugins describe the structure of their type-specific descriptors.

- **name**: A string that gives the plugin name. This is the name that will be listed in the `mysql.plugin` table and by which you refer to the plugin in SQL statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`, or with the `--plugin-load` option. The name is also visible in the `INFORMATION_SCHEMA.PLUGINS` table or the output from `SHOW PLUGINS`.

  The plugin name should not begin with the name of any server option. If it does, the server will fail to initialize it. For example, the server has a `--socket` option, so you should not use a plugin name such as `socket`, `socket_plugin`, and so forth.

- **author**: A string naming the plugin author. This can be whatever you like.

- **desc**: A string that provides a general description of the plugin. This can be whatever you like.

- **license**: The plugin license type. The value can be one of `PLUGIN_LICENSE_PROPRIETARY`, `PLUGIN_LICENSE_GPL`, or `PLUGIN_LICENSE_BSD`.

- **init**: A once-only initialization function, or `NULL` if there is no such function. The server executes this function when it loads the plugin, which happens for `INSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server startup. The function takes one argument that points to the internal structure used to identify the plugin. It returns zero for success and nonzero for failure.

- **deinit**: A once-only deinitialization function, or `NULL` if there is no such function. The server executes this function when it unloads the plugin, which happens for `UNINSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server shutdown. The function takes one argument that points to the internal structure used to identify the plugin. It returns zero for success and nonzero for failure.

- **version**: The plugin version number. When the plugin is installed, this value can be retrieved from the `INFORMATION_SCHEMA.PLUGINS` table. The value includes major and minor numbers. If you write
the value as a hex constant, the format is 0xMMNN, where MM and NN are the major and minor numbers, respectively. For example, 0x0302 represents version 3.2.

- **status_vars**: A pointer to a structure for status variables associated with the plugin, or NULL if there are no such variables. When the plugin is installed, these variables are displayed in the output of the SHOW STATUS statement.

The `status_vars` member, if not NULL, points to an array of `st_mysql_show_var` structures that describe status variables. See Server Plugin Status and System Variables.

- **system_vars**: A pointer to a structure for system variables associated with the plugin, or NULL if there are no such variables. These options and system variables can be used to help initialize variables within the plugin. When the plugin is installed, these variables are displayed in the output of the SHOW VARIABLES statement.

The `system_vars` member, if not NULL, points to an array of `st_mysql_sys_var` structures that describe system variables. See Server Plugin Status and System Variables.

- **__reserved1**: A placeholder for the future. It should be set to NULL.

- **flags**: Plugin flags. Individual bits correspond to different flags. The value should be set to the OR of the applicable flags. These flags are available:

```c
#define PLUGIN_OPT_NO_INSTALL   1UL   /* Not dynamically loadable */
#define PLUGIN_OPT_NO_UNINSTALL 2UL   /* Not dynamically unloadable */
```

The flags have the following meanings when enabled:

- **PLUGIN_OPT_NO_INSTALL**: The plugin cannot be loaded at runtime with the INSTALL PLUGIN statement. This is appropriate for plugins that must be loaded at server startup with the --plugin-load option.

- **PLUGIN_OPT_NO_UNINSTALL**: The plugin cannot be unloaded at runtime with the UNINSTALL PLUGIN statement.

This member was added in MySQL 5.5.16.

The server invokes the `init` and `deinit` functions in the general plugin descriptor only when loading and unloading the plugin. They have nothing to do with use of the plugin such as happens when an SQL statement causes the plugin to be invoked.

For example, the descriptor information for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

```c
code
mysql_declare_plugin(ftexample)
{
    MYSQL_FTPARSER_PLUGIN,  /* type */
    &simple_parser_descriptor,  /* descriptor */
    "Oracle Corporation",    /* author */
    "Simple Full-Text Parser",    /* description */
    PLUGIN_LICENSE_GPL,  /* plugin license */
    simple_parser_plugin_init,  /* init function (when loaded) */
    simple_parser_plugin_deinit,  /* deinit function (when unloaded) */
    0x0001,  /* version */
    simple_status,  /* status variables */
    simple_system_variables,  /* system variables */
    NULL,
    0
}
```
Writing Plugins

For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

`plugin.h` defines the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros like this:

```c
#ifndef MYSQL_DYNAMIC_PLUGIN
#define __MYSQL_DECLARE_PLUGIN(NAME, VERSION, PSIZE, DECLS) \
MYSQL_PLUGIN_EXPORT int VERSION= MYSQL_PLUGIN_INTERFACE_VERSION; \nMYSQL_PLUGIN_EXPORT int PSIZE= sizeof(struct st_mysql_plugin); \nMYSQL_PLUGIN_EXPORT struct st_mysql_plugin DECLS[] = { \
#endif
#define mysql_declare_plugin(NAME) \
__MYSQL_DECLARE_PLUGIN(NAME, \n builtin_##NAME##_plugin_interface_version, \n builtin_##NAME##_sizeof_struct_st_plugin, \n builtin_##NAME##_plugin)
#define mysql_declare_plugin_end ,{0,0,0,0,0,0,0,0,0,0,0,0,0}}
#endif
```

**Note**

Those declarations define the `_mysql_plugin_interface_version_` symbol only if the `MYSQL_DYNAMIC_PLUGIN` symbol is defined. This means that `DMYSQL_DYNAMIC_PLUGIN` must be provided as part of the compilation command to build the plugin as a shared library.

When the macros are used as just shown, they expand to the following code, which defines both of the required symbols `_mysql_plugin_interface_version_` and `_mysql_plugin_declarations_`:

```c
int _mysql_plugin_interface_version_= MYSQL_PLUGIN_INTERFACE_VERSION;
int _mysql_sizeof_struct_st_plugin_= sizeof(struct st_mysql_plugin);
struct st_mysql_plugin _mysql_plugin_declarations_[] = { 
{ 
 MYSQL_FTPARSER_PLUGIN, /* type */ 
 &simple_parser_descriptor, /* descriptor */ 
 "simple_parser", /* name */ 
 "Oracle Corporation", /* author */ 
 "Simple Full-Text Parser", /* description */ 
 PLUGIN_LICENSE_GPL, /* plugin license */ 
 simple_parser_plugin_init, /* init function (when loaded) */ 
 simple_parser_plugin_deinit,/* deinit function (when unloaded) */ 
 0x0001, /* version */ 
 simple_status, /* status variables */ 
 simple_system_variables, /* system variables */ 
 NULL, 
 0 
}, {0,0,0,0,0,0,0,0,0,0,0,0}}
};
```

The preceding example declares a single plugin in the general descriptor, but it is possible to declare multiple plugins. List the declarations one after the other between `mysql_declare_plugin()` and `mysql_declare_plugin_end`, separated by commas.
MySQL server plugins can be written in C or C++ (or another language that can use C calling conventions). If you write a C++ plugin, one C++ feature that you should not use is nonconstant variables to initialize global structures. Members of structures such as the `st_mysql_plugin` structure should be initialized only with constant variables. The `simple_parser` descriptor shown earlier is permissible in a C++ plugin because it satisfies that requirement:

```c
mysql_declare_plugin(ftexample)
{
    MYSQL_FTPARSER_PLUGIN,      /* type                            */
    &simple_parser_descriptor,  /* descriptor                      */
    "simple_parser",            /* name                            */
    "Oracle Corporation",       /* author                          */
    "Simple Full-Text Parser",  /* description                     */
    PLUGIN_LICENSE_GPL,         /* plugin license                  */
    simple_parser_plugin_init,  /* init function (when loaded)     */
    simple_parser_plugin_deinit,/* deinit function (when unloaded) */
    0x0001,                     /* version                         */
    simple_status,              /* status variables                */
    simple_system_variables,    /* system variables                */
    NULL,
    0
}
mysql_declare_plugin_end;
```

Here is another valid way to write the general descriptor. It uses constant variables to indicate the plugin name, author, and description:

```c
const char *simple_parser_name = "simple_parser";
const char *simple_parser_author = "Oracle Corporation";
const char *simple_parser_description = "Simple Full-Text Parser";
mysql_declare_plugin(ftexample)
{
    MYSQL_FTPARSER_PLUGIN,      /* type                            */
    &simple_parser_descriptor,  /* descriptor                      */
    simple_parser_name,         /* name                            */
    simple_parser_author,       /* author                          */
    simple_parser_description,  /* description                     */
    PLUGIN_LICENSE_GPL,         /* plugin license                  */
    simple_parser_plugin_init,  /* init function (when loaded)     */
    simple_parser_plugin_deinit,/* deinit function (when unloaded) */
    0x0001,                     /* version                         */
    simple_status,              /* status variables                */
    simple_system_variables,    /* system variables                */
    NULL,
    0
}
mysql_declare_plugin_end;
```

However, the following general descriptor is invalid. It uses structure members to indicate the plugin name, author, and description, but structures are not considered constant initializers in C++:

```c
typedef struct
{
    const char *name;
    const char *author;
    const char *description;
} plugin_info;

plugin_info parser_info = {
    "simple_parser",
    "Oracle Corporation",
    "Simple Full-Text Parser"
};
```
Writing Plugins

```c
mysql_declare_plugin(ftexample)
{
    MYSQL_FTPARSER_PLUGIN,      /* type                            */
    &simple_parser_descriptor,  /* descriptor                      */
    parser_info.name,           /* name                            */
    parser_info.author,         /* author                          */
    parser_info.description,    /* description                     */
    PLUGIN_LICENSE_GPL,         /* plugin license                  */
    simple_parser_plugin_init,  /* init function (when loaded)     */
    simple_parser_plugin_deinit,/* deinit function (when unloaded)   */
    0x0001,                     /* version                         */
    NULL,
    0
}
mysql_declare_plugin_end;
```

Server Plugin Status and System Variables

The server plugin interface enables plugins to expose status and system variables using the `status_vars` and `system_vars` members of the general plugin descriptor.

The `status_vars` member of the general plugin descriptor, if not 0, points to an array of `st_mysql_show_var` structures, each of which describes one status variable, followed by a structure with all members set to 0. The `st_mysql_show_var` structure has this definition:

```c
struct st_mysql_show_var {
    const char *name;
    char *value;
    enum enum_mysql_show_type type;
};
```

The following table shows the permissible status variable type values and what the corresponding variable should be.

**Table 24.1 Server Plugin Status Variable Types**

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOW_BOOL</td>
<td>Pointer to a boolean variable</td>
</tr>
<tr>
<td>SHOW_INT</td>
<td>Pointer to an integer variable</td>
</tr>
<tr>
<td>SHOW_LONG</td>
<td>Pointer to a long integer variable</td>
</tr>
<tr>
<td>SHOW_LONGLONG</td>
<td>Pointer to a longlong integer variable</td>
</tr>
<tr>
<td>SHOW_CHAR</td>
<td>A string</td>
</tr>
<tr>
<td>SHOW_CHAR_PTR</td>
<td>Pointer to a string</td>
</tr>
<tr>
<td>SHOW_ARRAY</td>
<td>Pointer to another <code>st_mysql_show_var</code> array</td>
</tr>
<tr>
<td>SHOW_FUNC</td>
<td>Pointer to a function</td>
</tr>
<tr>
<td>SHOW_DOUBLE</td>
<td>Pointer to a double</td>
</tr>
</tbody>
</table>

For the SHOW_FUNC type, the function is called and fills in its `out` parameter, which then provides information about the variable to be displayed. The function has this signature:

```c
#define SHOW_VAR_FUNC_BUFF_SIZE 1024

typedef int (*mysql_show_var_func) (void *thd,
                                       struct st_mysql_show_var *out,
                                       char *buf);
```
Writing Plugins

The `system_vars` member, if not 0, points to an array of `st_mysql_sys_var` structures, each of which describes one system variable (which can also be set from the command-line or configuration file), followed by a structure with all members set to 0. The `st_mysql_sys_var` structure is defined as follows:

```c
struct st_mysql_sys_var {
    int flags;
    const char *name, *comment;
    int (*check)(THD*, struct st_mysql_sys_var *, void*, st_mysql_value*);
    void (*update)(THD*, struct st_mysql_sys_var *, void*, const void*);
};
```

Additional fields are appended as required depending upon the flags.

For convenience, a number of macros are defined that make creating new system variables within a plugin much simpler.

Throughout the macros, the following fields are available:

- **name**: An unquoted identifier for the system variable.
- **varname**: The identifier for the static variable. Where not available, it is the same as the `name` field.
- **opt**: Additional use flags for the system variable. The following table shows the permissible flags.

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLUGIN_VAR_READONLY</td>
<td>The system variable is read only</td>
</tr>
<tr>
<td>PLUGIN_VAR_NOSYSVAR</td>
<td>The system variable is not user visible at runtime</td>
</tr>
<tr>
<td>PLUGIN_VAR_NOCMDOPT</td>
<td>The system variable is not configurable from the command line</td>
</tr>
<tr>
<td>PLUGIN_VAR_NOCMDARG</td>
<td>No argument is required at the command line (typically used for boolean variables)</td>
</tr>
<tr>
<td>PLUGIN_VAR_RQCMDARG</td>
<td>An argument is required at the command line (this is the default)</td>
</tr>
<tr>
<td>PLUGIN_VAR_OPCMDARG</td>
<td>An argument is optional at the command line</td>
</tr>
<tr>
<td>PLUGIN_VAR_MEMALLOC</td>
<td>Used for string variables; indicates that memory is to be allocated for storage of the string</td>
</tr>
</tbody>
</table>

- **comment**: A descriptive comment to be displayed in the server help message. `NULL` if this variable is to be hidden.
- **check**: The check function, `NULL` for default.
- **update**: The update function, `NULL` for default.
- **default**: The variable default value.
- **minimum**: The variable minimum value.
- **maximum**: The variable maximum value.
- **blocksize**: The variable block size. When the value is set, it is rounded to the nearest multiple of `blocksize`.

A system variable may be accessed either by using the static variable directly or by using the `SYSVAR()` accessor macro. The `SYSVAR()` macro is provided for completeness. Usually it should be used only when the code cannot directly access the underlying variable.
For example:

```c
static int my_foo;
static MYSQL_SYSVAR_INT(foo_var, my_foo,
                        PLUGIN_VAR_RQCMDARG, "foo comment",
                        NULL, NULL, 0, 0, INT_MAX, 0);
...
SYSVAR(foo_var)= value;
value= SYSVAR(foo_var);
my_foo= value;
value= my_foo;
```

Session variables may be accessed only through the `THDVAR()` accessor macro. For example:

```c
static MYSQL_THDVAR_BOOL(some_flag,
                        PLUGIN_VAR_NOCMDARG, "flag comment",
                        NULL, NULL, FALSE);
...
if (THDVAR(thd, some_flag))
{
    do_something();
    THDVAR(thd, some_flag)= FALSE;
}
```

All global and session system variables must be published to `mysqld` before use. This is done by constructing a `NULL`-terminated array of the variables and linking to it in the plugin public interface. For example:

```c
static struct st_mysql_sys_var *my_plugin_vars[]= {
    MYSQL_SYSVAR(foo_var),
    MYSQL_SYSVAR(some_flag),
    NULL
};
mysql_declare_plugin(fooplug)
{
    MYSQL_..._PLUGIN,
    &plugin_data,
    "fooplug",
    "foo author",
    "This does foo!",
    PLUGIN_LICENSE_GPL,
    foo_init,
    foo_fini,
    0x0001,
    NULL,
    my_plugin_vars,
    NULL,
    0
}
mysql_declare_plugin_end;
```

The following convenience macros enable you to declare different types of system variables:

- **Boolean system variables of type** `my_bool`, which is a 1-byte boolean. (0 = FALSE, 1 = TRUE)

  ```c
  MYSQL_THDVAR_BOOL(name, opt, comment, check, update, default)
  MYSQL_SYSVAR_BOOL(name, varname, opt, comment, check, update, default)
  ```

- **String system variables of type** `char*`, which is a pointer to a null-terminated string.

  ```c
  MYSQL_THDVAR_STR(name, opt, comment, check, update, default)
  MYSQL_SYSVAR_STR(name, varname, opt, comment, check, update, default)
  ```

- **Integer system variables**, of which there are several varieties.
• An int system variable, which is typically a 4-byte signed word.

MySQL_THDVAR_INT(name, opt, comment, check, update, default, min, max, blk)
MySQL_SYSVAR_INT(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• An unsigned int system variable, which is typically a 4-byte unsigned word.

MySQL_THDVAR_UINT(name, opt, comment, check, update, default, min, max, blk)
MySQL_SYSVAR_UINT(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• A long system variable, which is typically either a 4- or 8-byte signed word.

MySQL_THDVAR_LONG(name, opt, comment, check, update, default, min, max, blk)
MySQL_SYSVAR_LONG(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• An unsigned long system variable, which is typically either a 4- or 8-byte unsigned word.

MySQL_THDVAR_ULONG(name, opt, comment, check, update, default, min, max, blk)
MySQL_SYSVAR_ULONG(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• A long long system variable, which is typically an 8-byte signed word.

MySQL_THDVAR_LONGLONG(name, opt, comment, check, update, default, minimum, maximum, blocksize)
MySQL_SYSVAR_LONGLONG(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• An unsigned long long system variable, which is typically an 8-byte unsigned word.

MySQL_THDVAR_ULONGLONG(name, opt, comment, check, update, default, minimum, maximum, blocksize)
MySQL_SYSVAR_ULONGLONG(name, varname, opt, comment, check, update, default, minimum, maximum, blocksize)

• An unsigned long system variable, which is typically either a 4- or 8-byte unsigned word. The range of possible values is an ordinal of the number of elements in the typelib, starting from 0.

MySQL_THDVAR_ENUM(name, opt, comment, check, update, default, typelib)
MySQL_SYSVAR_ENUM(name, varname, opt, comment, check, update, default, typelib)

• An unsigned long long system variable, which is typically an 8-byte unsigned word. Each bit represents an element in the typelib.

MySQL_THDVAR_SET(name, opt, comment, check, update, default, typelib)
MySQL_SYSVAR_SET(name, varname, opt, comment, check, update, default, typelib)

Internally, all mutable and plugin system variables are stored in a HASH structure.

Display of the server command-line help text is handled by compiling a DYNAMIC ARRAY of all variables relevant to command-line options, sorting them, and then iterating through them to display each option.

When a command-line option has been handled, it is then removed from the argv by the handle_option() function (my_getopt.c); in effect, it is consumed.

The server processes command-line options during the plugin installation process, immediately after the plugin has been successfully loaded but before the plugin initialization function has been called.
Plugins loaded at runtime do not benefit from any configuration options and must have usable defaults. Once they are installed, they are loaded at `mysqld` initialization time and configuration options can be set at the command line or within `my.cnf`.

Plugins should consider the `thd` parameter to be read only.

**Client Plugin Descriptors**

Each client plugin must have a descriptor that provides information to the client plugin API. The descriptor structure begins with a fixed set of members common to all client plugins, followed by any members specific to the plugin type.

The `st_mysql_client_plugin` structure in the `client_plugin.h` file defines a “generic” descriptor that contains the common members:

```c
struct st_mysql_client_plugin
{
  int type;
  unsigned int interface_version;
  const char *name;
  const char *author;
  const char *desc;
  unsigned int version[3];
  const char *license;
  void *mysql_api;
  int (*init)(char *, size_t, int, va_list);
  int (*deinit)();
  int (*options)(const char *option, const void *);
};
```

The common `st_mysql_client_plugin` descriptor structure members are used as follows. `char *` members should be specified as null-terminated strings.

- **type**: The plugin type. This must be one of the plugin-type values from `client_plugin.h`, such as `MYSQL_CLIENT_AUTHENTICATION_PLUGIN`.

- **interface_version**: The plugin interface version. For example, this is `MYSQL_CLIENT_AUTHENTICATION_PLUGIN_INTERFACE_VERSION` for an authentication plugin.

- **name**: A string that gives the plugin name. This is the name by which you refer to the plugin when you call `mysql_options()` with the `MYSQL_DEFAULT_AUTH` option or specify the `--default-auth` option to a MySQL client program.

- **author**: A string naming the plugin author. This can be whatever you like.

- **desc**: A string that provides a general description of the plugin. This can be whatever you like.

- **version**: The plugin version as an array of three integers indicating the major, minor, and teeny versions. For example, `{1, 2, 3}` indicates version 1.2.3.

- **license**: A string that specifies the license type.

- **mysql_api**: For internal use. Specify it as `NULL` in the plugin descriptor.

- **init**: A once-only initialization function, or `NULL` if there is no such function. The client library executes this function when it loads the plugin. The function returns zero for success and nonzero for failure.

  The `init` function uses its first two arguments to return an error message if an error occurs. The first argument is a pointer to a `char` buffer, and the second argument indicates the buffer length. Any message returned by the `init` function must be null-terminated, so the maximum message length is the
buffer length minus one. The next arguments are passed to \texttt{mysql\_load\_plugin()}. The first indicates how many more arguments there are (0 if none), followed by any remaining arguments.

- \texttt{deinit}: A once-only deinitialization function, or \texttt{NULL} if there is no such function. The client library executes this function when it unloads the plugin. The function takes no arguments. It returns zero for success and nonzero for failure.

- \texttt{options}: A function for handling options passed to the plugin, or \texttt{NULL} if there is no such function. The function takes two arguments representing the option name and a pointer to its value. The function returns zero for success and nonzero for failure.

For a given client plugin type, the common descriptor members may be followed by additional members necessary to implement plugins of that type. For example, the \texttt{st\_mysql\_client\_plugin\_AUTHENTICATION} structure for authentication plugins has a function at the end that the client library calls to perform authentication.

To declare a plugin, use the \texttt{mysql\_declare\_client\_plugin()} and \texttt{mysql\_end\_client\_plugin} macros:

```c
mysql_declare_client_plugin(plugin_type)
    ... members common to all client plugins ...
    ... type-specific extra members ...
mysql_end_client_plugin;
```

Do not specify the \texttt{type} or \texttt{interface\_version} member explicitly. The \texttt{mysql\_declare\_client\_plugin()} macro uses the \texttt{plugin\_type} argument to generate their values automatically. For example, declare an authentication client plugin like this:

```c
mysql_declare_client_plugin(AUTHENTICATION)
    "my_auth_plugin",
    "Author Name",
    "My Client Authentication Plugin",
    [1,0,0],
    "GPL",
    NULL,
    my_auth_init,
    my_auth_deinit,
    my_auth_options,
    my_auth_main
mysql_end_client_plugin;
```

This declaration uses the \texttt{AUTHENTICATION} argument to set the \texttt{type} and \texttt{interface\_version} members to \texttt{MYSQL\_CLIENT\_AUTHENTICATION\_PLUGIN} and \texttt{MYSQL\_CLIENT\_AUTHENTICATION\_PLUGIN\_INTERFACE\_VERSION}.

Depending on the plugin type, the descriptor may have other members following the common members. For example, for an authentication plugin, there is a function (\texttt{my_auth\_main()} in the descriptor just shown) that handles communication with the server. See Section 24.2.4.9, “Writing Authentication Plugins”.

Normally, a client program that supports the use of authentication plugins causes a plugin to be loaded by calling \texttt{mysql\_options()} to set the \texttt{MYSQL\_DEFAULT\_AUTH} and \texttt{MYSQL\_PLUGIN\_DIR} options:

```c
char *plugin\_dir = "path\_to\_plugin\_dir";
char *default\_auth = "plugin\_name";

/* ... process command-line options ... */

mysql_options(&mysql, MYSQL\_PLUGIN\_DIR, plugin\_dir);
mysql_options(&mysql, MYSQL\_DEFAULT\_AUTH, default\_auth);
```

Typically, the program will also accept \texttt{--plugin\_dir} and \texttt{--default\_auth} options that enable users to override the default values.
Writing Plugins

Should a client program require lower-level plugin management, the client library contains functions that take an `st_mysql_client_plugin` argument. See Section 23.7.13, “C API Client Plugin Functions”.

24.2.4.3 Compiling and Installing Plugin Libraries

After your plugin is written, you must compile it and install it. The procedure for compiling shared objects varies from system to system. If you build your library using CMake, it should be able to generate the correct compilation commands for your system. If the library is named `somepluglib`, you should end up with a shared library file that has a name something like `somepluglib.so`. (The `.so` file name suffix might differ on your system.)

To use CMake, you'll need to set up the configuration files to enable the plugin to be compiled and installed. Use the plugin examples under the `plugin` directory of a MySQL source distribution as a guide.

Create `CMakeLists.txt`, which should look something like this:

```plaintext
MYSQL_ADD_PLUGIN(somepluglib somepluglib.c
MODULE_ONLY MODULE_OUTPUT_NAME "somepluglib")
```

When CMake generates the Makefile, it should take care of passing to the compilation command the `-DMYSQL_DYNAMIC_PLUGIN` flag, and passing to the linker the `-lmysqlservices` flag, which is needed to link in any functions from services provided through the plugin services interface. See Section 24.3, “MySQL Services for Plugins”.

Run CMake, then run `make`:

```plaintext
shell> cmake .
shell> make
```

If you need to specify configuration options to CMake, see Section 2.9.7, “MySQL Source-Configuration Options”, for a list. For example, you might want to specify `CMAKE_INSTALL_PREFIX` to indicate the MySQL base directory under which the plugin should be installed. You can see what value to use for this option with `SHOW VARIABLES`:

```plaintext
mysql> SHOW VARIABLES LIKE 'basedir';
+---------------+------------------+
| Variable_name | Value            |
+---------------+------------------+
| base          | /usr/local/mysql |
+---------------+------------------+
```

The location of the plugin directory where you should install the library is given by the `plugin_dir` system variable. For example:

```plaintext
mysql> SHOW VARIABLES LIKE 'plugin_dir';
+---------------+-----------------------------------+
| Variable_name | Value                             |
+---------------+-----------------------------------+
| plugin_dir    | /usr/local/mysql/lib/mysql/plugin |
+---------------+-----------------------------------+
```

To install the plugin library, use `make`:

```plaintext
shell> make install
```

Verify that `make install` installed the plugin library in the proper directory. After installing it, make sure that the library permissions permit it to be executed by the server.

24.2.4.4 Writing Full-Text Parser Plugins

MySQL supports server-side full-text parser plugins only with MyISAM. For introductory information about full-text parser plugins, see Full-Text Parser Plugins.
A full-text parser plugin can be used to replace or modify the built-in full-text parser. This section describes how to write a full-text parser plugin named `simple_parser`. This plugin performs parsing based on simpler rules than those used by the MySQL built-in full-text parser: Words are nonempty runs of whitespace characters.

The instructions use the source code in the `plugin/fulltext` directory of MySQL source distributions, so change location into that directory. The following procedure describes how the plugin library is created:

1. To write a full-text parser plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

   ```c
   #include <mysql/plugin.h>
   ```

   `plugin.h` defines the `MYSQL_FTPARSER_PLUGIN` server plugin type and the data structures needed to declare the plugin.

2. Set up the library descriptor for the plugin library file.

   This descriptor contains the general plugin descriptor for the server plugin. For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

   For example, the library descriptor for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

   ```c
   mysql_declare_plugin(ftexample)
   |
   | MYSQL_FTPARSER_PLUGIN, /* type */
   | &simple_parser_descriptor, /* descriptor */
   | "simple_parser", /* name */
   | "Oracle Corporation", /* author */
   | "Simple Full-Text Parser", /* description */
   | PLUGIN_LICENSE_GPL, /* plugin license */
   | simple_parser_plugin_init, /* init function (when loaded) */
   | simple_parser_plugin_deinit, /* deinit function (when unloaded) */
   | 0x0001, /* version */
   | simple_status, /* status variables */
   | simple_system_variables, /* system variables */
   | NULL,
   | 0
   |
   mysql_declare_plugin_end;
   ```

   The `name` member (`simple_parser`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

   For more information, see Server Plugin Library and Plugin Descriptors.

3. Set up the type-specific plugin descriptor.

   Each general plugin descriptor in the library descriptor points to a type-specific descriptor. For a full-text parser plugin, the type-specific descriptor is an instance of the `st_mysql_ftparser` structure in the `plugin.h` file:

   ```c
   struct st_mysql_ftparser
   |
   | int interface_version;
   | int (*parse)(MYSQL_FTPARSER_PARAM *param);
   | int (*init)(MYSQL_FTPARSER_PARAM *param);
   ```
As shown by the structure definition, the descriptor has an interface version number and contains pointers to three functions.

The interface version number is specified using a symbol, which is in the form: `MYSQL_xxx_INTERFACE_VERSION`. For full-text parser plugins, the symbol is `MYSQL_FTPARSER_INTERFACE_VERSION`. In the source code, you will find the actual interface version number for the full-text parser plugin defined in `include/mysql/plugin_ftparser.h`.

The `init` and `deinit` members should point to a function or be set to 0 if the function is not needed. The `parse` member must point to the function that performs the parsing.

In the `simple_parser` declaration, that descriptor is indicated by `&simple_parser_descriptor`. The descriptor specifies the version number for the full-text plugin interface (as given by `MYSQL_FTPARSER_INTERFACE_VERSION`), and the plugin’s parsing, initialization, and deinitialization functions:

```c
static struct st_mysql_ftparser simple_parser_descriptor=
{
    MYSQL_FTPARSER_INTERFACE_VERSION, /* interface version      */
    simple_parser_parse,              /* parsing function       */
    simple_parser_init,               /* parser init function   */
    simple_parser_deinit              /* parser deinit function */
};
```

A full-text parser plugin is used in two different contexts, indexing and searching. In both contexts, the server calls the initialization and deinitialization functions at the beginning and end of processing each SQL statement that causes the plugin to be invoked. However, during statement processing, the server calls the main parsing function in context-specific fashion:

- For indexing, the server calls the parser for each column value to be indexed.

- For searching, the server calls the parser to parse the search string. The parser might also be called for rows processed by the statement. In natural language mode, there is no need for the server to call the parser. For boolean mode phrase searches or natural language searches with query expansion, the parser is used to parse column values for information that is not in the index. Also, if a boolean mode search is done for a column that has no `FULLTEXT` index, the built-in parser will be called. (Plugins are associated with specific indexes. If there is no index, no plugin is used.)

The plugin declaration in the general plugin descriptor has `init` and `deinit` members that point initialization and deinitialization functions, and so does the type-specific plugin descriptor to which it points. However, these pairs of functions have different purposes and are invoked for different reasons:

- For the plugin declaration in the general plugin descriptor, the initialization and deinitialization functions are invoked when the plugin is loaded and unloaded.

- For the type-specific plugin descriptor, the initialization and deinitialization functions are invoked per SQL statement for which the plugin is used.

Each interface function named in the plugin descriptor should return zero for success or nonzero for failure, and each of them receives an argument that points to a `MYSQL_FTPARSER_PARAM` structure containing the parsing context. The structure has this definition:

```c
typedef struct st_mysql_ftparser_param
{
    int (*mysql_parse)(struct st_mysql_ftparser_param *,
,...
```
Writing Plugins

char *doc, int doc_len);
int (*mysql_add_word)(struct st_mysql_ftparser_param *,
    char *word, int word_len,
    MYSQL_FTPARSER_BOOLEAN_INFO *boolean_info);

void *ftparser_state;
void *mysql_ftparam;
struct charset_info_st *cs;
char *doc;
int length;
int flags;
enum enum_ftparser_mode mode;
) MYSQL_FTPARSER_PARAM;

The structure members are used as follows:

- **mysql_parse**: A pointer to a callback function that invokes the server's built-in parser. Use this callback when the plugin acts as a front end to the built-in parser. That is, when the plugin parsing function is called, it should process the input to extract the text and pass the text to the mysql_parse callback.

  The first parameter for this callback function should be the **param** value itself:

  ```
  param->mysql_parse(param, ...);
  ```

  A front end plugin can extract text and pass it all at once to the built-in parser, or it can extract and pass text to the built-in parser a piece at a time. However, in this case, the built-in parser treats the pieces of text as though there are implicit word breaks between them.

- **mysql_add_word**: A pointer to a callback function that adds a word to a full-text index or to the list of search terms. Use this callback when the parser plugin replaces the built-in parser. That is, when the plugin parsing function is called, it should parse the input into words and invoke the mysql_add_word callback for each word.

  The first parameter for this callback function should be the **param** value itself:

  ```
  param->mysql_add_word(param, ...);
  ```

- **ftparser_state**: This is a generic pointer. The plugin can set it to point to information to be used internally for its own purposes.

- **mysql_ftparam**: This is set by the server. It is passed as the first argument to the mysql_parse or mysql_add_word callback.

- **cs**: A pointer to information about the character set of the text, or 0 if no information is available.

- **doc**: A pointer to the text to be parsed.

- **length**: The length of the text to be parsed, in bytes.

- **flags**: Parser flags. This is zero if there are no special flags. The only nonzero flag is MYSQL_FTFLAGS_NEED_COPY, which means that mysql_add_word() must save a copy of the word (that is, it cannot use a pointer to the word because the word is in a buffer that will be overwritten.)

  This flag might be set or reset by MySQL before calling the parser plugin, by the parser plugin itself, or by the mysql_parse() function.
Writing Plugins

- **mode:** The parsing mode. This value will be one of the following constants:
  - `MYSQL_FTPARSER_SIMPLE_MODE`: Parse in fast and simple mode, which is used for indexing and for natural language queries. The parser should pass to the server only those words that should be indexed. If the parser uses length limits or a stopword list to determine which words to ignore, it should not pass such words to the server.
  - `MYSQL_FTPARSER_WITH_STOPWORDS`: Parse in stopword mode. This is used in boolean searches for phrase matching. The parser should pass all words to the server, even stopwords or words that are outside any normal length limits.
  - `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`: Parse in boolean mode. This is used for parsing boolean query strings. The parser should recognize not only words but also boolean-mode operators and pass them to the server as tokens using the `mysql_add_word` callback. To tell the server what kind of token is being passed, the plugin needs to fill in a `MYSQL_FTPARSER_BOOLEAN_INFO` structure and pass a pointer to it.

If the parser is called in boolean mode, the `param->mode` value will be `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`. The `MYSQL_FTPARSER_BOOLEAN_INFO` structure that the parser uses for passing token information to the server looks like this:

```c
typedef struct st_mysql_ftparser_boolean_info {
    enum enum_ft_token_type type;
    int yesno;
    int weight_adjust;
    char wasign;
    char trunc;
    /* These are parser state and must be removed. */
    char prev;
    char *quot;
} MYSQL_FTPARSER_BOOLEAN_INFO;
```

The parser should fill in the structure members as follows:

- **type:** The token type. The following table shows the permissible types.

<table>
<thead>
<tr>
<th>Token Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>FT_TOKEN_EOF</code></td>
<td>End of data</td>
</tr>
<tr>
<td><code>FT_TOKEN_WORD</code></td>
<td>A regular word</td>
</tr>
<tr>
<td><code>FT_TOKEN_LEFT_PAREN</code></td>
<td>The beginning of a group or subexpression</td>
</tr>
<tr>
<td><code>FT_TOKEN_RIGHT_PAREN</code></td>
<td>The end of a group or subexpression</td>
</tr>
<tr>
<td><code>FT_TOKEN_STOPWORD</code></td>
<td>A stopword</td>
</tr>
</tbody>
</table>

- **yesno:** Whether the word must be present for a match to occur. 0 means that the word is optional but increases the match relevance if it is present. Values larger than 0 mean that the word must be present. Values smaller than 0 mean that the word must not be present.

- **weight_adjust:** A weighting factor that determines how much a match for the word counts. It can be used to increase or decrease the word's importance in relevance calculations. A value of zero indicates no weight adjustment. Values greater than or less than zero mean higher or lower weight, respectively. The examples at Section 12.9.2, "Boolean Full-Text Searches", that use the `<` and `>` operators illustrate how weighting works.
• **wassign**: The sign of the weighting factor. A negative value acts like the - boolean-search operator, which causes the word’s contribution to the relevance to be negative.

• **trunc**: Whether matching should be done as if the boolean-mode * truncation operator had been given.

Plugins should not use the prev and quot members of the MYSQL_FTPARSER_BOOLEAN_INFO structure.

---

## Note

The plugin parser framework does not support:

- The @distance boolean operator.
- A leading plus sign (+) or minus sign (-) boolean operator followed by a space and then a word ('+ apple' or '- apple'). The leading plus or minus sign must be directly adjacent to the word, for example: '+apple' or '-apple'.

For information about boolean full-text search operators, see Section 12.9.2, “Boolean Full-Text Searches”.

4. Set up the plugin interface functions.

The general plugin descriptor in the library descriptor names the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. For **simple_parser**, these functions do nothing but return zero to indicate that they succeeded:

```c
static int simple_parser_plugin_init(void *arg __attribute__((unused)))
{
    return(0);
}

static int simple_parser_plugin_deinit(void *arg __attribute__((unused)))
{
    return(0);
}
```

Because those functions do not actually do anything, you could omit them and specify 0 for each of them in the plugin declaration.

The type-specific plugin descriptor for **simple_parser** names the initialization, deinitialization, and parsing functions that the server invokes when the plugin is used. For **simple_parser**, the initialization and deinitialization functions do nothing:

```c
static int simple_parser_init(MYSQL_FTPARSER_PARAM *param
                                    __attribute__((unused)))
{
    return(0);
}

static int simple_parser_deinit(MYSQL_FTPARSER_PARAM *param
                                    __attribute__((unused)))
{
    return(0);
}
```
Here too, because those functions do nothing, you could omit them and specify 0 for each of them in the plugin descriptor.

The main parsing function, `simple_parser_parse()`, acts as a replacement for the built-in full-text parser, so it needs to split text into words and pass each word to the server. The parsing function's first argument is a pointer to a structure that contains the parsing context. This structure has a `doc` member that points to the text to be parsed, and a `length` member that indicates how long the text is. The simple parsing done by the plugin considers nonempty runs of whitespace characters to be words, so it identifies words like this:

```c
static int simple_parser_parse(MYSQL_FTPARSER_PARAM *param)
{
    char *end, *start, *docend= param->doc + param->length;

    for (end= start= param->doc;; end++)
    {
        if (end == docend)
            { if (end > start)
                add_word(param, start, end - start);
                break;
            }
        else if (isspace(*end))
            { if (end > start)
                add_word(param, start, end - start);
                start= end + 1;
            }
    }

    return(0);
}
```

As the parser finds each word, it invokes a function `add_word()` to pass the word to the server. `add_word()` is a helper function only; it is not part of the plugin interface. The parser passes the parsing context pointer to `add_word()`, as well as a pointer to the word and a length value:

```c
static void add_word(MYSQL_FTPARSER_PARAM *param, char *word, size_t len)
{
    MYSQL_FTPARSER_BOOLEAN_INFO bool_info= {
        FT_TOKEN_WORD, 0, 0, 0, ' ', 0 };

    param->mysql_add_word(param, word, len, &bool_info);
}
```

For boolean-mode parsing, `add_word()` fills in the members of the `bool_info` structure as described earlier in the discussion of the `st_mysql_ftparser_boolean_info` structure.

5. Set up the status variables. For the `simple_parser` plugin, the following status variable array sets up one status variable with a value that is static text, and another with a value that is stored in a long integer variable:

```c
long number_of_calls= 0;

struct st_mysql_show_var simple_status[]=
{
    {"simple_parser_static", (char *)"just a static text", SHOW_CHAR},
    {"simple_parser_called", (char *)&number_of_calls, SHOW_LONG},
    {0,0,0}
};
```
By using status variable names that begin with the plugin name, you can easily display the variables for a plugin with `SHOW STATUS`:

```sql
mysql> SHOW STATUS LIKE 'simple_parser%';
```

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple_parser_static</td>
<td>just a static text</td>
</tr>
<tr>
<td>simple_parser_called</td>
<td>0</td>
</tr>
</tbody>
</table>

6. To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `simple_parser` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `mypluglib.so` (the `.so` suffix might differ depending on your platform).

7. To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```sql
INSTALL PLUGIN simple_parser SONAME 'mypluglib.so';
```

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

8. To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

9. Test the plugin to verify that it works properly.

Create a table that contains a string column and associate the parser plugin with a `FULLTEXT` index on the column:

```sql
mysql> CREATE TABLE t (c VARCHAR(255),
-> FULLTEXT (c) WITH PARSER simple_parser
-> ) ENGINE=MyISAM;
```

```
Query OK, 0 rows affected (0.01 sec)
```

Insert some text into the table and try some searches. These should verify that the parser plugin treats all nonwhitespace characters as word characters:

```sql
mysql> INSERT INTO t VALUES
-> ('latin1_general_cs is a case-sensitive collation'),
-> ('I\'d like a case of oranges'),
-> ('this is sensitive information'),
-> ('another row'),
-> ('yet another row');
```

```
Query OK, 5 rows affected (0.02 sec)
Records: 5 Duplicates: 0 Warnings: 0
```

```sql
mysql> SELECT c FROM t;
```

```sql
+-------------------------------------------------+
<table>
<thead>
<tr>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>latin1_general_cs is a case-sensitive collation</td>
</tr>
<tr>
<td>I'd like a case of oranges</td>
</tr>
<tr>
<td>this is sensitive information</td>
</tr>
<tr>
<td>another row</td>
</tr>
<tr>
<td>yet another row</td>
</tr>
</tbody>
</table>
+-------------------------------------------------+

5 rows in set (0.00 sec)
Neither “case” nor “insensitive” match “case-insensitive” the way that they would for the built-in parser.

### 24.2.4.5 Writing Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. This section describes how to write a daemon server plugin, using the example plugin found in the `plugin/daemon_example` directory of MySQL source distributions. That directory contains the `daemon_example.cc` source file for a daemon plugin named `daemon_example` that writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory.

To write a daemon plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```c
#include <mysql/plugin.h>
```
Writing Plugins

`plugin.h` defines the `MYSQL_DAEMON_PLUGIN` server plugin type and the data structures needed to declare the plugin.

The `daemon_example.cc` file sets up the library descriptor as follows. The library descriptor includes a single general server plugin descriptor.

```c
mysql_declare_plugin(daemon_example)
{
  MYSQL_DAEMON_PLUGIN,
  &daemon_example_plugin,
  "daemon_example",
  "Brian Aker",
  "Daemon example, creates a heartbeat beat file in mysql-heartbeat.log",
  PLUGIN_LICENSE_GPL,
  daemon_example_plugin_init, /* Plugin Init */
  daemon_example_plugin_deinit, /* Plugin Deinit */
  0x0100 /* 1.0 */,
  NULL, /* status variables */
  NULL, /* system variables */
  NULL, /* config options */
  0, /* flags */
}
mysql_declare_plugin_end;
```

The `name` member (`daemon_example`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The second member of the plugin descriptor, `daemon_example_plugin`, points to the type-specific daemon plugin descriptor. This structure consists only of the type-specific API version number:

```c
struct st_mysql_daemon daemon_example_plugin=
{
  MYSQL_DAEMON_INTERFACE_VERSION
};
```

The type-specific structure has no interface functions. There is no communication between the server and the plugin, except that the server calls the initialization and deinitialization functions from the general plugin descriptor to start and stop the plugin:

- `daemon_example_plugin_init()` opens the heartbeat file and spawns a thread that wakes up periodically and writes the next message to the file.
- `daemon_example_plugin_deinit()` closes the file and performs other cleanup.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `daemon_example` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `libdaemon_example.so` (the `.so` suffix might differ depending on your platform).

To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```sql
INSTALL PLUGIN daemon_example SONAME 'libdaemon_example.so';
```

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”. 

2977
While the plugin is loaded, it writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory. This file grows without limit, so after you have satisfied yourself that the plugin operates correctly, unload it:

```
UNINSTALL PLUGIN daemon_example;
```

### 24.2.4.6 Writing INFORMATION_SCHEMA Plugins

This section describes how to write a server-side INFORMATION_SCHEMA table plugin. For example code that implements such plugins, see the `sql/sql_show.cc` file of a MySQL source distribution. You can also look at the example plugins found in the InnoDB source. See the `handler/i_s.cc` and `handler/ha_innodb.cc` files within the InnoDB source tree (in the `storage/innobase` directory).

To write an INFORMATION_SCHEMA table plugin, include the following header files in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <sql_class.h>
#include <table.h>
```

These header files are located in the `sql` directory of MySQL source distributions. They contain C++ structures, so the source file for an INFORMATION_SCHEMA plugin must be compiled as C++ (not C) code.

The source file for the example plugin developed here is named `simple_i_s_table.cc`. It creates a simple INFORMATION_SCHEMA table named `SIMPLE_I_S_TABLE` that has two columns named `NAME` and `VALUE`. The general descriptor for a plugin library that implements the table looks like this:

```
mysql_declare_plugin(simple_i_s_library)
{
    MYSQL_INFORMATION_SCHEMA_PLUGIN,
    &simple_table_info,          /* type-specific descriptor */
    "SIMPLE_I_S_TABLE",          /* table name */
    "Author Name",               /* author */
    "Simple INFORMATION_SCHEMA", /* description */
    PLUGIN_LICENSE_GPL,          /* license type */
    simple_table_init,           /* init function */
    NULL,
    0x0100,                       /* version = 1.0 */
    NULL,                         /* no status variables */
    NULL,                         /* no system variables */
    NULL,                         /* no reserved information */
    0                             /* no flags */
} mysql_declare_plugin_end;
```

The name member (`SIMPLE_I_S_TABLE`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The `simple_table_info` member of the general descriptor points to the type-specific descriptor, which consists only of the type-specific API version number:

```
static struct st_mysql_information_schema simple_table_info =
{ MYSQL_INFORMATION_SCHEMA_INTERFACE_VERSION };
```

The general descriptor points to the initialization and deinitialization functions:

- The initialization function provides information about the table structure and a function that populates the table.
- The deinitialization function performs any required cleanup. If no cleanup is needed, this descriptor member can be `NULL` (as in the example shown).
Writing Plugins

The initialization function should return 0 for success, 1 if an error occurs. The function receives a generic pointer, which it should interpret as a pointer to the table structure:

```c
static int table_init(void *ptr)
{
    ST_SCHEMA_TABLE *schema_table= (ST_SCHEMA_TABLE*)ptr;
    schema_table->fields_info= simple_table_fields;
    schema_table->fill_table= simple_fill_table;
    return 0;
}
```

The function should set these two members of the table structure:

- **fields_info**: An array of **ST_FIELD_INFO** structures that contain information about each column.
- **fill_table**: A function that populates the table.

The array pointed to by **fields_info** should contain one element per column of the **INFORMATION_SCHEMA** table plus a terminating element. The following `simple_table_fields` array for the example plugin indicates that **SIMPLE_I_S_TABLE** has two columns. **NAME** is string-valued with a length of 10 and **VALUE** is integer-valued with a display width of 20. The last structure marks the end of the array.

```c
static ST_FIELD_INFO simple_table_fields[] =
{
    {"NAME", 10, MYSQL_TYPE_STRING, 0, 0, 0, 0},
    {"VALUE", 6, MYSQL_TYPE_LONG, 0, MY_I_S_UNSIGNED, 0, 0},
    {0, 0, MYSQL_TYPE_NULL, 0, 0, 0, 0}
};
```

For more information about the column information structure, see the definition of **ST_FIELD_INFO** in the `table.h` header file. The permissible **MYSQL_TYPE_xxx** type values are those used in the C API; see Section 23.7.4, "C API Data Structures".

The **fill_table** member should be set to a function that populates the table and returns 0 for success, 1 if an error occurs. For the example plugin, the `simple_fill_table()` function looks like this:

```c
static int simple_fill_table(THD *thd, TABLE_LIST *tables, COND *cond)
{
    TABLE *table= tables->table;
    table->field[0]->store("Name 1", 6, system_charset_info);
    table->field[1]->store(1);
    if (schema_table_store_record(thd, table))
        return 1;
    table->field[0]->store("Name 2", 6, system_charset_info);
    table->field[1]->store(2);
    if (schema_table_store_record(thd, table))
        return 1;
    return 0;
}
```

For each row of the **INFORMATION_SCHEMA** table, this function initializes each column, then calls `schema_table_store_record()` to install the row. The **store()** method arguments depend on the type of value to be stored. For column 0 (**NAME**, a string), **store()** takes a pointer to a string, its length, and information about the character set of the string:

```c
store(const char *to, uint length, CHARSET_INFO *cs);
```

For column 1 (**VALUE**, an integer), **store()** takes the value and a flag indicating whether it is unsigned:

```c
store(longlong nr, bool unsigned_value);
```
For other examples of how to populate INFORMATION_SCHEMA tables, search for instances of schema_table_store_record() in sql_show.cc.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the plugin_dir system variable).

To test the plugin, install it:

```sql
mysql> INSTALL PLUGIN SIMPLE_I_S_TABLE SONAME 'simple_i_s_table.so';
```

Verify that the table is present:

```sql
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
     -> WHERE TABLE_NAME = 'SIMPLE_I_S_TABLE';
```

Try to select from it:

```sql
mysql> SELECT * FROM INFORMATION_SCHEMA.SIMPLE_I_S_TABLE;
```

Uninstall it:

```sql
mysql> UNINSTALL PLUGIN SIMPLE_I_S_TABLE;
```

### 24.2.4.7 Writing Semisynchronous Replication Plugins

This section describes how to write server-side semisynchronous replication plugins, using the example plugins found in the plugin/semisync directory of MySQL source distributions. That directory contains the source files for master and slave plugins named rpl_semi_sync_master and rpl_semi_sync_slave. The information here covers only how to set up the plugin framework. For details about how the plugins implement replication functions, see the source.

To write a semisynchronous replication plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```c
#include <mysql/plugin.h>
```

`plugin.h` defines the MYSQL_REPLICATION_PLUGIN server plugin type and the data structures needed to declare the plugin.

For the master side, semisync_master_plugin.cc contains this general descriptor for a plugin named rpl_semi_sync_master:

```c
mysql_declare_plugin(semi_sync_master)
{
    MYSQL_REPLICATION_PLUGIN,
    &semi_sync_master_plugin,
    "rpl_semi_sync_master",
    "He Zhenxing",
    "Semi-synchronous replication master",
}
Writing Plugins

```c
PLUGIN_LICENSE_GPL,
semi_sync_master_plugin_init, /* Plugin Init */
semi_sync_master_plugin_deinit, /* Plugin Deinit */
0x0100 /* 1.0 */,
semi_sync_master_status_vars, /* status variables */
semi_sync_master_system_vars, /* system variables */
NULL,                         /* config options */
0,                            /* flags */
}
mysql_declare_plugin_end;

For the slave side, `semisync_slave_plugin.cc` contains this general descriptor for a plugin named `rpl_semi_sync_slave`:

```c
mysql_declare_plugin(semi_sync_slave)
{
    MYSQL_REPLICATION_PLUGIN,
    &semi_sync_slave_plugin,
    "rpl_semi_sync_slave",
    "He Zhenxing",
    "Semi-synchronous replication slave",
    PLUGIN_LICENSE_GPL,
    semi_sync_slave_plugin_init, /* Plugin Init */
    semi_sync_slave_plugin_deinit, /* Plugin Deinit */
    0x0100 /* 1.0 */,
    semi_sync_slave_status_vars, /* status variables */
    semi_sync_slave_system_vars, /* system variables */
    NULL,                         /* config options */
    0,                            /* flags */
}
mysql_declare_plugin_end;
```

For both the master and slave plugins, the general descriptor has pointers to the type-specific descriptor, the initialization and deinitialization functions, and to the status and system variables implemented by the plugin. For information about variable setup, see Server Plugin Status and System Variables. The following remarks discuss the type-specific descriptor and the initialization and deinitialization functions for the master plugin but apply similarly to the slave plugin.

The `semi_sync_master_plugin` member of the master general descriptor points to the type-specific descriptor, which consists only of the type-specific API version number:

```c
struct Mysql_replication semi_sync_master_plugin= {
    MYSQL_REPLICATION_INTERFACE_VERSION
};
```

The initialization and deinitialization function declarations look like this:

```c
static int semi_sync_master_plugin_init(void *p);
static int semi_sync_master_plugin_deinit(void *p);
```

The initialization function uses the pointer to register transaction and binary logging “observers” with the server. After successful initialization, the server takes care of invoking the observers at the appropriate times. (For details on the observers, see the source files.) The deinitialization function cleans up by deregistering the observers. Each function returns 0 for success or 1 if an error occurs.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `rpl_semi_sync_master` and `rpl_semi_sync_slave` plugins, they are compiled and installed when you build MySQL from source. They are also included in binary distributions. The build process produces shared object libraries with names of `semisync_master.so` and `semisync_slave.so` (the `.so` suffix might differ depending on your platform).
24.2.4.8 Writing Audit Plugins

This section describes how to write a server-side audit plugin, using the example plugin found in the plugin/audit_null directory of MySQL source distributions. The audit_null.c source file in that directory implements a simple example audit plugin named NULL_AUDIT.

Within the server, the pluggable audit interface is implemented in the sql_audit.h and sql_audit.cc files in the sql directory of MySQL source distributions. Additionally, several places in the server call the audit interface when an auditable event occurs, so that registered audit plugins can be notified about the event if necessary. To see where such calls occur, search the server source files for invocations of functions with names of the form mysql_audit_xxx(). Audit notification occurs for server operations such as these:

- Client connect and disconnect events
- Writing a message to the general query log (if the log is enabled)
- Writing a message to the error log
- Sending a query result to a client

To write an audit plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```c
#include <mysql/plugin_audit.h>
```

The first member, MYSQL_AUDIT_PLUGIN, identifies this plugin as an audit plugin.

```c
mysql_declare_plugin(audit_null) {
    MYSQL_AUDIT_PLUGIN, /* type */
    &audit_null_descriptor, /* descriptor */
    "NULL_AUDIT", /* name */
    "Oracle Corp", /* author */
    "Simple NULL Audit", /* description */
    PLUGIN_LICENSE_GPL, /* license */
    audit_null_plugin_init, /* init function (when loaded) */
    audit_null_plugin_deinit, /* deinit function (when unloaded) */
    0x0002, /* version */
    simple_status, /* status variables */
    NULL, /* system variables */
    0,
}
```

The first member, MYSQL_AUDIT_PLUGIN, identifies this plugin as an audit plugin.

```c
audit_null_descriptor
```

points to the type-specific plugin descriptor, described later.

The name member (NULL_AUDIT) indicates the name to use for references to the plugin in statements such as INSTALL PLUGIN or UNINSTALL PLUGIN. This is also the name displayed by INFORMATION_SCHEMA.PLUGINS or SHOW PLUGINS.

The general plugin descriptor also refers to `simple_status`, a structure that exposes several status variables to the SHOW STATUS statement:
static struct st_mysql_show_var simple_status[] =
{
    { "Audit_null_called", (char *) &number_of_calls, SHOW_INT },
    { "Audit_null_general_log", (char *) &number_of_calls_general_log, SHOW_INT },
    { "Audit_null_general_error", (char *) &number_of_calls_general_error, SHOW_INT },
    { "Audit_null_general_result", (char *) &number_of_calls_general_result, SHOW_INT },
    { 0, 0, 0 }
};

The audit_null_plugin_init initialization function sets the status variables to zero when the plugin is loaded. The audit_null_plugin_deinit function performs cleanup when the plugin is unloaded. During operation, the plugin increments the first status variable for each notification it receives. It also increments the others according to the event class and subclass. In effect, the first variable is the aggregate of the counts for the event subclasses.

The audit_null_descriptor value in the general plugin descriptor points to the type-specific plugin descriptor. For audit plugins, this descriptor has the following structure:

struct st_mysql_audit
{
    int interface_version;
    void (*release_thd)(MYSQL_THD);
    void (*event_notify)(MYSQL_THD, unsigned int, const void *);
    unsigned long class_mask[MYSQL_AUDIT_CLASS_MASK_SIZE];
};

The type-specific plugin descriptor for audit plugins has these members:

• interface_version: By convention, type-specific plugin descriptors begin with the interface version for the given plugin type. The server checks interface_version when it loads the plugin to see whether the plugin is compatible with it. For audit plugins, the value of the interface_version member is MYSQL_AUDIT_INTERFACE_VERSION (defined in plugin_audit.h).

• release_thd: A function that the server calls to inform the plugin that it is being dissociated from its thread context. This should be NULL if there is no such function.

• event_notify: A function that the server calls to notify the plugin that an auditable event has occurred. This function should not be NULL; that would not make sense because no auditing would occur.

• class_mask: A bitmask that indicates the event classes for which the plugin wants to receive notification. If this value is 0, the server passes no events to the plugin.

The server uses the event_notify and release_thd functions together. They are called within the context of a specific thread, and a thread might perform an activity that produces several event notifications. The first time the server calls event_notify for a thread, it creates a binding of the plugin to the thread. The plugin cannot be uninstalled while this binding exists. When no more events for the thread will occur, the server informs the plugin of this by calling the release_thd function, and then destroys the binding. For example, when a client issues a statement, the thread processing the statement might notify audit plugins about the result set produced by the statement and about the statement being logged. After these notifications occur, the server releases the plugin before putting the thread to sleep until the client issues another statement.

This design enables the plugin to allocate resources needed for a given thread in the first call to the event_notify function and release them in the release_thd function:
Writing Plugins

... rest of notification processing ...

release_thd function:
if memory was allocated
    release memory
... rest of release processing ...

That is more efficient than allocating and releasing memory repeatedly in the notification function.

For the **NULL_AUDIT** audit plugin, the type-specific plugin descriptor looks like this:

```c
static struct st_mysql_audit audit_null_descriptor =
{
    MYSQL_AUDIT_INTERFACE_VERSION, /* interface version */
    NULL,                            /* release_thd function */
    audit_null_notify,               /* notify function */
    { (unsigned long) MYSQL_AUDIT_GENERAL_CLASSMASK } /* class mask */
};
```

The server calls `audit_null_notify()` to pass audit event information to the plugin. The plugin has no `release_thd` function.

The event class mask indicates an interest in all events of the “general” class. `plugin_audit.h` defines its symbol, `MYSQL_AUDIT_GENERAL_CLASS`, and a mask with a bit for this class:

```c
#define MYSQL_AUDIT_GENERAL_CLASS 0
#define MYSQL_AUDIT_GENERAL_CLASSMASK (1 << MYSQL_AUDIT_GENERAL_CLASS)
```

`plugin_audit.h` also has defines for a “connection” event class, although the **NULL_AUDIT** plugin does nothing with such events:

```c
#define MYSQL_AUDIT_CONNECTION_CLASS 1
#define MYSQL_AUDIT_CONNECTION_CLASSMASK (1 << MYSQL_AUDIT_CONNECTION_CLASS)
```

A plugin could be written to receive both general and connection events by setting its type-specific descriptor class mask like this:

```c
{ (unsigned long) MYSQL_AUDIT_GENERAL_CLASSMASK |
  MYSQL_AUDIT_CONNECTION_CLASSMASK } /* class mask */
```

In the type-specific plugin descriptor, the second and third parameters of the `event_notify` function prototype represent the event class and a generic pointer to an event structure:

```c
void (*event_notify)(MYSQL_THD, unsigned int, const void *);
```

Events in different classes may have different structures, so the notification function should use the event class value to determine how to interpret the pointer to the event structure.

If the server calls the notification function with an event class of `MYSQL_AUDIT_GENERAL_CLASS`, it passes the event structure as a pointer to a `mysql_event_general` structure:

```c
struct mysql_event_general
{
    unsigned int event_subclass;
    int general_error_code;
    unsigned long general_thread_id;
    const char *general_user;
    unsigned int general_user_length;
    const char *general_command;
    unsigned int general_command_length;
    const char *general_query;
    unsigned int general_query_length;
    const charset_info_st *general_charset;
    unsigned long long general_time;
    unsigned long long general_rows;
};
```
Audit plugins can interpret `mysql_event_general` members as follows:

- **event_subclass**: The event subclass, one of the following values:

- `#define MYSQL_AUDIT_GENERAL_LOG 0`
- `#define MYSQL_AUDIT_GENERAL_ERROR 1`
- `#define MYSQL_AUDIT_GENERAL_RESULT 2`
- `#define MYSQL_AUDIT_GENERAL_STATUS 3`

- **general_error_code**: The error code. This is a value like that returned by the `mysql_errno()` C API function; 0 means “no error.”

- **general_thread_id**: The ID of the thread for which the event occurred.

- **general_user**: The current user for the event.

- **general_user_length**: The length of `general_user`, in bytes.

- **general_command**: For general query log events, the type of operation. Examples: `Connect`, `Query`, `Shutdown`. For error log events, the error message. This is a value like that returned by the `mysql_error()` C API function; an empty string means “no error.” For result events, this is empty.

- **general_command_length**: The length of `general_command`, in bytes.

- **general_query**: The SQL statement that was logged or produced a result.

- **general_query_length**: The length of `general_query`, in bytes.

- **general_charset**: Character set information for the event.

- **general_time**: A `TIMESTAMP` value indicating the time just before the notification function was called.

- **general_rows**: For general query log events, zero. For error log events, the row number at which an error occurred. For result events, the number of rows in the result plus one. For statements that produce no result set, the value is 0. This encoding enables statements that produce no result set to be distinguished from those that produce an empty result set. For example, for a `DELETE` statement, this value is 0. For a `SELECT`, the result is always 1 or more, where 1 represents an empty result set.

- **general_host**: For general query log events, a string representing the client host name.

- **general_sql_command**: For general query log events, a string that indicates the type of action performed, such as `connect` or `drop_table`.

- **general_external_user**: For general query log events, a string representing the external user (empty if none).

- **general_ip**: For general query log events, a string representing the client IP address.

The `general_host`, `general_sql_command`, `general_external_user`, and `general_ip` members are new in MySQL 5.5.34. These are `MYSQL_LEX_STRING` structures that pair a string and its length. For example, if `event_general` is a pointer to a general event, you can access the members of the `general_host` value as follows:

```
event_general->general_host.length
event_general->general_host.str
```

The `NULL_AUDIT` plugin notification function is quite simple. It increments a global event counter, verifies that the event is of the “general” class, then looks at the event subclass to determine which subclass counter to increment:
To compile and install a plugin library file, use the instructions in Section 24.2.4.3, "Compiling and Installing Plugin Libraries". To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `NULL_AUDIT` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `adt_null.so` (the `.so` suffix might differ depending on your platform).

To register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN NULL_AUDIT SONAME 'adt_null.so';
```

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

While the audit plugin is installed, it exposes status variables that indicate the events for which the plugin has been called:

```
mysql> SHOW STATUS LIKE 'Audit_null%';
+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| Audit_null_called         | 1385  |
| Audit_null_general_error  | 1     |
| Audit_null_general_log    | 741   |
| Audit_null_general_result | 643   |
+---------------------------+-------+
```

`Audit_null_called` counts all events, and the other variables count instances of event subclasses. For example, the preceding `SHOW STATUS` statement causes the server to send a result to the client and to write a message to the general query log if that log is enabled. Thus, a client that issues the statement repeatedly causes `Audit_null_called` and `Audit_null_general_result` to be incremented each time, and `Audit_null_general_log` to be incremented if the log is enabled.

To disable the plugin after testing it, use this statement to unload it:
24.2.4.9 Writing Authentication Plugins

MySQL supports pluggable authentication, in which plugins are invoked to authenticate client connections. Authentication plugins enable the use of authentication methods other than the built-in method of passwords stored in the `mysql.user` system table. For example, plugins can be written to access external authentication methods. Also, authentication plugins can support the proxy user capability, such that the connecting user is a proxy for another user and is treated, for purposes of access control, as having the privileges of a different user. For more information, see Section 6.2.10, “Pluggable Authentication”, and Section 6.2.11, “Proxy Users”.

An authentication plugin can be written for the server side or the client side. Server-side plugins use the same plugin API that is used for the other server plugin types such as full-text parser or audit plugins (although with a different type-specific descriptor). Client-side plugins use the client plugin API.

Several header files contain information relevant to authentication plugins:

- `plugin.h`: Defines the `MYSQL_AUTHENTICATION_PLUGIN` server plugin type.
- `client_plugin.h`: Defines the API for client plugins. This includes the client plugin descriptor and function prototypes for client plugin C API calls (see Section 23.7.13, “C API Client Plugin Functions”).
- `plugin_auth.h`: Defines the part of the server plugin API specific to authentication plugins. This includes the type-specific descriptor for server-side authentication plugins and the `MYSQL_SERVER_AUTH_INFO` structure.
- `plugin_auth_common.h`: Contains common elements of client and server authentication plugins. This includes return value definitions and the `MYSQL_PLUGIN_VIO` structure.

To write an authentication plugin, include the following header files in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

- For a source file that implements a server authentication plugin, include this file:
  ```
  #include <mysql/plugin_auth.h>
  ```
- For a source file that implements a client authentication plugin, or both client and server plugins, include these files:
  ```
  #include <mysql/plugin_auth.h>
  #include <mysql/client_plugin.h>
  #include <mysql.h>
  ```

`plugin_auth.h` includes `plugin.h` and `plugin_auth_common.h`, so you need not include the latter files explicitly.

This section describes how to write a pair of simple server and client authentication plugins that work together.

**Warning**

These plugins accept any non-empty password and the password is sent as cleartext. This is insecure, so the plugins should not be used in production environments.

The server-side and client-side plugins developed here both are named `auth_simple`. As described in Section 24.2.4.2, “Plugin Data Structures”, the plugin library file must have the same base name.
writing plugins as the client plugin, so the source file name is auth_simple.c and produces a library named auth_simple.so (assuming that your system uses .so as the suffix for library files).

In MySQL source distributions, authentication plugin source is located in the plugin/auth directory and can be examined as a guide to writing other authentication plugins. Also, to see how the built-in authentication plugins are implemented, see sql/sql_acl.cc for plugins that are built in to the MySQL server and sql-common/client.c for plugins that are built in to the libmysqlclient client library. (For the built-in client plugins, note that the auth_plugin_t structures used there differ from the structures used with the usual client plugin declaration macros. In particular, the first two members are provided explicitly, not by declaration macros.)

writing the server-side authentication plugin

declare the server-side plugin with the usual general descriptor format that is used for all server plugin types (see server plugin library and plugin descriptors). For the auth_simple plugin, the descriptor looks like this:

```c
mysql_declare_plugin(auth_simple)
{
  MYSQL_AUTHENTICATION_PLUGIN,
  &auth_simple_handler, /* type-specific descriptor */
  "auth_simple", /* plugin name */
  "Author Name", /* author */
  "Any-password authentication plugin", /* description */
  PLUGIN_LICENSE_GPL, /* license type */
  NULL, /* no init function */
  NULL, /* no deinit function */
  0x0100, /* version = 1.0 */
  NULL, /* no status variables */
  NULL, /* no system variables */
  NULL, /* no reserved information */
  0 /* no flags */
}
mysql_declare_plugin_end;
```

The name member (auth_simple) indicates the name to use for references to the plugin in statements such as INSTALL PLUGIN or UNINSTALL PLUGIN. This is also the name displayed by SHOW PLUGINS or INFORMATION_SCHEMA.PLUGINS.

The auth_simple_handler member of the general descriptor points to the type-specific descriptor. For an authentication plugin, the type-specific descriptor is an instance of the st_mysql_auth structure (defined in plugin_auth.h):

```c
struct st_mysql_auth
{
  int interface_version;
  const char *client_auth_plugin;
  int (*authenticate_user)(MYSQL_PLUGIN_VIO *vio, MYSQL_SERVER_AUTH_INFO *info);
};
```

The st_mysql_auth structure has these members:

- interface_version: The type-specific API version number, always MYSQL_AUTHENTICATION_INTERFACE_VERSION
- client_auth_plugin: The client plugin name
- authenticate_user: A pointer to the main plugin function that communicates with the client

The client_auth_plugin member should indicate the name of the client plugin if a specific plugin is required. A value of NULL means “any plugin.” In the latter case, whatever plugin the client uses will do.
This is useful if the server plugin does not care about the client plugin or what user name or password it sends. For example, this might be true if the server plugin authenticates only local clients and uses some property of the operating system rather than the information sent by the client plugin.

For `auth_simple`, the type-specific descriptor looks like this:

```c
static struct st_mysql_auth auth_simple_handler =
{
  MYSQL_AUTHENTICATION_INTERFACE_VERSION,
  "auth_simple",           /* required client-side plugin name */
  auth_simple_server       /* server-side plugin main function */
};
```

The main function, `auth_simple_server()`, takes two arguments representing an I/O structure and a `MYSQL_SERVER_AUTH_INFO` structure. The structure definition, found in `plugin_auth.h`, looks like this:

```c
typedef struct st_mysql_server_auth_info
{
  char *user_name;
  unsigned int user_name_length;
  const char *auth_string;
  unsigned long auth_string_length;
  char authenticated_as[MYSQL_USERNAME_LENGTH+1];
  char external_user[512];
  int  password_used;
  const char *host_or_ip;
  unsigned int host_or_ip_length;
} MYSQL_SERVER_AUTH_INFO;
```

The character set for string members is UTF-8. If there is a `_length` member associated with a string, it indicates the string length in bytes. Strings are also null-terminated.

When an authentication plugin is invoked by the server, it should interpret the `MYSQL_SERVER_AUTH_INFO` structure members as follows. Some of these are used to set the value of SQL functions or system variables within the client session, as indicated.

- `user_name`: The user name sent by the client. The value becomes the `USER()` function value.
- `user_name_length`: The length of `user_name` in bytes.
- `auth_string`: The value of the `authentication_string` column of the row in the `mysql.user` system table for the matching account name (that is, the row that matches the client user name and host name and that the server uses to determine how to authenticate the client).
- `auth_string_length`: The length of `auth_string` in bytes.
- `authenticated_as`: The server sets this to the user name (the value of `user_name`). The plugin can alter it to indicate that the client should have the privileges of a different user. For example, if the plugin supports proxy users, the initial value is the name of the connecting (proxy) user, and the plugin can change this member to the proxied user name. The server then treats the proxy user as having the privileges of the proxied user (assuming that the other conditions for proxy user support are satisfied; see Implementing Proxy User Support in Authentication Plugins). The value is represented as a string
at most \texttt{MYSQL_USER_NAME_LENGTH} bytes long, plus a terminating null. The value becomes the \texttt{CURRENT_USER()} function value.

- \texttt{external_user}: The server sets this to the empty string (null terminated). Its value becomes the \texttt{external_user} system variable value. If the plugin wants that system variable to have a different value, it should set this member accordingly (for example, to the connecting user name). The value is represented as a string at most 511 bytes long, plus a terminating null.

- \texttt{password_used}: This member applies when authentication fails. The plugin can set it or ignore it. The value is used to construct the failure error message of \texttt{Authentication fails. Password used: \%s}. The value of \texttt{password_used} determines how \texttt{\%s} is handled, as shown in the following table.

<table>
<thead>
<tr>
<th>\texttt{password_used}</th>
<th>\texttt{%s Handling}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO</td>
</tr>
<tr>
<td>1</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>There will be no \texttt{%s}</td>
</tr>
</tbody>
</table>

- \texttt{host_or_ip}: The name of the client host if it can be resolved, or the IP address otherwise.

- \texttt{host_or_ip_length}: The length of \texttt{host_or_ip} in bytes.

The \texttt{auth_simple} main function, \texttt{auth_simple_server()}, reads the password (a null-terminated string) from the client and succeeds if the password is nonempty (first byte not null):

```c
static int auth_simple_server (MYSQL_PLUGIN_VIO *vio,
                                MYSQL_SERVER_AUTH_INFO *info)
{
    unsigned char *pkt;
    int pkt_len;

    /* read the password as null-terminated string, fail on error */
    if ((pkt_len= vio->read_packet(vio, &pkt)) < 0)
        return CR_ERROR;

    /* fail on empty password */
    if (!pkt_len || *pkt == '\0')
    {
        info->password_used= PASSWORD_USED_NO;
        return CR_ERROR;
    }

    /* accept any nonempty password */
    info->password_used= PASSWORD_USED_YES;
    return CR_OK;
}
```

The main function should return one of the error codes shown in the following table.

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR_OK</td>
<td>Success</td>
</tr>
<tr>
<td>CR_OK_HANDSHAKE_COMPLETE</td>
<td>Do not send a status packet back to client</td>
</tr>
<tr>
<td>CR_ERROR</td>
<td>Error</td>
</tr>
</tbody>
</table>

For an example of how the handshake works, see the \texttt{plugin/auth/dialog.c} source file.

\texttt{auth_simple_server()} is so basic that it does not use the authentication information structure except to set the member that indicates whether a password was received.
A plugin that supports proxy users must return to the server the name of the proxied user (the MySQL user whose privileges the client user should get). To do this, the plugin must set the `info->authenticated_as` member to the proxied user name. For information about proxying, see Section 6.2.11, “Proxy Users”, and Implementing Proxy User Support in Authentication Plugins.

**Writing the Client-Side Authentication Plugin**

Declare the client-side plugin descriptor with the `mysql_declare_client_plugin()` and `mysql_end_client_plugin` macros (see Client Plugin Descriptors). For the `auth_simple` plugin, the descriptor looks like this:

```c
mysql_declare_client_plugin(AUTHENTICATION)
  "auth_simple",                        /* plugin name */
  "Author Name",                        /* author */
  "Any-password authentication plugin", /* description */
  {1,0,0},                              /* version = 1.0.0 */
  "GPL",                                /* license type */
  NULL,                                 /* for internal use */
  NULL,                                 /* no init function */
  NULL,                                 /* no deinit function */
  NULL,                                 /* no option-handling function */
  auth_simple_client                    /* main function */
mysql_end_client_plugin;
```

The descriptor members from the plugin name through the option-handling function are common to all client plugin types. (For descriptions, see Client Plugin Descriptors.) Following the common members, the descriptor has an additional member specific to authentication plugins. This is the “main” function, which handles communication with the server. The function takes two arguments representing an I/O structure and a connection handler. For our simple any-password plugin, the main function does nothing but write to the server the password provided by the user:

```c
static int auth_simple_client (MYSQL_PLUGIN_VIO *vio, MYSQL *mysql)
{
  int res;
  /* send password as null-terminated string as cleartext */
  res= vio->write_packet(vio, (const unsigned char *) mysql->passwd,
                         strlen(mysql->passwd) + 1);
  return res ? CR_ERROR : CR_OK;
}
```

The main function should return one of the error codes shown in the following table.

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR_OK</td>
<td>Success</td>
</tr>
<tr>
<td>CR_OK_HANDSHAKE_COMPLETE</td>
<td>Success, client done</td>
</tr>
<tr>
<td>CR_ERROR</td>
<td>Error</td>
</tr>
</tbody>
</table>

`CR_OK_HANDSHAKE_COMPLETE` indicates that the client has done its part successfully and has read the last packet. A client plugin may return `CR_OK_HANDSHAKE_COMPLETE` if the number of round trips in the authentication protocol is not known in advance and the plugin must read another packet to determine whether authentication is finished.

**Using the Authentication Plugins**

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable).
Writing Plugins

Register the server-side plugin with the server. For example, to load the plugin at server startup, use a `--plugin-load=auth_simple.so` option (adjust the `.so` suffix for your platform as necessary).

Create a user for whom the server will use the `auth_simple` plugin for authentication:

```sql
mysql> CREATE USER 'x'@'localhost'
    -> IDENTIFIED WITH auth_simple;
```

Use a client program to connect to the server as user `x`. The server-side `auth_simple` plugin communicates with the client program that it should use the client-side `auth_simple` plugin, and the latter sends the password to the server. The server plugin should reject connections that send an empty password and accept connections that send a nonempty password. Invoke the client program each way to verify this:

```shell
shell> mysql --user=x --skip-password
ERROR 1045 (28000): Access denied for user 'x'@'localhost' (using password: NO)
shell> mysql --user=x --password
Enter password: abc
mysql>
```

Because the server plugin accepts any nonempty password, it should be considered insecure. After testing the plugin to verify that it works, restart the server without the `--plugin-load` option so as not to inadvertently leave the server running with an insecure authentication plugin loaded. Also, drop the user with `DROP USER 'x'@'localhost'`.

For additional information about loading and using authentication plugins, see Section 5.5.1, "Installing and Uninstalling Plugins", and Section 6.2.10, "Pluggable Authentication".

If you are writing a client program that supports the use of authentication plugins, normally such a program causes a plugin to be loaded by calling `mysql_options()` to set the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options:

```c
char *plugin_dir = "path_to_plugin_dir";
char *default_auth = "plugin_name";
/* ... process command-line options ... */
mysql_options(&mysql, MYSQL_PLUGIN_DIR, plugin_dir);
mysql_options(&mysql, MYSQL_DEFAULT_AUTH, default_auth);
```

Typically, the program will also accept `--plugin-dir` and `--default-auth` options that enable users to override the default values.

Should a client program require lower-level plugin management, the client library contains functions that take an `st_mysql_client_plugin` argument. See Section 23.7.13, "C API Client Plugin Functions".

Implementing Proxy User Support in Authentication Plugins

One of the capabilities that pluggable authentication makes possible is proxy users (see Section 6.2.11, "Proxy Users"). For a server-side authentication plugin to participate in proxy user support, these conditions must be satisfied:

- When a connecting client should be treated as a proxy user, the plugin must return a different name in the `authenticated_as` member of the `MYSQL_SERVER_AUTH_INFO` structure, to indicate the proxied user name. It may also optionally set the `external_user` member, to set the value of the `external_user` system variable.

- Proxy user accounts must be set up to be authenticated by the plugin. Use the `CREATE USER` or `GRANT` statement to associate accounts with plugins.
Writing Plugins

- Proxy user accounts must have the **PROXY** privilege for the proxied accounts. Use the **GRANT** statement to grant this privilege.

In other words, the only aspect of proxy user support required of the plugin is that it set **authenticated_as** to the proxied user name. The rest is optional (setting **external_user**) or done by the DBA using SQL statements.

How does an authentication plugin determine which proxied user to return when the proxy user connects? That depends on the plugin. Typically, the plugin maps clients to proxied users based on the authentication string passed to it by the server. This string comes from the **AS** part of the **IDENTIFIED WITH** clause of the **CREATE USER** statement that specifies use of the plugin for authentication.

The plugin developer determines the syntax rules for the authentication string and implements the plugin according to those rules. Suppose that a plugin takes a comma-separated list of pairs that map external users to MySQL users. For example:

```
CREATE USER ''@'%.example.com'
   IDENTIFIED WITH my_plugin AS 'extuser1=mysqlusera, extuser2=mysqluserb'
CREATE USER ''@'%.example.org'
   IDENTIFIED WITH my_plugin AS 'extuser1=mysqluserc, extuser2=mysqluserd'
```

When the server invokes a plugin to authenticate a client, it passes the appropriate authentication string to the plugin. The plugin is responsible to:

1. Parse the string into its components to determine the mapping to use
2. Compare the client user name to the mapping
3. Return the proper MySQL user name

For example, if **extuser2** connects from an **example.com** host, the server passes `'extuser1=mysqlusera, extuser2=mysqluserb'` to the plugin, and the plugin should copy **mysqluserb** into **authenticated_as**, with a terminating null byte. If **extuser2** connects from an **example.org** host, the server passes `'extuser1=mysqluserc, extuser2=mysqluserd'`, and the plugin should copy **mysqluserd** instead.

If there is no match in the mapping, the action depends on the plugin. If a match is required, the plugin likely will return an error. Or the plugin might simply return the client name; in this case, it should not change **authenticated_as**, and the server will not treat the client as a proxy.

The following example demonstrates how to handle proxy users using a plugin named **auth_simple_proxy**. Like the **auth_simple** plugin described earlier, **auth_simple_proxy** accepts any nonempty password as valid (and thus should not be used in production environments). In addition, it examines the **auth_string** authentication string member and uses these very simple rules for interpreting it:

- If the string is empty, the plugin returns the user name as given and no proxying occurs. That is, the plugin leaves the value of **authenticated_as** unchanged.
- If the string is nonempty, the plugin treats it as the name of the proxied user and copies it to **authenticated_as** so that proxying occurs.

For testing, set up one account that is not proxied according to the preceding rules, and one that is. This means that one account has no **AS** clause, and one includes an **AS** clause that names the proxied user:

```
CREATE USER 'plugin_user1'@'localhost'
   IDENTIFIED WITH auth_simple_proxy;
```
In addition, create an account for the proxied user and grant `plugin_user2` the `PROXY` privilege for it:

```sql
CREATE USER 'proxied_user'@'localhost'
IDENTIFIED BY 'proxied_user_pass';
GRANT PROXY
ON 'proxied_user'@'localhost'
TO 'plugin_user2'@'localhost';
```

Before the server invokes an authentication plugin, it sets `authenticated_as` to the client user name. To indicate that the user is a proxy, the plugin should set `authenticated_as` to the proxied user name. For `auth_simple_proxy`, this means that it must examine the `auth_string` value, and, if the value is nonempty, copy it to the `authenticated_as` member to return it as the name of the proxied user. In addition, when proxying occurs, the plugin sets the `external_user` member to the client user name; this becomes the value of the `external_user` system variable.

```c
static int auth_simple_proxy_server (MYSQL_PLUGIN_VIO *vio,
                                      MYSQL_SERVER_AUTH_INFO *info)
{
    unsigned char *pkt;
    int pkt_len;

    /* read the password as null-terminated string, fail on error */
    if ((pkt_len = vio->read_packet(vio, &pkt)) < 0)
        return CR_ERROR;
    /* fail on empty password */
    if (!pkt_len || *pkt == '\0')
    {
        info->password_used= PASSWORD_USED_NO;
        return CR_ERROR;
    }
    /* accept any nonempty password */
    info->password_used= PASSWORD_USED_YES;

    /* if authentication string is nonempty, use as proxied user name */
    /* and use client name as external_user value */
    if (info->auth_string_length > 0)
    {
        strcpy (info->authenticated_as, info->auth_string);
        strcpy (info->external_user, info->user_name);
    }
    return CR_OK;
}
```

After a successful connection, the `USER()` function should indicate the connecting client user and host name, and `CURRENT_USER()` should indicate the account whose privileges apply during the session. The latter value should be the connecting user account if no proxying occurs or the proxied account if proxying does occur.

Compile and install the plugin, then test it. First, connect as `plugin_user1`:

```
shell> mysql --user=plugin_user1 --password
Enter password: x
```

In this case, there should be no proxying:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user, @@external_user\G
*************************** 1. row ***************************
USER(): plugin_user1@localhost
```

After a successful connection, the `USER()` function should indicate the connecting client user and host name, and `CURRENT_USER()` should indicate the account whose privileges apply during the session. The latter value should be the connecting user account if no proxying occurs or the proxied account if proxying does occur.
CURRENT_USER(): plugin_user1@localhost
@@proxy_user: NULL
@@external_user: NULL

Then connect as `plugin_user2`:

```shell
mysql --user=plugin_user2 --password
```

Enter password: x

In this case, `plugin_user2` should be proxied to `proxied_user`:

```sql
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user, @@external_user;
+----------------+-----------------+-------------------------+-------------------------+
| USER()         | CURRENT_USER()  | @@proxy_user            | @@external_user         |
|----------------+-----------------+-------------------------+-------------------------+
| plugin_user2@localhost | proxied_user@localhost | 'plugin_user2'@'localhost' | 'plugin_user2'@'localhost' |
+----------------+-----------------+-------------------------+-------------------------+
```

24.3 MySQL Services for Plugins

MySQL server plugins have access to server “plugin services.” The plugin services interface exposes server functionality that plugins can call. It complements the plugin API and has these characteristics:

- Services enable plugins to access code inside the server using ordinary function calls. Services are also available to user-defined functions (UDFs).
- Services are portable and work on multiple platforms.
- The interface includes a versioning mechanism so that service versions supported by the server can be checked at load time against plugin versions. Versioning protects against incompatibilities between the version of a service that the server provides and the version of the service expected or required by a plugin.

The plugin services interface differs from the plugin API as follows:

- The plugin API enables plugins to be used by the server. The calling initiative lies with the server to invoke plugins. This enables plugins to extend server functionality or register to receive notifications about server processing.
- The plugin services interface enables plugins to call code inside the server. The calling initiative lies with plugins to invoke service functions. This enables functionality already implemented in the server to be used by many plugins; they need not individually implement it themselves.

To determine what services exist and what functions they provide, look in the `include/mysql` directory of a MySQL source distribution. The relevant files are:

- `plugin.h` includes `services.h`, which is the “umbrella” header that includes all available service-specific header files.
- Service-specific headers have names of the form `service_xxx.h`.

Each service-specific header should contain comments that provide full usage documentation for a given service, including what service functions are available, their calling sequences, and return values.

For developers who wish to modify the server to add a new service, see MySQL Internals: MySQL Services for Plugins.

Available services include the following:
Adding Functions to MySQL

- **my_snprintf**: A string-formatting service that produces consistent results across platforms.
- **my_thd_scheduler**: A service for plugins to select a thread scheduler.
- **thd_alloc**: A memory-allocation service.
- **thd_wait**: A service for plugins to report when they are going to sleep or stall.

The remainder of this section describes how a plugin uses server functionality that is available as a service. See also the source for the “daemon” example plugin, which uses the `my_snprintf` service. Within a MySQL source distribution, that plugin is located in the `plugin/daemon_example` directory.

To use a service or services from within a plugin, the plugin source file must include the `plugin.h` header file to access service-related information:

```c
#include <mysql/plugin.h>
```

This does not represent any additional setup cost. A plugin must include that file anyway because it contains definitions and structures that every plugin needs.

To access a service, a plugin calls service functions like any other function. For example, to format a string into a buffer for printing, call the `my_snprintf()` function provided by the service of the same name:

```c
char buffer[BUFFER_SIZE];
my_snprintf(buffer, sizeof(buffer), format_string, argument_to_format, ...);
```

When you build your plugin, use the `-lmysqlservices` flag at link time to link in the `libmysqlservices` library. For example, for CMake, put this in the top-level CMakeLists.txt file:

```cmake
FIND_LIBRARY(MYSQLSERVICES_LIB mysqlservices
PATHS "${MYSQL_SRCDIR}/libservices" NO_DEFAULT_PATH)
```

Put this in the CMakeLists.txt file in the directory containing the plugin source:

```cmake
# the plugin needs the mysql services library for error logging
TARGET_LINK_LIBRARIES (your_plugin_library_name ${MYSQLSERVICES_LIB})
```

### 24.4 Adding Functions to MySQL

There are three ways to add functions to MySQL:

- Through the user-defined function (UDF) interface. User-defined functions are compiled as library files and then added to and removed from the server dynamically using the `CREATE FUNCTION` and `DROP FUNCTION` statements. See Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”.

- By creating native (built-in) MySQL functions. Native functions are compiled into the `mysqld` server and become available on a permanent basis.

- By creating stored functions. These are written using SQL statements rather than by compiling object code. The syntax for writing stored functions is not covered here. See Section 20.2, “Using Stored Routines”.

Each method of creating compiled functions has advantages and disadvantages:

- If you write user-defined functions, you must install object files in addition to the server itself. If you compile your function into the server, you need not do that.
• Native functions require you to modify a source distribution. UDFs do not. You can add UDFs to a binary MySQL distribution. No access to MySQL source is necessary.

• If you upgrade your MySQL distribution, you can continue to use your previously installed UDFs, unless you upgrade to a newer version for which the UDF interface changes. For native functions, you must repeat your modifications each time you upgrade.

Whichever method you use to add functions, they can be invoked in SQL statements just like native functions such as `ABS()` or `SOUNDEX()`.

For the rules describing how the server interprets references to different kinds of functionss see Section 9.2.5, “Function Name Parsing and Resolution”.

The following sections describe features of the UDF interface, provide instructions for writing UDFs, discuss security precautions that MySQL takes to prevent UDF misuse, and describe how to add native MySQL functions.

For example source code that illustrates how to write UDFs, take a look at the `sql/udf_example.c` file that is provided in MySQL source distributions.

### 24.4.1 Features of the User-Defined Function Interface

The MySQL interface for user-defined functions provides the following features and capabilities:

• Functions can return string, integer, or real values and can accept arguments of those same types.

• You can define simple functions that operate on a single row at a time, or aggregate functions that operate on groups of rows.

• Information is provided to functions that enables them to check the number, types, and names of the arguments passed to them.

• You can tell MySQL to coerce arguments to a given type before passing them to a function.

• You can indicate that a function returns `NULL` or that an error occurred.

### 24.4.2 Adding a User-Defined Function

For the UDF mechanism to work, functions must be written in C or C++ and your operating system must support dynamic loading. MySQL source distributions include a file `sql/udf_example.c` that defines five UDF functions. Consult this file to see how UDF calling conventions work. The `include/mysql_com.h` header file defines UDF-related symbols and data structures, although you need not include this header file directly; it is included by `mysql.h`.

A UDF contains code that becomes part of the running server, so when you write a UDF, you are bound by any and all constraints that apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to UDFs that were originally written for older servers. For information about these constraints, see Section 2.9.7, “MySQL Source-Configuration Options”, and Section 2.9.8, “Dealing with Problems Compiling MySQL”.

To be able to use UDFs, you must link `mysqld` dynamically. If you want to use a UDF that needs to access symbols from `mysqld` (for example, the `metaphone` function in `sql/udf_example.c` uses `default_charset_info`), you must link the program with `-rdynamic` (see man `dlopen`).

For each function that you want to use in SQL statements, you should define corresponding C (or C++) functions. In the following discussion, the name “xxx” is used for an example function name. To
Adding a User-Defined Function

distinguish between SQL and C/C++ usage, \texttt{XXX()} (uppercase) indicates an SQL function call, and \texttt{xxx()} (lowercase) indicates a C/C++ function call.

\begin{itemize}
\item \texttt{xxx()} The main function. This is where the function result is computed. The correspondence between the SQL function data type and the return type of your C/C++ function is shown here.
\end{itemize}

\begin{tabular}{|l|l|}
\hline
\textbf{SQL Type} & \textbf{C/C++ Type} \\
\hline
STRING & char * \\
INTEGER & long long \\
REAL & double \\
\hline
\end{tabular}

It is also possible to declare a \texttt{DECIMAL} function, but the value is returned as a string, so you should write the UDF as though it were a \texttt{STRING} function. \texttt{ROW} functions are not implemented.

\begin{itemize}
\item \texttt{xxx_init()} The initialization function for \texttt{xxx()}. If present, it can be used for the following purposes:
\begin{itemize}
\item To check the number of arguments to \texttt{XXX()}.
\item To verify that the arguments are of a required type or, alternatively, to tell MySQL to coerce arguments to the required types when the main function is called.
\item To allocate any memory required by the main function.
\item To specify the maximum length of the result.
\end{itemize}
\end{itemize}

\begin{Verbatim}
extern "C" {
...
}
\end{Verbatim}

This ensures that your C++ function names remain readable in the completed UDF.

\begin{itemize}
\item User-Defined Function Interface Functions
\item UDF Calling Sequences for Simple Functions
\item UDF Calling Sequences for Aggregate Functions
\item UDF Argument Processing
\item UDF Return Values and Error Handling
\item UDF Compiling and Installing
\item UDF Security Precautions
\end{itemize}
Adding a User-Defined Function

• To specify (for \texttt{REAL} functions) the maximum number of decimal places in the result.

• To specify whether the result can be \texttt{NULL}.

\texttt{xxx\_deinit()}

The deinitialization function for \texttt{xxx()}. If present, it should deallocate any memory allocated by the initialization function.

When an SQL statement invokes \texttt{XXX()}, MySQL calls the initialization function \texttt{xxx\_init()} to let it perform any required setup, such as argument checking or memory allocation. If \texttt{xxx\_init()} returns an error, MySQL aborts the SQL statement with an error message and does not call the main or deinitialization functions. Otherwise, MySQL calls the main function \texttt{xxx()} once for each row. After all rows have been processed, MySQL calls the deinitialization function \texttt{xxx\_deinit()} so that it can perform any required cleanup.

For aggregate functions that work like \texttt{SUM()}, you must also provide the following functions:

\texttt{xxx\_clear()}

Reset the current aggregate value but do not insert the argument as the initial aggregate value for a new group.

\texttt{xxx\_add()}

Add the argument to the current aggregate value.

MySQL handles aggregate UDFs as follows:

1. Call \texttt{xxx\_init()} to let the aggregate function allocate any memory it needs for storing results.

2. Sort the table according to the \texttt{GROUP BY} expression.

3. Call \texttt{xxx\_clear()} for the first row in each new group.

4. Call \texttt{xxx\_add()} for each row that belongs in the same group.

5. Call \texttt{xxx()} to get the result for the aggregate when the group changes or after the last row has been processed.

6. Repeat steps 3 to 5 until all rows has been processed

7. Call \texttt{xxx\_deinit()} to let the UDF free any memory it has allocated.

All functions must be thread-safe. This includes not just the main function, but the initialization and deinitialization functions as well, and also the additional functions required by aggregate functions. A consequence of this requirement is that you are not permitted to allocate any global or static variables that change! If you need memory, you must it in \texttt{xxx\_init()} and free it in \texttt{xxx\_deinit()}.

**UDF Calling Sequences for Simple Functions**

This section describes the different functions that you must define to create a simple UDF. For information about the order in which MySQL calls these functions, see \texttt{User-Defined Function Interface Functions}.

The main \texttt{xxx()} function should be declared as shown in this section. Note that the return type and parameters differ, depending on whether you declare the SQL function \texttt{XXX()} to return \texttt{STRING}, \texttt{INTEGER}, or \texttt{REAL} in the \texttt{CREATE FUNCTION} statement:
Adding a User-Defined Function

For **STRING** functions:

```c
char *xxx(UDF_INIT *initid, UDF_ARGS *args,
         char *result, unsigned long *length,
         char *is_null, char *error);
```

For **INTEGER** functions:

```c
long long xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

For **REAL** functions:

```c
double xxx(UDF_INIT *initid, UDF_ARGS *args,
           char *is_null, char *error);
```

**DECIMAL** functions return string values and are declared the same way as **STRING** functions. **ROW** functions are not implemented.

Declare the initialization and deinitialization functions like this:

```c
my_bool xxx_init(UDF_INIT *initid, UDF_ARGS *args, char *message);
void xxx_deinit(UDF_INIT *initid);
```

The `initid` parameter is passed to all three functions. It points to a **UDF_INIT** structure that is used to communicate information between functions. The **UDF_INIT** structure members follow. The initialization function should fill in any members that it wishes to change. (To use the default for a member, leave it unchanged.)

- **my_bool maybe_null**

  `xxx_init()` should set `maybe_null` to `1` if `xxx()` can return `NULL`. The default value is `1` if any of the arguments are declared `maybe null`.

- **unsigned int decimals**

  The number of decimal digits to the right of the decimal point. The default value is the maximum number of decimal digits in the arguments passed to the main function. For example, if the function is passed `1.34, 1.345`, and `1.3`, the default would be `3`, because `1.345` has `3` decimal digits.

  For arguments that have no fixed number of decimals, the `decimals` value is set to `31`, which is `1` more than the maximum number of decimals permitted for the **DECIMAL**, **FLOAT**, and **DOUBLE** data types. This value is available as the constant `NOT_FIXED_DEC` in the `mysql_com.h` header file.

  A `decimals` value of `31` is used for arguments in cases such as a **FLOAT** or **DOUBLE** column declared without an explicit number of decimals (for example, **FLOAT** rather than **FLOAT**(10,3)) and for floating-point constants such as `1345E-3`. It is also used for string and other nonnumber arguments that might be converted within the function to numeric form.

  The value to which the `decimals` member is initialized is only a default. It can be changed within the function to reflect the actual calculation performed. The default is determined such that the largest number of decimals of the arguments is used. If the number of decimals is `NOT_FIXED_DEC` for even one of the arguments, that is the value used for `decimals`.

- **unsigned int max_length**

  The maximum length of the result. The default `max_length` value differs depending on the result type of the function. For string functions, the default is the length of the longest argument. For integer functions,
the default is 21 digits. For real functions, the default is 13 plus the number of decimal digits indicated by \texttt{initid->decimals}. (For numeric functions, the length includes any sign or decimal point characters.)

If you want to return a blob value, you can set \texttt{max_length} to 65KB or 16MB. This memory is not allocated, but the value is used to decide which data type to use if there is a need to temporarily store the data.

- \texttt{char *ptr}

A pointer that the function can use for its own purposes. For example, functions can use \texttt{initid->ptr} to communicate allocated memory among themselves. \texttt{xxx_init()} should allocate the memory and assign it to this pointer:

\begin{verbatim}
initid->ptr = allocated_memory;
\end{verbatim}

In \texttt{xxx()} and \texttt{xxx_deinit()}, refer to \texttt{initid->ptr} to use or deallocate the memory.

- \texttt{my_bool const_item}

\texttt{xxx_init()} should set \texttt{const_item} to 1 if \texttt{xxx()} always returns the same value and to 0 otherwise.

### UDF Calling Sequences for Aggregate Functions

This section describes the different functions that you need to define when you create an aggregate UDF. For information about the order in which MySQL calls these functions, see User-Defined Function Interface Functions.

- \texttt{xxx_reset()}

This function is called when MySQL finds the first row in a new group. It should reset any internal summary variables and then use the given \texttt{UDF_ARGS} argument as the first value in your internal summary value for the group. Declare \texttt{xxx_reset()} as follows:

\begin{verbatim}
void xxx_reset(UDF_INIT *initid, UDF_ARGS *args, char *is_null, char *error);
\end{verbatim}

\texttt{xxx_reset()} is not needed or used in MySQL 5.5, in which the UDF interface uses \texttt{xxx_clear()} instead. However, you can define both \texttt{xxx_reset()} and \texttt{xxx_clear()} if you want to have your UDF work with older versions of the server. (If you do include both functions, the \texttt{xxx_reset()} function in many cases can be implemented internally by calling \texttt{xxx_clear()} to reset all variables, and then calling \texttt{xxx_add()} to add the \texttt{UDF_ARGS} argument as the first value in the group.)

- \texttt{xxx_clear()}

This function is called when MySQL needs to reset the summary results. It is called at the beginning for each new group but can also be called to reset the values for a query where there were no matching rows. Declare \texttt{xxx_clear()} as follows:

\begin{verbatim}
void xxx_clear(UDF_INIT *initid, char *is_null, char *error);
\end{verbatim}

\texttt{is_null} is set to point to \texttt{CHAR(0)} before calling \texttt{xxx_clear()}.

If something went wrong, you can store a value in the variable to which the \texttt{error} argument points. \texttt{error} points to a single-byte variable, not to a string buffer.

\texttt{xxx_clear()} is required by MySQL 5.5.

- \texttt{xxx_add()}


This function is called for all rows that belong to the same group. You should use it to add the value in the UDF_ARGS argument to your internal summary variable.

```c
void xxx_add(UDF_INIT *initid, UDF_ARGS *args,
             char *is_null, char *error);
```

The `xxx()` function for an aggregate UDF should be declared the same way as for a nonaggregate UDF. See UDF Calling Sequences for Simple Functions.

For an aggregate UDF, MySQL calls the `xxx()` function after all rows in the group have been processed. You should normally never access its UDF_ARGS argument here but instead return a value based on your internal summary variables.

Return value handling in `xxx()` should be done the same way as for a nonaggregate UDF. See UDF Return Values and Error Handling.

The `xxx_reset()` and `xxx_add()` functions handle their UDF_ARGS argument the same way as functions for nonaggregate UDFs. See UDF Argument Processing.

The pointer arguments to `is_null` and `error` are the same for all calls to `xxx_reset()`, `xxx_clear()`, `xxx_add()` and `xxx()`. You can use this to remember that you got an error or whether the `xxx()` function should return NULL. You should not store a string into *error!error points to a single-byte variable, not to a string buffer.

*is_null* is reset for each group (before calling `xxx_clear()`). *error* is never reset.

If *is_null* or *error* are set when `xxx()` returns, MySQL returns NULL as the result for the group function.

**UDF Argument Processing**

The `args` parameter points to a UDF_ARGS structure that has the members listed here:

- unsigned int arg_count

  The number of arguments. Check this value in the initialization function if you require your function to be called with a particular number of arguments. For example:

  ```c
  if (args->arg_count != 2)
  {
    strcpy(message,"XXX() requires two arguments");
    return 1;
  }
  ```

  For other UDF_ARGS member values that are arrays, array references are zero-based. That is, refer to array members using index values from 0 to `args->arg_count` – 1.

- enum Item_result *arg_type

  A pointer to an array containing the types for each argument. The possible type values are STRING_RESULT, INT_RESULT, REAL_RESULT, and DECIMAL_RESULT.

  To make sure that arguments are of a given type and return an error if they are not, check the `arg_type` array in the initialization function. For example:

  ```c
  if (args->arg_type[0] != STRING_RESULT ||
      args->arg_type[1] != INT_RESULT)
  ```
Adding a User-Defined Function

```c
strcpy(message,"XXX() requires a string and an integer");
return 1;
}
```

Arguments of type `DECIMAL_RESULT` are passed as strings, so you handle them the same way as `STRING_RESULT` values.

As an alternative to requiring your function's arguments to be of particular types, you can use the initialization function to set the `arg_type` elements to the types you want. This causes MySQL to coerce arguments to those types for each call to `xxx()`. For example, to specify that the first two arguments should be coerced to string and integer, respectively, do this in `xxx_init()`:

```c
args->arg_type[0] = STRING_RESULT;
args->arg_type[1] = INT_RESULT;
```

Exact-value decimal arguments such as `1.3` or `DECIMAL` column values are passed with a type of `DECIMAL_RESULT`. However, the values are passed as strings. To receive a number, use the initialization function to specify that the argument should be coerced to a `REAL_RESULT` value:

```c
args->arg_type[2] = REAL_RESULT;
```

- `char **args`

  `args->args` communicates information to the initialization function about the general nature of the arguments passed to your function. For a constant argument `i`, `args->args[i]` points to the argument value. (See later for instructions on how to access the value properly.) For a nonconstant argument, `args->args[i]` is `0`. A constant argument is an expression that uses only constants, such as `3` or `4*7-2` or `SIN(3.14)`. A nonconstant argument is an expression that refers to values that may change from row to row, such as column names or functions that are called with nonconstant arguments.

For each invocation of the main function, `args->args` contains the actual arguments that are passed for the row currently being processed.

If argument `i` represents `NULL`, `args->args[i]` is a null pointer (0). If the argument is not `NULL`, functions can refer to it as follows:

- An argument of type `STRING_RESULT` is given as a string pointer plus a length, to enable handling of binary data or data of arbitrary length. The string contents are available as `args->args[i]` and the string length is `args->lengths[i]`. Do not assume that the string is null-terminated.

- For an argument of type `INT_RESULT`, you must cast `args->args[i]` to a `long long` value:

  ```c
  long long int_val;
  int_val = *((long long*) args->args[i]);
  ```

- For an argument of type `REAL_RESULT`, you must cast `args->args[i]` to a `double` value:

  ```c
  double real_val;
  real_val = *((double*) args->args[i]);
  ```

- For an argument of type `DECIMAL_RESULT`, the value is passed as a string and should be handled like a `STRING_RESULT` value.

- `ROW_RESULT` arguments are not implemented.

- `unsigned long *lengths`

  For the initialization function, the `lengths` array indicates the maximum string length for each argument. You should not change these. For each invocation of the main function, `lengths` contains the actual
lengths of any string arguments that are passed for the row currently being processed. For arguments of types `INT_RESULT` or `REAL_RESULT`, `lengths` still contains the maximum length of the argument (as for the initialization function).

- `char *maybe_null`
  
  For the initialization function, the `maybe_null` array indicates for each argument whether the argument value might be null (0 if no, 1 if yes).

- `char **attributes`
  
  `args->attributes` communicates information about the names of the UDF arguments. For argument `i`, the attribute name is available as a string in `args->attributes[i]` and the attribute length is `args->attribute_lengths[i]`. Do not assume that the string is null-terminated.

  By default, the name of a UDF argument is the text of the expression used to specify the argument. For UDFs, an argument may also have an optional `[AS] alias_name` clause, in which case the argument name is `alias_name`. The `attributes` value for each argument thus depends on whether an alias was given.

  Suppose that a UDF `my_udf()` is invoked as follows:

  ```sql
  SELECT my_udf(expr1, expr2 AS alias1, expr3 alias2);
  ```

  In this case, the `attributes` and `attribute_lengths` arrays will have these values:

  ```c
  args->attributes[0] = "expr1"
  args->attribute_lengths[0] = 5
  
  args->attributes[1] = "alias1"
  args->attribute_lengths[1] = 6
  
  args->attributes[2] = "alias2"
  args->attribute_lengths[2] = 6
  ```

- `unsigned long *attribute_lengths`
  
  The `attribute_lengths` array indicates the length of each argument name.

UDF Return Values and Error Handling

The initialization function should return 0 if no error occurred and 1 otherwise. If an error occurs, `xxx_init()` should store a null-terminated error message in the `message` parameter. The message is returned to the client. The message buffer is `MYSQL_ERRMSG_SIZE` characters long. Try to keep the message to less than 80 characters so that it fits the width of a standard terminal screen.

The return value of the main function `xxx()` is the function value, for `long long` and `double` functions. A string function should return a pointer to the result and set `*length` to the length (in bytes) of the return value. For example:

```c
memcpy(result, "result string", 13);
*length = 13;
```

MySQL passes a buffer to the `xxx()` function using the `result` parameter. This buffer is sufficiently long to hold 255 characters, which can be multibyte characters. The `xxx()` function can store the result in this buffer if it fits, in which case the return value should be a pointer to the buffer. If the function stores the result in a different buffer, it should return a pointer to that buffer.

If your string function does not use the supplied buffer (for example, if it needs to return a string longer than 255 characters), you must allocate the space for your own buffer with `malloc()` in the `xxx_init()`
function or the `xxx()` function and free it in your `xxx_deinit()` function. You can store the allocated memory in the `ptr` slot in the `UDF_INIT` structure for reuse by future `xxx()` calls. See UDF Calling Sequences for Simple Functions.

To indicate a return value of `NULL` in the main function, set `*is_null` to 1:

```c
*is_null = 1;
```

To indicate an error return in the main function, set `*error` to 1:

```c
*error = 1;
```

If `xxx()` sets `*error` to 1 for any row, the function value is `NULL` for the current row and for any subsequent rows processed by the statement in which `XXX()` was invoked. (`xxx()` is not even called for subsequent rows.)

**UDF Compiling and Installing**

Files implementing UDFs must be compiled and installed on the host where the server runs. The process is described here for the example UDF file `sql/udf_example.c` that is included in MySQL source distributions. For additional information about UDF installation, see Section 5.6.1, “Installing and Uninstalling User-Defined Functions”.

If a UDF will be referred to in statements that will be replicated to slave servers, you must ensure that every slave also has the function available. Otherwise, replication fails on the slaves when they attempt to invoke the function.

The `udf_example.c` file contains the following functions:

- `metaphon()` returns a metaphor string of the string argument. This is something like a soundex string, but it is more tuned for English.

- `myfunc_double()` returns the sum of the ASCII values of the characters in its arguments, divided by the sum of the length of its arguments.

- `myfunc_int()` returns the sum of the length of its arguments.

- `sequence([const int])` returns a sequence starting from the given number or 1 if no number has been given.

- `lookup()` returns the IP address for a host name.

- `reverse_lookup()` returns the host name for an IP address. The function may be called either with a single string argument of the form `'xxx.xxx.xxx.xxx'` or with four numbers.

- `avgcost()` returns an average cost. This is an aggregate function.

On Unix and Unix-like systems, compile user-defined functions using the following procedure:

A dynamically loadable file should be compiled as a sharable library file, using a command something like this:

```sh
gcc -shared -o udf_example.so udf_example.c
```

If you are using `gcc` with `CMake` (which is how MySQL itself is configured), you should be able to create `udf_example.so` with a simpler command:

```sh
make udf_example
```
Adding a User-Defined Function

After compiling a shared object containing UDFs, you must install it and tell MySQL about it. Compiling a shared object from `udf_example.c` using `gcc` directly produces a file named `udf_example.so`. Copy the shared object to the server's plugin directory and name it `udf_example.so`. This directory is given by the value of the `plugin_dir` system variable.

On some systems, the `ldconfig` program that configures the dynamic linker does not recognize a shared object unless its name begins with `lib`. In this case you should rename a file such as `udf_example.so` to `libudf_example.so`.

On Windows, compile user-defined functions using the following procedure:

1. Obtain a MySQL source distribution. See Section 2.1.2, “How to Get MySQL”.
2. Obtain the CMake build utility, if necessary, from http://www.cmake.org. (Version 2.6 or later is required).
3. In the source tree, look in the `sql` directory for files named `udf_example.def` and `udf_example.c`. Copy both files from this directory to your working directory.
4. Create a CMake makefile (CMakeLists.txt) with these contents:

```cmake
PROJECT(udf_example)
# Path for MySQL include directory
INCLUDE_DIRECTORIES("c:/mysql/include")
ADD_DEFINITIONS("-DHAVE_DLOPEN")
ADD_LIBRARY(udf_example MODULE udf_example.c udf_example.def)
TARGET_LINK_LIBRARIES(udf_example wsock32)
```
5. Create the VC project and solution files, substituting an appropriate `generator` value:

```bash
cmake -G "generator"
```

Invoking `cmake --help` shows you a list of valid generators.
6. Create `udf_example.dll`:

```bash
devenv udf_example.sln /build Release
```

On all platforms, after the shared library file has been copied to the `plugin_dir` directory, notify `mysqld` about the new functions with the following statements. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows), so adjust the `.so` suffix for your platform as necessary.

```sql
CREATE FUNCTION metaphon RETURNS STRING SONAME 'udf_example.so';
CREATE FUNCTION myfunc_double RETURNS REAL SONAME 'udf_example.so';
CREATE FUNCTION myfunc_int RETURNS INTEGER SONAME 'udf_example.so';
CREATE FUNCTION sequence RETURNS INTEGER SONAME 'udf_example.so';
CREATE FUNCTION lookup RETURNS STRING SONAME 'udf_example.so';
CREATE FUNCTION reverse_lookup RETURNS STRING SONAME 'udf_example.so';
CREATE AGGREGATE FUNCTION avgcost RETURNS REAL SONAME 'udf_example.so';
```

Once installed, a function remains installed until it is uninstalled.
To remove functions, use **DROP FUNCTION**:

```sql
DROP FUNCTION metaphon;
DROP FUNCTION myfunc_double;
DROP FUNCTION myfunc_int;
DROP FUNCTION sequence;
DROP FUNCTION lookup;
DROP FUNCTION reverse_lookup;
DROP FUNCTION avgcost;
```

The **CREATE FUNCTION** and **DROP FUNCTION** statements update the `func` table in the `mysql` system database that serves as a UDF registry. The function's name, type and shared library name are saved in the `mysql.func` table. To create functions, you must have the **INSERT** privilege for the `mysql` database. To drop functions, you must have the **DELETE** privilege for the `mysql` database.

You cannot use **CREATE FUNCTION** to reinstall a function that has previously been installed. To reinstall a function, first remove it with **DROP FUNCTION**, then install it with **CREATE FUNCTION**. You would need to do this, for example, if you upgrade to a new version of MySQL that provides an updated implementation of the function, or you recompile a new version of a function that you have written. Otherwise, the server continues to use the old version.

An active function is one that has been loaded with **CREATE FUNCTION** and not removed with **DROP FUNCTION**. All active functions are reloaded each time the server starts, unless you start `mysqld` with the **--skip-grant-tables** option. In this case, the server does not load UDFs during startup and UDFs are unavailable.

### UDF Security Precautions

MySQL takes several measures to prevent misuse of user-defined functions.

UDF library files cannot be placed in arbitrary directories. They must be located in the server's plugin directory. This directory is given by the value of the `plugin_dir` system variable.

To use **CREATE FUNCTION** or **DROP FUNCTION**, you must have the **INSERT** or **DELETE** privilege, respectively, for the `mysql` database. This is necessary because those statements add and delete rows from the `mysql.func` table.

UDFs should have at least one symbol defined in addition to the `xxx` symbol that corresponds to the main `xxx()` function. These auxiliary symbols correspond to the `xxx_init()`, `xxx_deinit()`, `xxx_reset()`, `xxx_clear()`, and `xxx_add()` functions. `mysqld` also supports an **--allow-suspicious-udfs** option that controls whether UDFs that have only an `xxx` symbol can be loaded. By default, the option is disabled, to prevent attempts at loading functions from shared library files other than those containing legitimate UDFs. If you have older UDFs that contain only the `xxx` symbol and that cannot be recompiled to include an auxiliary symbol, it may be necessary to specify the **--allow-suspicious-udfs** option. Otherwise, you should avoid enabling it.

### 24.4.3 Adding a Native Function

To add a native MySQL function, use the procedure described here, which requires that you use a source distribution. You cannot add native functions to a binary distribution because it is necessary to modify MySQL source code and compile MySQL from the modified source. If you migrate to another version of MySQL (for example, when a new version is released), you must repeat the procedure with the new version.

If the native function will be referred to in statements that will be replicated to slave servers, you must ensure that every slave server also has the function available. Otherwise, replication will fail on the slaves when they attempt to invoke the function.
Adding a Native Function

To add a native function, follow these steps to modify source files in the sql directory:

1. Create a subclass for the function in item_create.cc:
   - If the function takes a fixed number of arguments, create a subclass of Create_func_arg0, Create_func_arg1, Create_func_arg2, or Create_func_arg3, respectively, depending on whether the function takes zero, one, two, or three arguments. For examples, see the Create_func_uuid, Create_func_abs, Create_func_pow, and Create_func_lpad classes.
   - If the function takes a variable number of arguments, create a subclass of Create_native_func. For an example, see Create_func_concat.

2. To provide a name by which the function can be referred to in SQL statements, register the name in item_create.cc by adding a line to this array:

   ```c
   static Native_func_registry func_array[]
   ```

   You can register several names for the same function. For example, see the lines for "LCASE" and "LOWER", which are aliases for Create_func_lcase.

3. In item_func.h, declare a class inheriting from Item_num_func or Item_str_func, depending on whether your function returns a number or a string.

4. In item_func.cc, add one of the following declarations, depending on whether you are defining a numeric or string function:

   ```c
   double   Item_func_newname::val()
   longlong Item_func_newname::val_int()
   String  *Item_func_newname::Str(String *str)
   ```

   If you inherit your object from any of the standard items (like Item_num_func), you probably only have to define one of these functions and let the parent object take care of the other functions. For example, the Item_str_func class defines a val() function that executes atof() on the value returned by ::str().

5. If the function is nondeterministic, include the following statement in the item constructor to indicate that function results should not be cached:

   ```c
   current_thd->lex->safe_to_cache_query=0;
   ```

   A function is nondeterministic if, given fixed values for its arguments, it can return different results for different invocations.

6. You should probably also define the following object function:

   ```c
   void Item_func_newname::fix_length_and_dec()
   ```

   This function should at least calculate max_length based on the given arguments. max_length is the maximum number of characters the function may return. This function should also set maybe_null = 0 if the main function cannot return a NULL value. The function can check whether any of the function arguments can return NULL by checking the arguments' maybe_null variable. Look at Item_func_mod::fix_length_and_dec for a typical example of how to do this.

   All functions must be thread-safe. In other words, do not use any global or static variables in the functions without protecting them with mutexes.

   If you want to return NULL from ::val(), ::val_int(), or ::str(), you should set null_value to 1 and return 0.
For `::str()` object functions, these additional considerations apply:

- The `String *str` argument provides a string buffer that may be used to hold the result. (For more information about the `String` type, take a look at the `sql_string.h` file.)
- The `::str()` function should return the string that holds the result, or `(char*) 0` if the result is `NULL`.
- All current string functions try to avoid allocating any memory unless absolutely necessary!

## 24.5 Debugging and Porting MySQL

This section helps you port MySQL to other operating systems. Do check the list of currently supported operating systems first. See [https://www.mysql.com/support/supportedplatforms/database.html](https://www.mysql.com/support/supportedplatforms/database.html). If you have created a new port of MySQL, please let us know so that we can list it here and on our website ([http://www.mysql.com/](http://www.mysql.com/)), recommending it to other users.

### Note

If you create a new port of MySQL, you are free to copy and distribute it under the GPL license, but it does not make you a copyright holder of MySQL.

A working POSIX thread library is needed for the server.

To build MySQL from source, your system must satisfy the tool requirements listed at [Section 2.9, “Installing MySQL from Source”](#).

### Important

If you are trying to build MySQL 5.5 with `icc` on the IA64 platform, and need support for NDB Cluster, you should first ensure that you are using `icc` version 9.1.043 or later. (For details, see Bug #21875.)

If you run into problems with a new port, you may have to do some debugging of MySQL! See [Section 24.5.1, “Debugging a MySQL Server”](#).

### Note

Before you start debugging `mysqld`, first get the test programs `mysys/thr_alarm` and `mysys/thr_lock` to work. This ensures that your thread installation has even a remote chance to work!

## 24.5.1 Debugging a MySQL Server

If you are using some functionality that is very new in MySQL, you can try to run `mysqld` with the `--skip-new` option (which disables all new, potentially unsafe functionality). See [Section B.4.3.3, “What to Do If MySQL Keeps Crashing”](#).

If `mysqld` does not want to start, verify that you have no `my.cnf` files that interfere with your setup! You can check your `my.cnf` arguments with `mysqld --print-defaults` and avoid using them by starting with `mysqld --no-defaults` ....

If `mysqld` starts to eat up CPU or memory or if it “hangs,” you can use `mysqladmin processlist status` to find out if someone is executing a query that takes a long time. It may be a good idea to run `mysqladmin -i10 processlist status` in some window if you are experiencing performance problems or problems when new clients cannot connect.
The command `mysqladmin debug` dumps some information about locks in use, used memory and query usage to the MySQL log file. This may help solve some problems. This command also provides some useful information even if you have not compiled MySQL for debugging!

If the problem is that some tables are getting slower and slower you should try to optimize the table with `OPTIMIZE TABLE` or `myisamchk`. See Chapter 5, *MySQL Server Administration*. You should also check the slow queries with `EXPLAIN`.

You should also read the OS-specific section in this manual for problems that may be unique to your environment. See Section 2.1, “General Installation Guidance”.

### 24.5.1.1 Compiling MySQL for Debugging

If you have some very specific problem, you can always try to debug MySQL. To do this you must configure MySQL with the `-DWITH_DEBUG=1` option. You can check whether MySQL was compiled with debugging by doing: `mysqld --help`. If the `--debug` flag is listed with the options then you have debugging enabled. `mysqladmin ver` also lists the `mysqld` version as `mysql ... --debug` in this case.

If `mysqld` stops crashing when you configure it with the `-DWITH_DEBUG=1` CMake option, you probably have found a compiler bug or a timing bug within MySQL. In this case, you can try to add `--g` using the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options and not use `-DWITH_DEBUG=1`. If `mysqld` dies, you can at least attach to it with `gdb` or use `gdb` on the core file to find out what happened.

When you configure MySQL for debugging you automatically enable a lot of extra safety check functions that monitor the health of `mysqld`. If they find something “unexpected,” an entry is written to `stderr`, which `mysqld_safe` directs to the error log! This also means that if you are having some unexpected problems with MySQL and are using a source distribution, the first thing you should do is to configure MySQL for debugging. If you believe that you have found a bug, please use the instructions at Section 1.6, “How to Report Bugs or Problems”.

In the Windows MySQL distribution, `mysqld.exe` is by default compiled with support for trace files.

### 24.5.1.2 Creating Trace Files

If the `mysqld` server does not start or it crashes easily, you can try to create a trace file to find the problem.

To do this, you must have a `mysqld` that has been compiled with debugging support. You can check this by executing `mysqld --V`. If the version number ends with `--debug`, it is compiled with support for trace files. (On Windows, the debugging server is named `mysqld-debug` rather than `mysqld`.)

Start the `mysqld` server with a trace log in `/tmp/mysqld.trace` on Unix or `\mysqld.trace` on Windows:

```
shell> mysqld --debug
```

On Windows, you should also use the `--standalone` flag to not start `mysqld` as a service. In a console window, use this command:

```
C:\> mysqld-debug --debug --standalone
```

After this, you can use the `mysql.exe` command-line tool in a second console window to reproduce the problem. You can stop the `mysqld` server with `mysqladmin shutdown`.

The trace file can become very large! To generate a smaller trace file, you can use debugging options something like this:
Debugging a MySQL Server

mysqld --debug=d,info,error,query,general,where:O,/tmp/mysqld.trace

This only prints information with the most interesting tags to the trace file.

If you file a bug, please add only those lines from the trace file to the bug report that indicate where something seems to go wrong. If you cannot locate the wrong place, open a bug report and upload the whole trace file to the report, so that a MySQL developer can take a look at it. For instructions, see Section 1.6, “How to Report Bugs or Problems”.

The trace file is made with the DBUG package by Fred Fish. See Section 24.5.3, “The DBUG Package”.

24.5.1.3 Using WER with PDB to create a Windows crashdump

Program Database (PDB) files (with file name suffix pdb) are included in ZIP Archive distributions (but not MSI distributions) of MySQL. These files provide information for debugging your MySQL installation in the event of a problem.

Note
The PDB files are available in a separate file labeled “ZIP Archive Debug Binaries & Test Suite”.

The PDB file contains more detailed information about mysqld and other tools that enables more detailed trace and dump files to be created. You can use these with WinDbg or Visual Studio to debug mysqld.

For more information on PDB files, see Microsoft Knowledge Base Article 121366. For more information on the debugging options available, see Debugging Tools for Windows.

To use WinDbg, either install the full Windows Driver Kit (WDK) or install the standalone version.

Important
The .exe and .pdb files must be an exact match (both version number and MySQL server edition) or WinDBG will complain while attempting to load the symbols.

1. To generate a minidump mysqld.dmp, enable the core-file option under the [mysqld] section in my.ini. Restart the MySQL server after making these changes.
2. Create a directory to store the generated files, such as c:symbols
3. Determine the path to your windbg.exe executable using the Find GUI or from the command line, for example: dir /s /b windbg.exe -- a common default is C:\Program Files\Debugging Tools for Windows (x64)\windbg.exe
4. Launch windbg.exe giving it the paths to mysqld.exe, mysqld.pdb, mysqld.dmp, and the source code. Alternatively, pass in each path from the WinDbg GUI. For example:

    windbg.exe -i "C:\mysql-5.5.62-winx64\bin\"^ 
    -z "C:\mysql-5.5.62-winx64\data\mysqld.dmp"^ 
    -srcpath "E:\ade\mysql_archives\5.5\5.5.62\mysql-5.5.62"^ 
    -y "C:\mysql-5.5.62-winx64\bin;SRV*c:\symbols*http://msdl.microsoft.com/download/symbols"^ 
    -v -n -c "!analyze -vvvvv"

Note
The ^ character and newline are removed by the Windows command line processor, so be sure the spaces remain intact.
24.5.1.4 Debugging mysqld under gdb

On most systems you can also start mysqld from gdb to get more information if mysqld crashes.

With some older gdb versions on Linux you must use run --one-thread if you want to be able to debug mysqld threads. In this case, you can only have one thread active at a time.

NPTL threads (the new thread library on Linux) may cause problems while running mysqld under gdb. Some symptoms are:

- mysqld hangs during startup (before it writes ready for connections).
- mysqld crashes during a pthread_mutex_lock() or pthread_mutex_unlock() call.

In this case, you should set the following environment variable in the shell before starting gdb:

```
LD_ASSUME_KERNEL=2.4.1
export LD_ASSUME_KERNEL
```

When running mysqld under gdb, you should disable the stack trace with --skip-stack-trace to be able to catch segfaults within gdb.

Use the --gdb option to mysqld to install an interrupt handler for SIGINT (needed to stop mysqld with ^C to set breakpoints) and disable stack tracing and core file handling.

It is very hard to debug MySQL under gdb if you do a lot of new connections the whole time as gdb does not free the memory for old threads. You can avoid this problem by starting mysqld with thread_cache_size set to a value equal to max_connections + 1. In most cases just using --thread_cache_size=5' helps a lot!

If you want to get a core dump on Linux if mysqld dies with a SIGSEGV signal, you can start mysqld with the --core-file option. This core file can be used to make a backtrace that may help you find out why mysqld died:

```
shell> gdb mysqld core
gdb> backtrace full
gdb> quit
```

See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

If you are using gdb on Linux, you should install a .gdb file, with the following information, in your current directory:

```
set print sevenbit off
handle SIGUSR1 nostop noprint
handle SIGUSR2 nostop noprint
handle SIGTSTK nostop noprint
handle SIGTTOU nostop noprint
handle SIGTTOU nostop noprint
handle SIGCHLD nostop noprint
handle SIGINT nostop noprint
handle SIGTERM nostop noprint
handle SIGSTOP nostop noprint
```

Here is an example how to debug mysqld:

```
shell> gdb /usr/local/libexec/mysqld
gdb> run
... backtrace full # Do this when mysqld crashes
```
Include the preceding output in a bug report, which you can file using the instructions in Section 1.6, “How to Report Bugs or Problems”.

If mysqld hangs, you can try to use some system tools like `strace` or `/usr/proc/bin/pstack` to examine where mysqld has hung.

```
strace /tmp/log libexec/mysqld
```

If you are using the Perl DBI interface, you can turn on debugging information by using the `trace` method or by setting the `DBI_TRACE` environment variable.

### 24.5.1.5 Using a Stack Trace

On some operating systems, the error log contains a stack trace if mysqld dies unexpectedly. You can use this to find out where mysqld died. See Section 5.4.2, “The Error Log”. To get a stack trace, you must not compile mysqld with the `-fomit-frame-pointer` option to gcc. See Section 24.5.1.1, “Compiling MySQL for Debugging”.

A stack trace in the error log looks something like this:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...

stack_bottom = 0x41fd0110 thread_stack 0x400000
mysqld(my_print_stacktrace+0x32)[0x9da402]
/usr/lib/libpthread.so.0[0x7f1a5af000f0]
/mysqld(_Z21check_change_passwordP3THDPcS2_Pcj+0x7c)[0x7412cb]
/my_executemysql_execute_commandP3THD+0x41a0)[0x67a170]
/my_executemysql_parseP3THDPck+0xbb7)[0x67f0ad]
my_executemysql_dispatch_command19enum_server_commandP3THDPc+0x28d)[0x6811b6]
/my_executemysqlhandle_one_connection+0x11c)[0x66e05e]
```

If resolution of function names for the trace fails, the trace contains less information:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...

stack_bottom = 0x41fd0110 thread_stack 0x400000
[0x9da402]
[0x7f1a5af000f0]
[0x7412cb]
[0x67a170]
[0x67f0ad]
[0x6811b6]
[0x66e05e]
```

In the latter case, you can use the `resolve_stack_dump` utility to determine where mysqld died by using the following procedure:
Debugging a MySQL Server

1. Copy the numbers from the stack trace to a file, for example `mysqld.stack`. The numbers should not include the surrounding square brackets:

   0x9da402
   0x6648e9
   0x7f1a5af000f0
   0x7f1a5a10f0f2
   0x7412cb
   0x688354
   0x688494
   0x67a170
   0x67f0ad
   0x67rdf8
   0x6811b6
   0x66e05e

2. Make a symbol file for the `mysqld` server:

   ```shell
   shell> nm -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If `mysqld` is not linked statically, use the following command instead:

   ```shell
   shell> nm -D -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If you want to decode C++ symbols, use the `--demangle`, if available, to `nm`. If your version of `nm` does not have this option, you will need to use the `c++filt` command after the stack dump has been produced to demangle the C++ names.

3. Execute the following command:

   ```shell
   shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack
   ```

   If you were not able to include demangled C++ names in your symbol file, process the `resolve_stack_dump` output using `c++filt`:

   ```shell
   shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack | c++filt
   ```

   This prints out where `mysqld` died. If that does not help you find out why `mysqld` died, you should create a bug report and include the output from the preceding command with the bug report.

   However, in most cases it does not help us to have just a stack trace to find the reason for the problem. To be able to locate the bug or provide a workaround, in most cases we need to know the statement that killed `mysqld` and preferably a test case so that we can repeat the problem! See Section 1.6, “How to Report Bugs or Problems”.

   Newer versions of `glibc` stack trace functions also print the address as relative to the object. On `glibc`-based systems (Linux), the trace for a crash within a plugin looks something like:

   ```
   plugin/auth/auth_test_plugin.so(+0x9a6)[0x7ff4d11c29a6]
   ```

   To translate the relative address `(+0x9a6)` into a file name and line number, use this command:

   ```shell
   shell> addr2line -fie auth_test_plugin.so 0x9a6
   auth_test_plugin
   mysql-trunk/plugin/auth/test_plugin.c:65
   ```

   The `addr2line` utility is part of the `binutils` package on Linux.

   On Solaris, the procedure is similar. The Solaris `printstack()` already prints relative addresses:

   ```
   plugin/auth/auth_test_plugin.so:0x1510
   ```
To translate, use this command:

```
shell> gaddr2line -fie auth_test_plugin.so 0x1510
mysql-trunk/plugin/auth/test_plugin.c:88
```

Windows already prints the address, function name and line:

```
000007FEF07E10A4 auth_test_plugin.dll!auth_test_plugin()[test_plugin.c:72]
```

### 24.5.1.6 Using Server Logs to Find Causes of Errors in `mysqld`

Note that before starting `mysqld` with the general query log enabled, you should check all your tables with `myisamchk`. See Chapter 5, *MySQL Server Administration*.

If `mysqld` dies or hangs, you should start `mysqld` with the general query log enabled. See Section 5.4.3, “The General Query Log”. When `mysqld` dies again, you can examine the end of the log file for the query that killed `mysqld`.

If you use the default general query log file, the log is stored in the database directory as `host_name.log`. In most cases it is the last query in the log file that killed `mysqld`, but if possible you should verify this by restarting `mysqld` and executing the found query from the `mysql` command-line tools. If this works, you should also test all complicated queries that did not complete.

You can also try the command `EXPLAIN` on all `SELECT` statements that takes a long time to ensure that `mysqld` is using indexes properly. See Section 13.8.2, “EXPLAIN Statement”.

You can find the queries that take a long time to execute by starting `mysqld` with the slow query log enabled. See Section 5.4.5, “The Slow Query Log”.

If you find the text `mysqld restarted` in the error log (normally a file named `host_name.err`) you probably have found a query that causes `mysqld` to fail. If this happens, you should check all your tables with `myisamchk` (see Chapter 5, *MySQL Server Administration*), and test the queries in the MySQL log files to see whether one fails. If you find such a query, try first upgrading to the newest MySQL version. If this does not help, report a bug, see Section 1.6, “How to Report Bugs or Problems”.

If you have started `mysqld` with the `myisam_recover_options` system variable set, MySQL automatically checks and tries to repair `MyISAM` tables if they are marked as ‘not closed properly’ or ‘crashed’. If this happens, MySQL writes an entry in the `hostname.err` file 'Warning: Checking table ...' which is followed by Warning: Repairing table if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further. See Section 5.1.6, “Server Command Options”.

When the server detects `MyISAM` table corruption, it writes additional information to the error log, such as the name and line number of the source file, and the list of threads accessing the table. Example: Got an error from thread_id=1, mi_dynrec.c:368. This is useful information to include in bug reports.

It is not a good sign if `mysqld` did die unexpectedly, but in this case, you should not investigate the Checking table... messages, but instead try to find out why `mysqld` died.

### 24.5.1.7 Making a Test Case If You Experience Table Corruption

The following procedure applies to `MyISAM` tables. For information about steps to take when encountering `InnoDB` table corruption, see Section 1.6, “How to Report Bugs or Problems”.

If you encounter corrupted `MyISAM` tables or if `mysqld` always fails after some update statements, you can test whether the issue is reproducible by doing the following:
1. Stop the MySQL daemon with `mysqladmin shutdown`.

2. Make a backup of the tables to guard against the very unlikely case that the repair does something bad.

3. Check all tables with `myisamchk -s database/*.MYI`. Repair any corrupted tables with `myisamchk -r database/table.MYI`.

4. Make a second backup of the tables.

5. Remove (or move away) any old log files from the MySQL data directory if you need more space.

6. Start `mysqld` with the binary log enabled. If you want to find a statement that crashes `mysqld`, you should start the server with the general query log enabled as well. See Section 5.4.3, “The General Query Log”, and Section 5.4.4, “The Binary Log”.

7. When you have gotten a crashed table, stop the `mysqld` server.

8. Restore the backup.

9. Restart the `mysqld` server without the binary log enabled.

10. Re-execute the statements with `mysqlbinlog binary-log-file | mysql`. The binary log is saved in the MySQL database directory with the name `hostname-bin.NNNNNN`.

11. If the tables are corrupted again or you can get `mysqld` to die with the above command, you have found a reproducible bug. FTP the tables and the binary log to our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If you are a support customer, you can use the MySQL Customer Support Center (https://www.mysql.com/support/) to alert the MySQL team about the problem and have it fixed as soon as possible.

You can also use the script `mysql_find_rows` to just execute some of the update statements if you want to narrow down the problem.

### 24.5.2 Debugging a MySQL Client

To be able to debug a MySQL client with the integrated debug package, you should configure MySQL with `-DWITH_DEBUG=1`. See Section 2.9.7, “MySQL Source-Configuration Options”.

Before running a client, you should set the `MYSQL_DEBUG` environment variable:

```
shell> MYSQL_DEBUG=d:t:O,/tmp/client.trace
shell> export MYSQL_DEBUG
```

This causes clients to generate a trace file in `/tmp/client.trace`.

If you have problems with your own client code, you should attempt to connect to the server and run your query using a client that is known to work. Do this by running `mysql` in debugging mode (assuming that you have compiled MySQL with debugging on):

```
shell> mysql --debug=d:t:O,/tmp/client.trace
```

This provides useful information in case you mail a bug report. See Section 1.6, “How to Report Bugs or Problems”.

If your client crashes at some ‘legal’ looking code, you should check that your `mysql.h` include file matches your MySQL library file. A very common mistake is to use an old `mysql.h` file from an old MySQL installation with new MySQL library.
24.5.3 The DBUG Package

The MySQL server and most MySQL clients are compiled with the DBUG package originally created by Fred Fish. When you have configured MySQL for debugging, this package makes it possible to get a trace file of what the program is doing. See Section 24.5.1.2, "Creating Trace Files".

This section summarizes the argument values that you can specify in debug options on the command line for MySQL programs that have been built with debugging support.

The DBUG package can be used by invoking a program with the --debug [=debug_options] or -# [debug_options] option. If you specify the --debug or -# option without a debug_options value, most MySQL programs use a default value. The server default is d:t:i:o,/tmp/mysqld.trace on Unix and d:t:i:O,\mysqld.trace on Windows. The effect of this default is:

- d: Enable output for all debug macros
- t: Trace function calls and exits
- i: Add PID to output lines
- o,/tmp/mysqld.trace, O,\mysqld.trace: Set the debug output file.

Most client programs use a default debug_options value of d:t:o,/tmp/program_name.trace, regardless of platform.

Here are some example debug control strings as they might be specified on a shell command line:

```
--debug=d:t
--debug=d,f,main,subr1:F:L:t,20
--debug=d,input,output,files:n
--debug=d:t:i:O,\mysqld.trace
```

For mysqld, it is also possible to change DBUG settings at runtime by setting the debug system variable. This variable has global and session values:

```
mysql> SET GLOBAL debug = 'debug_options';
mysql> SET SESSION debug = 'debug_options';
```

Changing the global debug value requires privileges sufficient to set global system variables. Changing the session debug value requires privileges sufficient to set restricted session system variables. See Section 5.1.8.1, "System Variable Privileges".

The debug_options value is a sequence of colon-separated fields:

```
field_1:field_2:...:field_N
```

Each field within the value consists of a mandatory flag character, optionally preceded by a + or - character, and optionally followed by a comma-delimited list of modifiers:

```
[+|-]flag[,modifier,modifier,...,modifier]
```

The following table describes the permitted flag characters. Unrecognized flag characters are silently ignored.

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>Enable output from DBUG_XXX macros for the current state. May be followed by a list of keywords, which enables output only for the DBUG macros with that keyword. An empty list of keywords enables output for all macros.</td>
</tr>
</tbody>
</table>
**The DBUG Package**

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In MySQL, common debug macro keywords to enable are <code>enter</code>, <code>exit</code>, <code>error</code>, <code>warning</code>, <code>info</code>, and <code>loop</code>.</td>
</tr>
<tr>
<td>D</td>
<td>Delay after each debugger output line. The argument is the delay, in tenths of seconds, subject to machine capabilities. For example, D, 20 specifies a delay of two seconds.</td>
</tr>
<tr>
<td>f</td>
<td>Limit debugging, tracing, and profiling to the list of named functions. An empty list enables all functions. The appropriate d or t flags must still be given; this flag only limits their actions if they are enabled.</td>
</tr>
<tr>
<td>F</td>
<td>Identify the source file name for each line of debug or trace output.</td>
</tr>
<tr>
<td>i</td>
<td>Identify the process with the PID or thread ID for each line of debug or trace output.</td>
</tr>
<tr>
<td>L</td>
<td>Identify the source file line number for each line of debug or trace output.</td>
</tr>
<tr>
<td>n</td>
<td>Print the current function nesting depth for each line of debug or trace output.</td>
</tr>
<tr>
<td>N</td>
<td>Number each line of debug output.</td>
</tr>
<tr>
<td>o</td>
<td>Redirect the debugger output stream to the specified file. The default output is <code>stderr</code>.</td>
</tr>
<tr>
<td>O</td>
<td>Like o, but the file is really flushed between each write. When needed, the file is closed and reopened between each write.</td>
</tr>
<tr>
<td>p</td>
<td>Limit debugger actions to specified processes. A process must be identified with the <code>DBUG_PROCESS</code> macro and match one in the list for debugger actions to occur.</td>
</tr>
<tr>
<td>P</td>
<td>Print the current process name for each line of debug or trace output.</td>
</tr>
<tr>
<td>r</td>
<td>When pushing a new state, do not inherit the previous state's function nesting level. Useful when the output is to start at the left margin.</td>
</tr>
<tr>
<td>S</td>
<td>Do function <code>_sanity(_file_, _line_)</code> at each debugged function until <code>_sanity()</code> returns something that differs from 0.</td>
</tr>
<tr>
<td>t</td>
<td>Enable function call/exit trace lines. May be followed by a list (containing only one modifier) giving a numeric maximum trace level, beyond which no output occurs for either debugging or tracing macros. The default is a compile time option.</td>
</tr>
</tbody>
</table>

The leading + or – character and trailing list of modifiers are used for flag characters such as d or f that can enable a debug operation for all applicable modifiers or just some of them:

- With no leading + or –, the flag value is set to exactly the modifier list as given.
- With a leading + or –, the modifiers in the list are added to or subtracted from the current modifier list.

The following examples show how this works for the d flag. An empty d list enabled output for all debug macros. A nonempty list enables output only for the macro keywords in the list.

These statements set the d value to the modifier list as given:

```sql
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
mysql> SET debug = 'd,error,warning';
mysql> SELECT @@debug;
+-----------------+
| @@debug         |
+-----------------+
| d,error,warning |
```

3018
A leading \texttt{+} or \texttt{--} adds to or subtracts from the current \texttt{d} value:

\begin{verbatim}
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+-----------------------+
| @@debug               |
+-----------------------+
| d,error,warning,loop  |
+-----------------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
+-----------------------+
| @@debug               |
+-----------------------+
| d,warning             |
+-----------------------+
\end{verbatim}

Adding to “all macros enabled” results in no change:

\begin{verbatim}
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
\end{verbatim}

Disabling all enabled macros disables the \texttt{d} flag entirely:

\begin{verbatim}
mysql> SET debug = 'd,error,loop';
mysql> SELECT @@debug;
+--------------+
| @@debug      |
+--------------+
| d,error,loop |
+--------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
|         |
+---------+
\end{verbatim}

\begin{note}
\textbf{Note} \\
The \texttt{+} and \texttt{--} modifiers are not always handled correctly and can leave a flag value in an incorrect state. Verify your \texttt{debug}-setting sequence in advance or set it without using \texttt{+} or \texttt{--}.
\end{note}
Chapter 25 MySQL Enterprise Edition

Table of Contents

25.1 MySQL Enterprise Monitor Overview ............................................................... 3021
25.2 MySQL Enterprise Backup Overview ............................................................ 3022
25.3 MySQL Enterprise Security Overview ........................................................... 3023
25.4 MySQL Enterprise Encryption Overview ....................................................... 3023
25.5 MySQL Enterprise Audit Overview ............................................................... 3023
25.6 MySQL Enterprise Firewall Overview .......................................................... 3024
25.7 MySQL Enterprise Thread Pool Overview ...................................................... 3024
25.8 MySQL Enterprise Data Masking and De-Identification Overview .................. 3024

MySQL Enterprise Edition is a commercial product. Like MySQL Community Edition, MySQL Enterprise Edition includes MySQL Server, a fully integrated transaction-safe, ACID-compliant database with full commit, rollback, crash-recovery, and row-level locking capabilities. In addition, MySQL Enterprise Edition includes the following components designed to provide monitoring and online backup, as well as improved security and scalability:

The following sections briefly discuss each of these components and indicate where to find more detailed information. To learn more about commercial products, see https://www.mysql.com/products/.

• MySQL Enterprise Monitor
• MySQL Enterprise Backup
• MySQL Enterprise Security
• MySQL Enterprise Encryption
• MySQL Enterprise Audit
• MySQL Enterprise Firewall
• MySQL Enterprise Thread Pool
• MySQL Enterprise Data Masking and De-Identification

25.1 MySQL Enterprise Monitor Overview

MySQL Enterprise Monitor is an enterprise monitoring system for MySQL that keeps an eye on your MySQL servers, notifies you of potential issues and problems, and advises you how to fix the issues. MySQL Enterprise Monitor can monitor all kinds of configurations, from a single MySQL server that is important to your business, all the way up to a huge farm of MySQL servers powering a busy website.

The following discussion briefly summarizes the basic components that make up the MySQL Enterprise Monitor product. For more information, see the MySQL Enterprise Monitor manual, available at https://dev.mysql.com/doc/mysql-monitor/en/.

MySQL Enterprise Monitor components can be installed in various configurations depending on your database and network topology, to give you the best combination of reliable and responsive monitoring data, with minimal overhead on the database server machines. A typical MySQL Enterprise Monitor installation consists of:
• One or more MySQL servers to monitor. MySQL Enterprise Monitor can monitor both Community and Enterprise MySQL server releases.

• A MySQL Enterprise Monitor Agent for each monitored host.

• A single MySQL Enterprise Service Manager, which collates information from the agents and provides the user interface to the collected data.

MySQL Enterprise Monitor is designed to monitor one or more MySQL servers. The monitoring information is collected by using an agent, MySQL Enterprise Monitor Agent. The agent communicates with the hosts and MySQL servers that it monitors, collecting variables, status and health information, and sending this information to the MySQL Enterprise Service Manager.

The information collected by the agent about each MySQL server and host you are monitoring is sent to the MySQL Enterprise Service Manager. This server collates all of the information from the agents. As it collates the information sent by the agents, the MySQL Enterprise Service Manager continually tests the collected data, comparing the status of the server to reasonable values. When thresholds are reached, the server can trigger an event (including an alarm and notification) to highlight a potential issue, such as low memory, high CPU usage, or more complex conditions such insufficient buffer sizes and status information. We call each test, with its associated threshold value, a rule.

These rules, and the alarms and notifications, are each known as a MySQL Enterprise Advisors. Advisors form a critical part of the MySQL Enterprise Service Manager, as they provide warning information and troubleshooting advice about potential problems.

The MySQL Enterprise Service Manager includes a web server, and you interact with it through any web browser. This interface, the MySQL Enterprise Monitor User Interface, displays all of the information collected by the agents, and lets you view all of your servers and their current status as a group or individually. You control and configure all aspects of the service using the MySQL Enterprise Monitor User Interface.

The information supplied by the MySQL Enterprise Monitor Agent processes also includes statistical and query information, which you can view in the form of graphs. For example, you can view aspects such as server load, query numbers, or index usage information as a graph over time. The graph lets you pinpoint problems or potential issues on your server, and can help diagnose the impact from database or external problems (such as external system or network failure) by examining the data from a specific time interval.

The MySQL Enterprise Monitor Agent can also be configured to collect detailed information about the queries executed on your server, including the row counts and performance times for executing each query. You can correlate the detailed query data with the graphical information to identify which queries were executing when you experienced a particularly high load, index or other issue. The query data is supported by a system called Query Analyzer, and the data can be presented in different ways depending on your needs.

25.2 MySQL Enterprise Backup Overview

MySQL Enterprise Backup performs hot backup operations for MySQL databases. The product is architected for efficient and reliable backups of tables created by the InnoDB storage engine. For completeness, it can also back up tables from MyISAM and other storage engines.

The following discussion briefly summarizes MySQL Enterprise Backup. For more information, see the MySQL Enterprise Backup manual, available at https://dev.mysql.com/doc/mysql-enterprise-backup/en/.

Hot backups are performed while the database is running and applications are reading and writing to it. This type of backup does not block normal database operations, and it captures even changes that occur while the backup is happening. For these reasons, hot backups are desirable when your database
“grows up” -- when the data is large enough that the backup takes significant time, and when your data is important enough to your business that you must capture every last change, without taking your application, website, or web service offline.

MySQL Enterprise Backup does a hot backup of all tables that use the InnoDB storage engine. For tables using MyISAM or other non-InnoDB storage engines, it does a “warm” backup, where the database continues to run, but those tables cannot be modified while being backed up. For efficient backup operations, you can designate InnoDB as the default storage engine for new tables, or convert existing tables to use the InnoDB storage engine.

**25.3 MySQL Enterprise Security Overview**

MySQL Enterprise Edition provides plugins that implement security features using external services:

- MySQL Enterprise Edition includes an authentication plugin that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as Unix passwords or an LDAP directory. For more information, see Section 6.4.1.4, “PAM Pluggable Authentication”.

- MySQL Enterprise Edition includes an authentication plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password. For more information, see Section 6.4.1.5, “Windows Pluggable Authentication”.

- MySQL Enterprise Edition 5.6 and higher includes a set of encryption functions based on the OpenSSL library that expose OpenSSL capabilities at the SQL level. These functions enable masking existing data using several methods such as obfuscation (removing identifying characteristics), generation of formatted random data, and data replacement or substitution. For more information, see Section 25.4, “MySQL Enterprise Encryption Overview”.

- MySQL Enterprise Edition 5.7 and higher includes a keyring plugin that uses Oracle Key Vault as a back end for keyring storage. For more information, see The MySQL Keyring.

For other related Enterprise security features, see Section 25.3, “MySQL Enterprise Security Overview”.

**25.4 MySQL Enterprise Encryption Overview**

MySQL Enterprise Edition 5.6 and higher includes a set of encryption functions based on the OpenSSL library that expose OpenSSL capabilities at the SQL level. These functions enable Enterprise applications to perform the following operations:

- Implement added data protection using public-key asymmetric cryptography
- Create public and private keys and digital signatures
- Perform asymmetric encryption and decryption
- Use cryptographic hashing for digital signing and data verification and validation

For more information, see MySQL Enterprise Encryption Functions.

For other related Enterprise security features, see Section 25.3, “MySQL Enterprise Security Overview”.

**25.5 MySQL Enterprise Audit Overview**
MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

For more information, see Section 6.4.2, “MySQL Enterprise Audit”.

25.6 MySQL Enterprise Firewall Overview

MySQL Enterprise Edition 5.6 and higher includes MySQL Enterprise Firewall, an application-level firewall that enables database administrators to permit or deny SQL statement execution based on matching against whitelists of accepted statement patterns. This helps harden MySQL Server against attacks such as SQL injection or attempts to exploit applications by using them outside of their legitimate query workload characteristics.

Each MySQL account registered with the firewall has its own statement whitelist, enabling protection to be tailored per account. For a given account, the firewall can operate in recording or protecting mode, for training in the accepted statement patterns or protection against unacceptable statements.

For more information, see MySQL Enterprise Firewall.

25.7 MySQL Enterprise Thread Pool Overview

MySQL Enterprise Edition includes MySQL Enterprise Thread Pool, implemented using a server plugin. The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. In MySQL Enterprise Edition, a thread pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections.

For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

25.8 MySQL Enterprise Data Masking and De-Identification Overview

MySQL Enterprise Edition 5.7 and higher includes MySQL Enterprise Data Masking and De-Identification, implemented as a plugin library containing a plugin and a set of user-defined functions. Data masking hides sensitive information by replacing real values with substitutes. MySQL Enterprise Data Masking and De-Identification functions enable masking existing data using several methods such as obfuscation (removing identifying characteristics), generation of formatted random data, and data replacement or substitution.

For more information, see MySQL Enterprise Data Masking and De-Identification.
Chapter 26 MySQL Workbench

MySQL Workbench provides a graphical tool for working with MySQL servers and databases. MySQL Workbench fully supports MySQL versions 5.5 and higher.

The following discussion briefly describes MySQL Workbench capabilities. For more information, see the MySQL Workbench manual, available at https://dev.mysql.com/doc/workbench/en/.

MySQL Workbench provides five main areas of functionality:

• **SQL Development**: Enables you to create and manage connections to database servers. As well as enabling you to configure connection parameters, MySQL Workbench provides the capability to execute SQL queries on the database connections using the built-in SQL Editor. This functionality replaces that previously provided by the Query Browser standalone application.

• **Data Modeling**: Enables you to create models of your database schema graphically, reverse and forward engineer between a schema and a live database, and edit all aspects of your database using the comprehensive Table Editor. The Table Editor provides easy-to-use facilities for editing Tables, Columns, Indexes, Triggers, Partitioning, Options, Inserts and Privileges, Routines and Views.

• **Server Administration**: Enables you to create and administer server instances.

• **Data Migration**: Allows you to migrate from Microsoft SQL Server, Sybase ASE, SQLite, SQL Anywhere, PostreSQL, and other RDBMS tables, objects and data to MySQL. Migration also supports migrating from earlier versions of MySQL to the latest releases.

• **MySQL Enterprise Support**: Support for Enterprise products such as MySQL Enterprise Backup and MySQL Audit.

MySQL Workbench is available in two editions, the Community Edition and the Commercial Edition. The Community Edition is available free of charge. The Commercial Edition provides additional Enterprise features, such as database documentation generation, at low cost.
Appendix A MySQL 5.5 Frequently Asked Questions

Table of Contents
A.1 MySQL 5.5 FAQ: General .................................................................................................................. 3027
A.2 MySQL 5.5 FAQ: Storage Engines .................................................................................................. 3029
A.3 MySQL 5.5 FAQ: Server SQL Mode .................................................................................................. 3029
A.4 MySQL 5.5 FAQ: Stored Procedures and Functions ......................................................................... 3030
A.5 MySQL 5.5 FAQ: Triggers ................................................................................................................. 3034
A.6 MySQL 5.5 FAQ: Views ....................................................................................................................... 3036
A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA ...................................................................................... 3037
A.8 MySQL 5.5 FAQ: Migration ................................................................................................................ 3037
A.9 MySQL 5.5 FAQ: Security .................................................................................................................. 3038
A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster ..................................................................................... 3039
A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets ...................................... 3052
A.12 MySQL 5.5 FAQ: Connectors & APIs .............................................................................................. 3065
A.13 MySQL 5.5 FAQ: C API, libmysql ................................................................................................... 3065
A.14 MySQL 5.5 FAQ: Replication ........................................................................................................... 3066
A.15 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool ........................................................................... 3070
A.16 MySQL 5.5 FAQ: InnoDB Change Buffer ....................................................................................... 3071
A.17 MySQL 5.5 FAQ: Virtualization Support .......................................................................................... 3073

A.1 MySQL 5.5 FAQ: General

A.1.1 Which version of MySQL is production-ready (GA)? ................................................................. 3027
A.1.2 Can MySQL 5.5 do subqueries? .................................................................................................... 3028
A.1.3 Can MySQL 5.5 perform multiple-table inserts, updates, and deletes? ..................................... 3028
A.1.4 Does MySQL 5.5 have a Query Cache? Does it work on Server, Instance or Database? .......... 3028
A.1.5 Does MySQL 5.5 have Sequences? ................................................................................................. 3028
A.1.6 Does MySQL 5.5 have a NOW() function with fractions of seconds? ........................................ 3028
A.1.7 Does MySQL 5.5 work with multi-core processors? ..................................................................... 3028
A.1.8 Why do I see multiple processes for mysqld? ............................................................................. 3028
A.1.9 Can MySQL 5.5 perform ACID transactions? ............................................................................ 3028

A.1.1. Which version of MySQL is production-ready (GA)?

MySQL 8.0, 5.7, and MySQL 5.6 are supported for production use.

MySQL 8.0 achieved General Availability (GA) status with MySQL 8.0.11, which was released for production use on 19 April 2018.

MySQL 5.7 achieved General Availability (GA) status with MySQL 5.7.9, which was released for production use on 21 October 2015.

MySQL 5.6 achieved General Availability (GA) status with MySQL 5.6.10, which was released for production use on 5 February 2013.

MySQL 5.5 achieved General Availability (GA) status with MySQL 5.5.8, which was released for production use on 3 December 2010. The MySQL 5.5 series is no longer current, but still supported in production.

MySQL 5.1 achieved General Availability (GA) status with MySQL 5.1.30, which was released for production use on 14 November 2008. Active development for MySQL 5.1 has ended.
MySQL 5.0 achieved General Availability (GA) status with MySQL 5.0.15, which was released for production use on 19 October 2005. Active development for MySQL 5.0 has ended.

**A.1.2.** Can MySQL 5.5 do subqueries?

Yes. See Section 13.2.10, “Subqueries”.

**A.1.3.** Can MySQL 5.5 perform multiple-table inserts, updates, and deletes?

Yes. For the syntax required to perform multiple-table updates, see Section 13.2.11, “UPDATE Statement”; for that required to perform multiple-table deletes, see Section 13.2.2, “DELETE Statement”.

A multiple-table insert can be accomplished using a trigger whose `FOR EACH ROW` clause contains multiple `INSERT` statements within a `BEGIN ... END` block. See Section 20.3, “Using Triggers”.

**A.1.4.** Does MySQL 5.5 have a Query Cache? Does it work on Server, Instance or Database?

Yes. The query cache operates on the server level, caching complete result sets matched with the original query string. If an exactly identical query is made (which often happens, particularly in web applications), no parsing or execution is necessary; the result is sent directly from the cache. Various tuning options are available. See Section 8.10.3, “The MySQL Query Cache”.

**A.1.5.** Does MySQL 5.5 have Sequences?

No. However, MySQL has an `AUTO_INCREMENT` system, which in MySQL 5.5 can also handle inserts in a multi-master replication setup. With the `auto_increment_increment` and `auto_increment_offset` system variables, you can set each server to generate auto-increment values that don’t conflict with other servers. The `auto_increment_increment` value should be greater than the number of servers, and each server should have a unique offset.

**A.1.6.** Does MySQL 5.5 have a `NOW()` function with fractions of seconds?

No, but support was added in 5.6.4.

Also, MySQL does parse time strings with a fractional component. See Section 11.2.3, “The TIME Type”.

**A.1.7.** Does MySQL 5.5 work with multi-core processors?

Yes. MySQL is fully multithreaded, and will make use of multiple CPUs, provided that the operating system supports them.

**A.1.8.** Why do I see multiple processes for `mysqld`?

When using LinuxThreads, you should see a minimum of three `mysqld` processes running. These are in fact threads. There is one thread for the LinuxThreads manager, one thread to handle connections, and one thread to handle alarms and signals.

**A.1.9.** Can MySQL 5.5 perform ACID transactions?

Yes. All current MySQL versions support transactions. The InnoDB storage engine offers full ACID transactions with row-level locking, multi-versioning, nonlocking repeatable reads, and all four SQL standard isolation levels.

The NDB storage engine supports the `READ COMMITTED` transaction isolation level only.
A.2 MySQL 5.5 FAQ: Storage Engines

A.2.1 Where can I obtain complete documentation for MySQL storage engines?

See Chapter 15, Alternative Storage Engines. That chapter contains information about all MySQL storage engines except for the InnoDB storage engine and the NDB storage engine (used for MySQL Cluster). InnoDB is covered in Chapter 14, The InnoDB Storage Engine. NDB is covered in Chapter 18, MySQL NDB Cluster 7.2.

A.2.2 Are there any new storage engines in MySQL 5.5?

The features from the optional InnoDB Plugin from MySQL 5.1 are folded into the built-in InnoDB storage engine, so you can take advantage of features such as the Barracuda file format, InnoDB table compression, and the new configuration options for performance. InnoDB also becomes the default storage engine for new tables. See Section 14.1, “Introduction to InnoDB” for details.

A.2.3 Have any storage engines been removed in MySQL 5.5?

No.

A.2.4 What are the unique benefits of the ARCHIVE storage engine?

The ARCHIVE storage engine stores large amounts of data without indexes; it has a small footprint, and performs selects using table scans. See Section 15.6, “The ARCHIVE Storage Engine”, for details.

A.3 MySQL 5.5 FAQ: Server SQL Mode

A.3.1 What are server SQL modes?

Server SQL modes define what SQL syntax MySQL should support and what kind of data validation checks it should perform. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers. The MySQL Server apply these modes individually to different clients. For more information, see Section 5.1.10, “Server SQL Modes”.

A.3.2 How many server SQL modes are there?

Each mode can be independently switched on and off. See Section 5.1.10, “Server SQL Modes”, for a complete list of available modes.

A.3.3 How do you determine the server SQL mode?

You can set the default SQL mode (for mysql startup) with the --sql-mode option. Using the statement SET [GLOBAL|SESSION] sql_mode='modes', you can change the settings from
within a connection, either locally to the connection, or to take effect globally. You can retrieve the current mode by issuing a `SELECT @@sql_mode` statement.

A.3.4. Is the mode dependent on the database or connection?

A mode is not linked to a particular database. Modes can be set locally to the session (connection), or globally for the server. You can change these settings using `SET [GLOBAL|SESSION] sql_mode='modes'`.

A.3.5. Can the rules for strict mode be extended?

When we refer to `strict mode`, we mean a mode where at least one of the modes `TRADITIONAL`, `STRICT_TRANS_TABLES`, or `STRICT_ALL_TABLES` is enabled. Options can be combined, so you can add restrictions to a mode. See Section 5.1.10, “Server SQL Modes”, for more information.

A.3.6. Does strict mode impact performance?

The intensive validation of input data that some settings require more time than if the validation is not done. While the performance impact is not that great, if you do not require such validation (perhaps your application already handles all of this), then MySQL gives you the option of leaving strict mode disabled. However, if you do require it, strict mode can provide such validation.

A.3.7. What is the default server SQL mode when MySQL 5.5 is installed?

By default, no special modes are enabled. For information about all available modes and default MySQL behavior, see Section 5.1.10, “Server SQL Modes”.

A.4 MySQL 5.5 FAQ: Stored Procedures and Functions

A.4.1 Does MySQL 5.5 support stored procedures and functions? .................................................. 3031
A.4.2 Where can I find documentation for MySQL stored procedures and stored functions? ............... 3031
A.4.3 Is there a discussion forum for MySQL stored procedures? ....................................................... 3031
A.4.4 Where can I find the ANSI SQL 2003 specification for stored procedures? .................................. 3031
A.4.5 How do you manage stored routines? .......................................................... 3031
A.4.6 Is there a way to view all stored procedures and stored functions in a given database? ............... 3031
A.4.7 Where are stored procedures stored? ................................................................. 3031
A.4.8 Is it possible to group stored procedures or stored functions into packages? ................................. 3031
A.4.9 Can a stored procedure call another stored procedure? ........................................................... 3032
A.4.10 Can a stored procedure call a trigger? .............................................................................. 3032
A.4.11 Can a stored procedure access tables? ................................................................. 3032
A.4.12 Do stored procedures have a statement for raising application errors? .................................. 3032
A.4.13 Do stored procedures provide exception handling? .............................................................. 3032
A.4.14 Can MySQL 5.5 stored routines return result sets? .............................................................. 3032
A.4.15 Is WITH RECOMPILE supported for stored procedures? ....................................................... 3032
A.4.16 Is there a MySQL equivalent to using `mod_plsql` as a gateway on Apache to talk directly to a stored procedure in the database? .......................................................... 3032
A.4.17 Can I pass an array as input to a stored procedure? ............................................................. 3032
A.4.18 Can I pass a cursor as an `IN` parameter to a stored procedure? ........................................... 3032
A.4.19 Can I return a cursor as an `OUT` parameter from a stored procedure? ................................. 3032
A.4.20 Can I print out a variable's value within a stored routine for debugging purposes? ................... 3032
A.4.21 Can I commit or roll back transactions inside a stored procedure? ......................................... 3033
A.4.22 Do MySQL 5.5 stored procedures and functions work with replication? .................................. 3033
A.4.23 Are stored procedures and functions created on a master server replicated to a slave? ............... 3033
A.4.24 How are actions that take place inside stored procedures and functions replicated? ................... 3033
A.4.25 Are there special security requirements for using stored procedures and functions together with replication? ................................................................. 3033
A.4.1. Does MySQL 5.5 support stored procedures and functions?

Yes. MySQL 5.5 supports two types of stored routines, stored procedures and stored functions.

A.4.2. Where can I find documentation for MySQL stored procedures and stored functions?

See Section 20.2, “Using Stored Routines”.

A.4.3. Is there a discussion forum for MySQL stored procedures?


A.4.4. Where can I find the ANSI SQL 2003 specification for stored procedures?

Unfortunately, the official specifications are not freely available (ANSI makes them available for purchase). However, there are books, such as SQL-99 Complete, Really by Peter Gulutzan and Trudy Pelzer, that provide a comprehensive overview of the standard, including coverage of stored procedures.

A.4.5. How do you manage stored routines?

It is always good practice to use a clear naming scheme for your stored routines. You can manage stored procedures with CREATE [FUNCTION|PROCEDURE], ALTER [FUNCTION|PROCEDURE], DROP [FUNCTION|PROCEDURE], and SHOW CREATE [FUNCTION|PROCEDURE]. You can obtain information about existing stored procedures using the ROUTINES table in the INFORMATION_SCHEMA database (see Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”).

A.4.6. Is there a way to view all stored procedures and stored functions in a given database?

Yes. For a database named `dbname`, use this query on the INFORMATION_SCHEMA.ROUTINES table:

```sql
SELECT ROUTINE_TYPE, ROUTINE_NAME
FROM INFORMATION_SCHEMA.ROUTINES
WHERE ROUTINE_SCHEMA='dbname';
```

For more information, see Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”.

The body of a stored routine can be viewed using SHOW CREATE FUNCTION (for a stored function) or SHOW CREATE PROCEDURE (for a stored procedure). See Section 13.7.5.11, “SHOW CREATE PROCEDURE Statement”, for more information.

A.4.7. Where are stored procedures stored?

In the `proc` table of the `mysql` system database. However, you should not access the tables in the system database directly. Instead, query the INFORMATION_SCHEMA ROUTINES and PARAMETERS tables. See Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”, and Section 21.12, “The INFORMATION_SCHEMA PARAMETERS Table”.

You can also use SHOW CREATE FUNCTION to obtain information about stored functions, and SHOW CREATE PROCEDURE to obtain information about stored procedures. See Section 13.7.5.11, “SHOW CREATE PROCEDURE Statement”.

A.4.8. Is it possible to group stored procedures or stored functions into packages?
A.4.9. Can a stored procedure call another stored procedure?

Yes.

A.4.10. Can a stored procedure call a trigger?

A stored procedure can execute an SQL statement, such as an `UPDATE`, that causes a trigger to activate.

A.4.11. Can a stored procedure access tables?

Yes. A stored procedure can access one or more tables as required.

A.4.12. Do stored procedures have a statement for raising application errors?

Yes. MySQL 5.5 implements the SQL standard `SIGNAL` and `RESIGNAL` statements. See Section 13.6.7, “Condition Handling”.

A.4.13. Do stored procedures provide exception handling?

MySQL implements `HANDLER` definitions according to the SQL standard. See Section 13.6.7.2, “DECLARE ... HANDLER Statement”, for details.

A.4.14. Can MySQL 5.5 stored routines return result sets?

`Stored procedures` can, but stored functions cannot. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You need to use the MySQL 4.1 (or higher) client/server protocol for this to work. This means that, for example, in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.15. Is `WITH RECOMPILE` supported for stored procedures?

Not in MySQL 5.5.

A.4.16. Is there a MySQL equivalent to using `mod_plsql` as a gateway on Apache to talk directly to a stored procedure in the database?

There is no equivalent in MySQL 5.5.

A.4.17. Can I pass an array as input to a stored procedure?

Not in MySQL 5.5.

A.4.18. Can I pass a cursor as an `IN` parameter to a stored procedure?

In MySQL 5.5, cursors are available inside stored procedures only.

A.4.19. Can I return a cursor as an `OUT` parameter from a stored procedure?

In MySQL 5.5, cursors are available inside stored procedures only. However, if you do not open a cursor on a `SELECT`, the result will be sent directly to the client. You can also `SELECT INTO` variables. See Section 13.2.9, “SELECT Statement”.

A.4.20. Can I print out a variable's value within a stored routine for debugging purposes?

Yes, you can do this in a `stored procedure`, but not in a stored function. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You will need to
use the MySQL 4.1 (or above) client/server protocol for this to work. This means that, for example, in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.21 Can I commit or roll back transactions inside a stored procedure?

Yes. However, you cannot perform transactional operations within a stored function.

A.4.22 Do MySQL 5.5 stored procedures and functions work with replication?

Yes, standard actions carried out in stored procedures and functions are replicated from a master MySQL server to a slave server. There are a few limitations that are described in detail in Section 20.7, “Stored Program Binary Logging”.

A.4.23 Are stored procedures and functions created on a master server replicated to a slave?

Yes, creation of stored procedures and functions carried out through normal DDL statements on a master server are replicated to a slave, so the objects will exist on both servers. `ALTER` and `DROP` statements for stored procedures and functions are also replicated.

A.4.24 How are actions that take place inside stored procedures and functions replicated?

MySQL records each DML event that occurs in a stored procedure and replicates those individual actions to a slave server. The actual calls made to execute stored procedures are not replicated.

A.4.25 Are there special security requirements for using stored procedures and functions together with replication?

Yes. Because a slave server has authority to execute any statement read from a master’s binary log, special security constraints exist for using stored functions with replication. If replication or binary logging in general (for the purpose of point-in-time recovery) is active, then MySQL DBAs have two security options open to them:

1. Any user wishing to create stored functions must be granted the `SUPER` privilege.

2. Alternatively, a DBA can set the `log_bin_trust_function_creators` system variable to 1, which enables anyone with the standard `CREATE ROUTINE` privilege to create stored functions.

A.4.26 What limitations exist for replicating stored procedure and function actions?

Nondeterministic (random) or time-based actions embedded in stored procedures may not replicate properly. By their very nature, randomly produced results are not predictable and cannot be exactly reproduced, and therefore, random actions replicated to a slave will not mirror those performed on a master. Declaring stored functions to be `DETERMINISTIC` or setting the `log_bin_trust_function_creators` system variable to 0 will not allow random-valued operations to be invoked.

In addition, time-based actions cannot be reproduced on a slave because the timing of such actions in a stored procedure is not reproducible through the binary log used for replication. It records only DML events and does not factor in timing constraints.

Finally, nontransactional tables for which errors occur during large DML actions (such as bulk inserts) may experience replication issues in that a master may be partially updated from DML activity, but no updates are done to the slave because of the errors that occurred. A workaround is for a function's DML actions to be carried out with the `IGNORE` keyword so that updates on the
master that cause errors are ignored and updates that do not cause errors are replicated to the slave.

A.4.27 Do the preceding limitations affect the ability of MySQL to do point-in-time recovery?

The same limitations that affect replication do affect point-in-time recovery.

A.4.28 What is being done to correct the aforementioned limitations?

You can choose either statement-based replication or row-based replication. The original replication implementation is based on statement-based binary logging. Row-based binary logging resolves the limitations mentioned earlier.

Mixed replication is also available (by starting the server with \texttt{--binlog-format=mixed}). This hybrid form of replication “knows” whether statement-level replication can safely be used, or row-level replication is required.

For additional information, see Section 17.1.2, “Replication Formats”.

A.5 MySQL 5.5 FAQ: Triggers

A.5.1 Where can I find the documentation for MySQL 5.5 triggers? .............................. 3034
A.5.2 Is there a discussion forum for MySQL Triggers? .................................................. 3034
A.5.3 Does MySQL 5.5 have statement-level or row-level triggers? .............................. 3034
A.5.4 Are there any default triggers? .............................................................................. 3034
A.5.5 How are triggers managed in MySQL? ................................................................. 3034
A.5.6 Is there a way to view all triggers in a given database? ........................................ 3035
A.5.7 Where are triggers stored? .................................................................................... 3035
A.5.8 Can a trigger call a stored procedure? ............................................................... 3035
A.5.9 Can triggers access tables? .................................................................................. 3035
A.5.10 Can a table have multiple triggers with the same trigger event and action time? .............. 3035
A.5.11 Can triggers call an external application through a UDF? ....................................... 3035
A.5.12 Is it possible for a trigger to update tables on a remote server? ............................. 3035
A.5.13 Do triggers work with replication? ........................... .......................... 3035
A.5.14 How are actions carried out through triggers on a master replicated to a slave? ........... 3036

A.5.1. Where can I find the documentation for MySQL 5.5 triggers?

See Section 20.3, “Using Triggers”.

A.5.2. Is there a discussion forum for MySQL Triggers?

Yes. It is available at \url{https://forums.mysql.com/list.php?99}.

A.5.3. Does MySQL 5.5 have statement-level or row-level triggers?

In MySQL 5.5, all triggers are \texttt{FOR EACH ROW}; that is, the trigger is activated for each row that is inserted, updated, or deleted. MySQL 5.5 does not support triggers using \texttt{FOR EACH STATEMENT}.

A.5.4. Are there any default triggers?

Not explicitly. MySQL does have specific special behavior for some \texttt{TIMESTAMP} columns, as well as for columns which are defined using \texttt{AUTO_INCREMENT}.

A.5.5. How are triggers managed in MySQL?

In MySQL 5.5, triggers can be created using the \texttt{CREATE TRIGGER} statement, and dropped using \texttt{DROP TRIGGER}. See Section 13.1.19, “CREATE TRIGGER Statement”, and Section 13.1.30, “DROP TRIGGER Statement”, for more about these statements.
Information about triggers can be obtained by querying the `INFORMATION_SCHEMA.TRIGGERS` table. See Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”.

A.5.6. Is there a way to view all triggers in a given database?

Yes. You can obtain a listing of all triggers defined on database `dbname` using a query on the `INFORMATION_SCHEMA.TRIGGERS` table such as the one shown here:

```
SELECT TRIGGER_NAME, EVENT_MANIPULATION, EVENT_OBJECT_TABLE, ACTION_STATEMENT
FROM INFORMATION_SCHEMA.TRIGGERS
WHERE TRIGGER_SCHEMA='dbname';
```

For more information about this table, see Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”.

You can also use the `SHOW TRIGGERS` statement, which is specific to MySQL. See Section 13.7.5.39, “SHOW TRIGGERS Statement”.

A.5.7. Where are triggers stored?

Triggers are stored in `.TRG` files, with one such file one per table.

A.5.8. Can a trigger call a stored procedure?

Yes.

A.5.9. Can triggers access tables?

A trigger can access both old and new data in its own table. A trigger can also affect other tables, but it is not permitted to modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.

A.5.10. Can a table have multiple triggers with the same trigger event and action time?

In MySQL 5.5, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. This limitation is lifted in MySQL 5.7.

A.5.11. Can triggers call an external application through a UDF?

Yes. For example, a trigger could invoke the `sys_exec()` UDF.

A.5.12. Is it possible for a trigger to update tables on a remote server?

Yes. A table on a remote server could be updated using the `FEDERATED` storage engine. (See Section 15.9, “The FEDERATED Storage Engine”).

A.5.13. Do triggers work with replication?

Yes. However, the way in which they work depends whether you are using MySQL’s “classic” statement-based or row-based replication format.

When using statement-based replication, triggers on the slave are executed by statements that are executed on the master (and replicated to the slave).

When using row-based replication, triggers are not executed on the slave due to statements that were run on the master and then replicated to the slave. Instead, when using row-based replication, the changes caused by executing the trigger on the master are applied on the slave.
A.5.14 How are actions carried out through triggers on a master replicated to a slave?

Again, this depends on whether you are using statement-based or row-based replication.

**Statement-based replication.** First, the triggers that exist on a master must be re-created on the slave server. Once this is done, the replication flow works as any other standard DML statement that participates in replication. For example, consider a table `EMP` that has an *AFTER* insert trigger, which exists on a master MySQL server. The same `EMP` table and *AFTER* insert trigger exist on the slave server as well. The replication flow would be:

1. An *INSERT* statement is made to `EMP`.
2. The *AFTER* trigger on `EMP` activates.
3. The *INSERT* statement is written to the binary log.
4. The replication slave picks up the *INSERT* statement to `EMP` and executes it.
5. The *AFTER* trigger on `EMP` that exists on the slave activates.

**Row-based replication.** When you use row-based replication, the changes caused by executing the trigger on the master are applied on the slave. However, the triggers themselves are not actually executed on the slave under row-based replication. This is because, if both the master and the slave applied the changes from the master and, in addition, the trigger causing these changes were applied on the slave, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

In most cases, the outcome is the same for both row-based and statement-based replication. However, if you use different triggers on the master and slave, you cannot use row-based replication. (This is because the row-based format replicates the changes made by triggers executing on the master to the slaves, rather than the statements that caused the triggers to execute, and the corresponding triggers on the slave are not executed.) Instead, any statements causing such triggers to be executed must be replicated using statement-based replication.

For more information, see Section 17.4.1.35, “Replication and Triggers”.

### A.6 MySQL 5.5 FAQ: Views

A.6.1 Where can I find documentation covering MySQL Views? ................................................................. 3036
A.6.2 Is there a discussion forum for MySQL Views? ................................................................. 3036
A.6.3 What happens to a view if an underlying table is dropped or renamed? .......................... 3036
A.6.4 Does MySQL 5.5 have table snapshots? ................................................................. 3037
A.6.5 Does MySQL 5.5 have materialized views? ................................................................. 3037
A.6.6 Can you insert into views that are based on joins? ......................................................... 3037

**A.6.1.** Where can I find documentation covering MySQL Views?

See Section 20.5, “Using Views”.

**A.6.2.** Is there a discussion forum for MySQL Views?

Yes. See https://forums.mysql.com/list.php?100

**A.6.3.** What happens to a view if an underlying table is dropped or renamed?
After a view has been created, it is possible to drop or alter a table or view to which the definition refers. To check a view definition for problems of this kind, use the `CHECK TABLE` statement. (See Section 13.7.2.2, "CHECK TABLE Statement").

A.6.4. Does MySQL 5.5 have table snapshots?

No.

A.6.5. Does MySQL 5.5 have materialized views?

No.

A.6.6. Can you insert into views that are based on joins?

It is possible, provided that your `INSERT` statement has a column list that makes it clear there is only one table involved.

You cannot insert into multiple tables with a single insert on a view.

A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA

A.7.1 Where can I find documentation for the MySQL `INFORMATION_SCHEMA` database?

See Chapter 21, `INFORMATION_SCHEMA` Tables

A.7.2 Is there a discussion forum for `INFORMATION_SCHEMA`?


A.7.3 Where can I find the ANSI SQL 2003 specification for `INFORMATION_SCHEMA`?

Unfortunately, the official specifications are not freely available. (ANSI makes them available for purchase.) However, there are books available, such as `SQL-99 Complete, Really` by Peter Gulutzan and Trudy Pelzer, that provide a comprehensive overview of the standard, including `INFORMATION_SCHEMA`.

A.7.4 What is the difference between the Oracle Data Dictionary and MySQL `INFORMATION_SCHEMA`?

Both Oracle and MySQL provide metadata in tables. However, Oracle and MySQL use different table names and column names. The MySQL implementation is more similar to those found in DB2 and SQL Server, which also support `INFORMATION_SCHEMA` as defined in the SQL standard.

A.7.5 Can I add to or otherwise modify the tables found in the `INFORMATION_SCHEMA` database?

No. Since applications may rely on a certain standard structure, this should not be modified. For this reason, we cannot support bugs or other issues which result from modifying `INFORMATION_SCHEMA` tables or data.

A.8 MySQL 5.5 FAQ: Migration

A.8.1 Where can I find information on how to migrate from MySQL 5.1 to MySQL 5.5?

See Chapter 21, `INFORMATION_SCHEMA` Tables
A.8.2 How has storage engine (table type) support changed in MySQL 5.5 from previous versions? ...

A.8.1. Where can I find information on how to migrate from MySQL 5.1 to MySQL 5.5?

For detailed upgrade information, see Section 2.11, “Upgrading MySQL”. Do not skip a major version when upgrading, but rather complete the process in steps, upgrading from one major version to the next in each step. This may seem more complicated, but it will you save time and trouble. If you encounter problems during the upgrade, their origin will be easier to identify, either by you or, if you have a MySQL Enterprise subscription, by MySQL support.

A.8.2. How has storage engine (table type) support changed in MySQL 5.5 from previous versions?

Storage engine support has changed as follows:

- Support for ISAM tables was removed in MySQL 5.0 and you should now use the MyISAM storage engine in place of ISAM. To convert a table `tblname` from ISAM to MyISAM, simply issue a statement such as this one:

  ```sql
  ALTER TABLE tblname ENGINE=MYISAM;
  ```

- Internal RAID for MyISAM tables was also removed in MySQL 5.0. This was formerly used to allow large tables in file systems that did not support file sizes greater than 2GB. All modern file systems allow for larger tables; in addition, there are now other solutions such as MERGE tables and views.

- The VARCHAR column type now retains trailing spaces in all storage engines.

- MEMORY tables (formerly known as HEAP tables) can also contain VARCHAR columns.

A.9 MySQL 5.5 FAQ: Security

A.9.1 Where can I find documentation that addresses security issues for MySQL? .......................... 3038
A.9.2 What is the default authentication plugin in MySQL 5.5? ......................................................... 3039
A.9.3 Does MySQL 5.5 have native support for SSL? ................................................................. 3039
A.9.4 Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it? .......................... 3039
A.9.5 Does MySQL 5.5 have built-in authentication against LDAP directories? ................................. 3039
A.9.6 Does MySQL 5.5 include support for Roles Based Access Control (RBAC)? .............................. 3039

A.9.1. Where can I find documentation that addresses security issues for MySQL?

The best place to start is Chapter 6, Security.

Other portions of the MySQL Documentation which you may find useful with regard to specific security concerns include the following:

- Section 6.1.1, “Security Guidelines”.
- Section 6.1.3, “Making MySQL Secure Against Attackers”.
- Section B.4.3.2, “How to Reset the Root Password”.
- Section 6.1.5, “How to Run MySQL as a Normal User”.
- UDF Security Precautions.
- Section 6.1.4, “Security-Related mysqld Options and Variables”.
- Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

3038
A.9.2. What is the default authentication plugin in MySQL 5.5?

The default authentication plugin in MySQL 5.5 is `mysql_native_password`. For information about this plugin, see Section 6.4.1.1, “Native Pluggable Authentication”. For general information about pluggable authentication and other available authentication plugins, see Section 6.2.10, “Pluggable Authentication”, and Section 6.4.1, “Authentication Plugins”.

A.9.3. Does MySQL 5.5 have native support for SSL?

Most 5.5 binaries have support for SSL connections between the client and server. See Section 6.3, “Using Encrypted Connections”.

You can also tunnel a connection using SSH, if (for example) the client application does not support SSL connections. For an example, see Section 6.3.5, “Connecting to MySQL Remotely from Windows with SSH”.

A.9.4. Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it?

Most 5.5 binaries have SSL enabled for client/server connections that are secured, authenticated, or both. See Section 6.3, “Using Encrypted Connections”.

A.9.5. Does MySQL 5.5 have built-in authentication against LDAP directories?

The Enterprise edition includes a PAM Authentication Plugin that supports authentication against an LDAP directory.

A.9.6. Does MySQL 5.5 include support for Roles Based Access Control (RBAC)?

Not at this time.

A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster

In the following section, we answer questions that are frequently asked about NDB Cluster and the `NDBCLUSTER` storage engine.

A.10.1 Which versions of the MySQL software support NDB Cluster? Do I have to compile from source? ................................................................. 3040
A.10.2 What do “NDB” and “NDBCLUSTER” mean? ................................................................. 3041
A.10.3 What is the difference between using NDB Cluster versus using MySQL Replication? ............. 3041
A.10.4 Do I need any special networking to run NDB Cluster? How do computers in a cluster communicate? .................................................................................................................. 3041
A.10.5 How many computers do I need to run an NDB Cluster, and why? ................................ 3041
A.10.6 What do the different computers do in an NDB Cluster? .................................................. 3042
A.10.7 When I run the `SHOW` command in the NDB Cluster management client, I see a line of output that looks like this: ................................................................. 3042
A.10.8 With which operating systems can I use NDB Cluster? .................................................... 3043
A.10.9 What are the hardware requirements for running NDB Cluster? ........................................ 3043
A.10.10 How much RAM do I need to use NDB Cluster? Is it possible to use disk memory at all? ...... 3043
A.10.11 What file systems can I use with NDB Cluster? What about network file systems or network shares? ................................................................................................................. 3044
A.10.12 Can I run NDB Cluster nodes inside virtual machines (such as those created by VMWare, Parallels, or Xen)? ................................................................. 3045
A.10.13 I am trying to populate an NDB Cluster database. The loading process terminates prematurely and I get an error message like this one: ......................................................... 3045
A.10.14 NDB Cluster uses TCP/IP. Does this mean that I can run it over the Internet, with one or more nodes in remote locations? ................................................................. 3045
A.10.15 Do I have to learn a new programming or query language to use NDB Cluster? ......................... 3045
A.10.16 What programming languages and APIs are supported by NDB Cluster? ..................................... 3046
A.10.17 Does NDB Cluster include any management tools? ................................................................. 3046
A.10.18 How do I find out what an error or warning message means when using NDB Cluster? ............... 3046
A.10.19 Is NDB Cluster transaction-safe? What isolation levels are supported? ................................... 3047
A.10.20 What storage engines are supported by NDB Cluster? .......................................................... 3047
A.10.21 In the event of a catastrophic failure— for example, the whole city loses power and my UPS fails—would I lose all my data? ................................................................. 3047
A.10.22 Is it possible to use FULLTEXT indexes with NDB Cluster? ...................................................... 3047
A.10.23 Can I run multiple nodes on a single computer? ....................................................................... 3047
A.10.24 Can I add data nodes to an NDB Cluster without restarting it? .................................................... 3047
A.10.25 Are there any limitations that I should be aware of when using NDB Cluster? ........................... 3048
A.10.26 Does NDB Cluster support foreign keys? ................................................................................ 3048
A.10.27 How do I import an existing MySQL database into an NDB Cluster? ....................................... 3048
A.10.28 How do NDB Cluster nodes communicate with one another? .................................................. 3049
A.10.29 What is an arbitrator? ............................................................................................................. 3049
A.10.30 What data types are supported by NDB Cluster? ....................................................................... 3049
A.10.31 How do I start and stop NDB Cluster? ...................................................................................... 3050
A.10.32 What happens to NDB Cluster data when the NDB Cluster is shut down? .............................. 3050
A.10.33 Is it a good idea to have more than one management node for an NDB Cluster? ....................... 3050
A.10.34 Can I mix different kinds of hardware and operating systems in one NDB Cluster? ................. 3051
A.10.35 Can I run two data nodes on a single host? Two SQL nodes? .................................................... 3051
A.10.36 Can I use host names with NDB Cluster? .................................................................................. 3051
A.10.37 Does NDB Cluster support IPv6? ............................................................................................. 3051
A.10.38 How do I handle MySQL users in an NDB Cluster having multiple MySQL servers? .............. 3051
A.10.39 How do I continue to send queries in the event that one of the SQL nodes fails? ...................... 3051
A.10.40 How do I back up and restore an NDB Cluster? ..................................................................... 3051
A.10.41 What is an “angel process”? .................................................................................................. 3052

A.10.1 Which versions of the MySQL software support NDB Cluster? Do I have to compile from source?

NDB Cluster is not supported in standard MySQL Server 5.5 releases. Instead, MySQL NDB Cluster is provided as a separate product. Available NDB Cluster release series include the following:

- **NDB Cluster 7.2.** This series is a previous General Availability (GA) version of NDB Cluster, still supported for existing deployments, although we recommend that new deployments use the latest NDB Cluster 7.6 release. The most recent NDB Cluster 7.2 release can be obtained from https://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.3.** This series is a previous General Availability (GA) version of NDB Cluster, still available for production, although we recommend that new deployments use the latest NDB Cluster 7.6 release. The most recent NDB Cluster 7.3 release can be obtained from https://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.4.** This series is a previous General Availability (GA) version of NDB Cluster, still available for production, although we recommend that new deployments use the latest NDB Cluster 7.6 release. The most recent NDB Cluster 7.4 release can be obtained from https://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.5.** This series is a previous General Availability (GA) version of NDB Cluster, still available for production, although we recommend that new deployments use the latest NDB Cluster 7.6 release. The most recent NDB Cluster 7.5 release can be obtained from https://dev.mysql.com/downloads/cluster/.
NDB Cluster 7.6 release. The latest NDB Cluster 7.5 releases can be obtained from https://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.6.** This series is the most recent General Availability (GA) version of NDB Cluster, based on version 7.6 of the NDB storage engine and MySQL Server 5.7. NDB Cluster 7.6 is available for production use; new deployments intended for production should use the latest GA release in this series, which is currently NDB Cluster 7.6.13. You can obtain the most recent NDB Cluster 7.6 release from https://dev.mysql.com/downloads/cluster/. For information about new features and other important changes in this series, see What is New in NDB Cluster 7.6.

- **NDB Cluster 8.0.** This series is now available as a Developer Preview release for evaluation and testing of new features in the NDBCLUSTER storage engine; for more information, see MySQL NDB Cluster 8.0.

You should use NDB Cluster 7.6 for any new deployments; if you are using an older version of NDB Cluster, you should upgrade to this version soon as possible. For an overview of improvements made in NDB Cluster 7.6, see What is New in NDB Cluster 7.6. For an overview of improvements made in NDB Cluster 7.5, see What is New in NDB Cluster 7.5.

You can determine whether your MySQL Server has NDB support using one of the statements `SHOW VARIABLES LIKE 'have_%'`, `SHOW ENGINES`, or `SHOW PLUGINS`.

**A.10.2 What do “NDB” and “NDBCLUSTER” mean?**

“NDB” stands for “Network Database”. NDB and NDBCLUSTER are both names for the storage engine that enables clustering support with MySQL. NDB is preferred, but either name is correct.

**A.10.3 What is the difference between using NDB Cluster versus using MySQL Replication?**

In traditional MySQL replication, a master MySQL server updates one or more slaves. Transactions are committed sequentially, and a slow transaction can cause the slave to lag behind the master. This means that if the master fails, it is possible that the slave might not have recorded the last few transactions. If a transaction-safe engine such as InnoDB is being used, a transaction will either be complete on the slave or not applied at all, but replication does not guarantee that all data on the master and the slave will be consistent at all times. In NDB Cluster, all data nodes are kept in synchrony, and a transaction committed by any one data node is committed for all data nodes. In the event of a data node failure, all remaining data nodes remain in a consistent state.

In short, whereas standard MySQL replication is asynchronous, NDB Cluster is synchronous.

Asynchronous replication is also available in NDB Cluster. *NDB Cluster Replication* (also sometimes known as “geo-replication”) includes the capability to replicate both between two NDB Clusters, and from an NDB Cluster to a non-Cluster MySQL server. See Section 18.6, “NDB Cluster Replication”.

**A.10.4 Do I need any special networking to run NDB Cluster? How do computers in a cluster communicate?**

NDB Cluster is intended to be used in a high-bandwidth environment, with computers connecting using TCP/IP. Its performance depends directly upon the connection speed between the cluster’s computers. The minimum connectivity requirements for NDB Cluster include a typical 100-megabit Ethernet network or the equivalent. We recommend you use gigabit Ethernet whenever available.

**A.10.5 How many computers do I need to run an NDB Cluster, and why?**

A minimum of three computers is required to run a viable cluster. However, the minimum recommended number of computers in an NDB Cluster is four; one each to run the management and SQL nodes, and two computers to serve as data nodes. The purpose of the two data nodes
is to provide redundancy; the management node must run on a separate machine to guarantee continued arbitration services in the event that one of the data nodes fails.

To provide increased throughput and high availability, you should use multiple SQL nodes (MySQL Servers connected to the cluster). It is also possible (although not strictly necessary) to run multiple management servers.

A.10.6 What do the different computers do in an NDB Cluster?

An NDB Cluster has both a physical and logical organization, with computers being the physical elements. The logical or functional elements of a cluster are referred to as nodes, and a computer housing a cluster node is sometimes referred to as a cluster host. There are three types of nodes, each corresponding to a specific role within the cluster. These are:

- **Management node.** This node provides management services for the cluster as a whole, including startup, shutdown, backups, and configuration data for the other nodes. The management node server is implemented as the application ndb_mgmd; the management client used to control NDB Cluster is ndb_mgm. See Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon", and Section 18.4.5, "ndb_mgm — The NDB Cluster Management Client", for information about these programs.

- **Data node.** This type of node stores and replicates data. Data node functionality is handled by instances of the NDB data node process ndbd. For more information, see Section 18.4.1, "ndbd — The NDB Cluster Data Node Daemon".

- **SQL node.** This is simply an instance of MySQL Server (mysqld) that is built with support for the NDBCLUSTER storage engine and started with the --ndb-cluster option to enable the engine and the --ndb-connectstring option to enable it to connect to an NDB Cluster management server. For more about these options, see MySQL Server Options for NDB Cluster.

Note

An API node is any application that makes direct use of Cluster data nodes for data storage and retrieval. An SQL node can thus be considered a type of API node that uses a MySQL Server to provide an SQL interface to the Cluster. You can write such applications (that do not depend on a MySQL Server) using the NDB API, which supplies a direct, object-oriented transaction and scanning interface to NDB Cluster data; see NDB Cluster API Overview: The NDB API, for more information.

A.10.7 When I run the **SHOW** command in the NDB Cluster management client, I see a line of output that looks like this:

```
id=2  @10.100.10.32  (Version: 5.6.47-ndb-7.4.27 Nodegroup: 0, *)
```

What does the * mean? How is this node different from the others?

The simplest answer is, “It's not something you can control, and it's nothing that you need to worry about in any case, unless you're a software engineer writing or analyzing the NDB Cluster source code”.

If you don't find that answer satisfactory, here's a longer and more technical version:

A number of mechanisms in NDB Cluster require distributed coordination among the data nodes. These distributed algorithms and protocols include global checkpointing, DDL (schema) changes, and node restart handling. To make this coordination simpler, the data nodes “elect” one of their number to act as leader. (This node was once referred to as a “master”, but this terminology was
dropped to avoid confusion with master server in MySQL Replication.) There is no user-facing mechanism for influencing this selection, which is completely automatic; the fact that it is automatic is a key part of NDB Cluster's internal architecture.

When a node acts as the “leader” for any of these mechanisms, it is usually the point of coordination for the activity, and the other nodes act as “followers”, carrying out their parts of the activity as directed by the leader. If the node acting as leader fails, then the remaining nodes elect a new leader. Tasks in progress that were being coordinated by the old leader may either fail or be continued by the new leader, depending on the actual mechanism involved.

It is possible for some of these different mechanisms and protocols to have different leader nodes, but in general the same leader is chosen for all of them. The node indicated as the leader in the output of `SHOW` in the management client is known internally as the DICT manager (see The DBDICT Block, in the NDB Cluster API Developer Guide, for more information), responsible for coordinating DDL and metadata activity.

NDB Cluster is designed in such a way that the choice of leader has no discernible effect outside the cluster itself. For example, the current leader does not have significantly higher CPU or resource usage than the other data nodes, and failure of the leader should not have a significantly different impact on the cluster than the failure of any other data node.

A.10.8 With which operating systems can I use NDB Cluster?

NDB Cluster is supported on most Unix-like operating systems. NDB Cluster is also supported in production settings on Microsoft Windows operating systems.

For more detailed information concerning the level of support which is offered for NDB Cluster on various operating system versions, operating system distributions, and hardware platforms, please refer to https://www.mysql.com/support/supportedplatforms/cluster.html.

A.10.9 What are the hardware requirements for running NDB Cluster?

NDB Cluster should run on any platform for which NDB-enabled binaries are available. For data nodes and API nodes, faster CPUs and more memory are likely to improve performance, and 64-bit CPUs are likely to be more effective than 32-bit processors. There must be sufficient memory on machines used for data nodes to hold each node's share of the database (see How much RAM do I Need? for more information). For a computer which is used only for running the NDB Cluster management server, the requirements are minimal; a common desktop PC (or the equivalent) is generally sufficient for this task. Nodes can communicate through the standard TCP/IP network and hardware. They can also use the high-speed SCI protocol; however, special networking hardware and software are required to use SCI (see Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”).

A.10.10 How much RAM do I need to use NDB Cluster? Is it possible to use disk memory at all?

NDB Cluster was originally implemented as in-memory only, but all versions currently available also provide the ability to store NDB Cluster on disk. See Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.

For in-memory NDB tables, you can use the following formula for obtaining a rough estimate of how much RAM is needed for each data node in the cluster:

\[(\text{Size of Database} \times \text{Number of Replicas} \times 1.1) / \text{Number of Data Nodes}\]

To calculate the memory requirements more exactly requires determining, for each table in the cluster database, the storage space required per row (see Section 11.6, “Data Type Storage” for more information).
Each primary key or hash index created for an NDBCLUSTER table requires 21–25 bytes per record. These indexes use IndexMemory.

Each ordered index requires 10 bytes storage per record, using DataMemory.

Creating a primary key or unique index also creates an ordered index, unless this index is created with USING HASH. In other words:

- A primary key or unique index on a Cluster table normally takes up 31 to 35 bytes per record.
- However, if the primary key or unique index is created with USING HASH, then it requires only 21 to 25 bytes per record.

Creating NDB Cluster tables with USING HASH for all primary keys and unique indexes will generally cause table updates to run more quickly—in some cases by a much as 20 to 30 percent faster than updates on tables where USING HASH was not used in creating primary and unique keys. This is due to the fact that less memory is required (because no ordered indexes are created), and that less CPU must be utilized (because fewer indexes must be read and possibly updated). However, it also means that queries that could otherwise use range scans must be satisfied by other means, which can result in slower selects.

When calculating Cluster memory requirements, you may find useful the ndb_size.pl utility which is available in recent MySQL 5.5 releases. This Perl script connects to a current (non-Cluster) MySQL database and creates a report on how much space that database would require if it used the NDBCLUSTER storage engine. For more information, see Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”.

It is especially important to keep in mind that every NDB Cluster table must have a primary key. The NDB storage engine creates a primary key automatically if none is defined; this primary key is created without USING HASH.

You can determine how much memory is being used for storage of NDB Cluster data and indexes at any given time using the REPORT MEMORYUSAGE command in the ndb_mgm client; see Section 18.5.2, “Commands in the NDB Cluster Management Client”, for more information. In addition, warnings are written to the cluster log when 80% of available DataMemory or IndexMemory is in use, and again when usage reaches 85%, 90%, and so on.

A.10.1 What file systems can I use with NDB Cluster? What about network file systems or network shares?

Generally, any file system that is native to the host operating system should work well with NDB Cluster. If you find that a given file system works particularly well (or not so especially well) with NDB Cluster, we invite you to discuss your findings in the NDB Cluster Forums.

For Windows, we recommend that you use NTFS file systems for NDB Cluster, just as we do for standard MySQL. We do not test NDB Cluster with FAT or VFAT file systems. Because of this, we do not recommend their use with MySQL or NDB Cluster.

NDB Cluster is implemented as a shared-nothing solution; the idea behind this is that the failure of a single piece of hardware should not cause the failure of multiple cluster nodes, or possibly even the failure of the cluster as a whole. For this reason, the use of network shares or network file systems is not supported for NDB Cluster. This also applies to shared storage devices such as SANs.
A.10.12. Can I run NDB Cluster nodes inside virtual machines (such as those created by VMWare, Parallels, or Xen)?

NDB Cluster is supported for use in virtual machines. We currently support and test using Oracle VM.

Some NDB Cluster users have successfully deployed NDB Cluster using other virtualization products; in such cases, Oracle can provide NDB Cluster support, but issues specific to the virtual environment must be referred to that product's vendor.

A.10.13. I am trying to populate an NDB Cluster database. The loading process terminates prematurely and I get an error message like this one:

```
ERROR 1114: The table 'my_cluster_table' is full
```

Why is this happening?

The cause is very likely to be that your setup does not provide sufficient RAM for all table data and all indexes, including the primary key required by the NDB storage engine and automatically created in the event that the table definition does not include the definition of a primary key.

It is also worth noting that all data nodes should have the same amount of RAM, since no data node in a cluster can use more memory than the least amount available to any individual data node. For example, if there are four computers hosting Cluster data nodes, and three of these have 3GB of RAM available to store Cluster data while the remaining data node has only 1GB RAM, then each data node can devote at most 1GB to NDB Cluster data and indexes.

In some cases it is possible to get Table is full errors in MySQL client applications even when `ndb_mgm -e "ALL REPORT MEMORYUSAGE"` shows significant free DataMemory. You can force NDB to create extra partitions for NDB Cluster tables and thus have more memory available for hash indexes by using the MAX_ROWS option for CREATE TABLE. In general, setting MAX_ROWS to twice the number of rows that you expect to store in the table should be sufficient.

For similar reasons, you can also sometimes encounter problems with data node restarts on nodes that are heavily loaded with data. The MinFreePct parameter can help with this issue by reserving a portion (5% by default) of DataMemory and IndexMemory for use in restarts. This reserved memory is not available for storing NDB tables or data.

A.10.14. NDB Cluster uses TCP/IP. Does this mean that I can run it over the Internet, with one or more nodes in remote locations?

It is very unlikely that a cluster would perform reliably under such conditions, as NDB Cluster was designed and implemented with the assumption that it would be run under conditions guaranteeing dedicated high-speed connectivity such as that found in a LAN setting using 100 Mbps or gigabit Ethernet—preferably the latter. We neither test nor warrant its performance using anything slower than this.

Also, it is extremely important to keep in mind that communications between the nodes in an NDB Cluster are not secure; they are neither encrypted nor safeguarded by any other protective mechanism. The most secure configuration for a cluster is in a private network behind a firewall, with no direct access to any Cluster data or management nodes from outside. (For SQL nodes, you should take the same precautions as you would with any other instance of the MySQL server.) For more information, see Section 18.5.11, “NDB Cluster Security Issues”.

A.10.15. Do I have to learn a new programming or query language to use NDB Cluster?
No. Although some specialized commands are used to manage and configure the cluster itself, only standard (My)SQL statements are required for the following operations:

- Creating, altering, and dropping tables
- Inserting, updating, and deleting table data
- Creating, changing, and dropping primary and unique indexes

Some specialized configuration parameters and files are required to set up an NDB Cluster—see Section 18.3.3, “NDB Cluster Configuration Files”, for information about these.

A few simple commands are used in the NDB Cluster management client (**ndb_mgm**) for tasks such as starting and stopping cluster nodes. See Section 18.5.2, “Commands in the NDB Cluster Management Client”.

**A.10.16 What programming languages and APIs are supported by NDB Cluster?**

NDB Cluster supports the same programming APIs and languages as the standard MySQL Server, including ODBC, .Net, the MySQL C API, and numerous drivers for popular scripting languages such as PHP, Perl, and Python. NDB Cluster applications written using these APIs behave similarly to other MySQL applications; they transmit SQL statements to a MySQL Server (in the case of NDB Cluster, an SQL node), and receive responses containing rows of data. For more information about these APIs, see Chapter 23, Connectors and APIs.

NDB Cluster also supports application programming using the NDB API, which provides a low-level C++ interface to NDB Cluster data without needing to go through a MySQL Server. See The NDB API. In addition, many NDBCLUSTER management functions are exposed by the C-language MGM API; see The MGM API, for more information.

NDB Cluster also supports Java application programming using ClusterJ, which supports a domain object model of data using sessions and transactions. See Java and NDB Cluster, for more information.

In addition, NDB Cluster provides support for **memcached**, allowing developers to access data stored in NDB Cluster using the **memcached** interface; for more information, see **ndbmemcache—Memcache API for NDB Cluster**.

**A.10.17 Does NDB Cluster include any management tools?**

NDB Cluster includes a command line client for performing basic management functions. See Section 18.4.5, “**ndb_mgm** — The NDB Cluster Management Client”, and Section 18.5.2, “Commands in the NDB Cluster Management Client”.

NDB Cluster is also supported by MySQL Cluster Manager, a separate product providing an advanced command line interface that can automate many NDB Cluster management tasks such as rolling restarts and configuration changes. For more information about MySQL Cluster Manager, see MySQL™ Cluster Manager 1.4.8 User Manual.

**A.10.18 How do I find out what an error or warning message means when using NDB Cluster?**

There are two ways in which this can be done:

- From within the **mysql** client, use **SHOW ERRORS** or **SHOW WARNINGS** immediately upon being notified of the error or warning condition.
- From a system shell prompt, use **perror --ndb error_code**.
Yes. For tables created with the NDB storage engine, transactions are supported. Currently, NDB Cluster supports only the READ COMMITTED transaction isolation level.

Clustering with MySQL is supported only by the NDB storage engine. That is, in order for a table to be shared between nodes in an NDB Cluster, the table must be created using ENGINE=NDB (or the equivalent option ENGINE=NDBCLUSTER).

It is possible to create tables using other storage engines (such as InnoDB or MyISAM) on a MySQL server being used with an NDB Cluster, but since these tables do not use NDB, they do not participate in clustering; each such table is strictly local to the individual MySQL server instance on which it is created.

All committed transactions are logged. Therefore, although it is possible that some data could be lost in the event of a catastrophe, this should be quite limited. Data loss can be further reduced by minimizing the number of operations per transaction. (It is not a good idea to perform large numbers of operations per transaction in any case.)

FULLTEXT indexing is currently supported only by the MyISAM storage engine. See Section 12.9, "Full-Text Search Functions", for more information.

It is possible but not always advisable. One of the chief reasons to run a cluster is to provide redundancy. To obtain the full benefits of this redundancy, each node should reside on a separate machine. If you place multiple nodes on a single machine and that machine fails, you lose all of those nodes. For this reason, if you do run multiple data nodes on a single machine, it is extremely important that they be set up in such a way that the failure of this machine does not cause the loss of all the data nodes in a given node group.

Given that NDB Cluster can be run on commodity hardware loaded with a low-cost (or even no-cost) operating system, the expense of an extra machine or two is well worth it to safeguard mission-critical data. It also worth noting that the requirements for a cluster host running a management node are minimal. This task can be accomplished with a 300 MHz Pentium or equivalent CPU and sufficient RAM for the operating system, plus a small amount of overhead for the ndb_mgmd and ndb_mgm processes.

It is acceptable to run multiple cluster data nodes on a single host that has multiple CPUs, cores, or both. The NDB Cluster distribution also provides a multithreaded version of the data node binary intended for use on such systems. For more information, see Section 18.4.3, “ndbmt.d — The NDB Cluster Data Node Daemon (Multi-Threaded)”. It is also possible in some cases to run data nodes and SQL nodes concurrently on the same machine; how well such an arrangement performs is dependent on a number of factors such as number of cores and CPUs as well as the amount of disk and memory available to the data node and SQL node processes, and you must take these factors into account when planning such a configuration.
It is possible to add new data nodes to a running NDB Cluster without taking the cluster offline. For more information, see Section 18.5.14, “Adding NDB Cluster Data Nodes Online”.

For other types of NDB Cluster nodes, a rolling restart is all that is required (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).

A.10.25. Are there any limitations that I should be aware of when using NDB Cluster?

Limitations on NDB tables in MySQL NDB Cluster 7.2 include the following:

- Temporary tables are not supported; a CREATE TEMPORARY TABLE statement using ENGINE=NDB or ENGINE=NDBCLUSTER fails with an error.
- The only types of user-defined partitioning supported for NDBCLUSTER tables are KEY and LINEAR KEY. Trying to create an NDB table using any other partitioning type fails with an error.
- FULLTEXT indexes are not supported.
- Index prefixes are not supported. Only complete columns may be indexed.
- Spatial indexes are not supported (although spatial columns can be used). See Section 11.4, “Spatial Data Types”.
- Support for partial transactions and partial rollbacks is comparable to that of other transactional storage engines such as InnoDB that can roll back individual statements.
- The maximum number of attributes allowed per table is 512. Attribute names cannot be any longer than 31 characters. For each table, the maximum combined length of the table and database names is 122 characters.
- The maximum size for a table row is 14 kilobytes, not counting BLOB values.
- There is no set limit for the number of rows per NDB table. Limits on table size depend on a number of factors, in particular on the amount of RAM available to each data node.
- The NDBCLUSTER engine does not support foreign key constraints. As with MyISAM tables, if these are specified in a CREATE TABLE or ALTER TABLE statement, they are ignored.

For a complete listing of limitations in NDB Cluster, see Section 18.1.7, “Known Limitations of NDB Cluster”. See also Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”.

A.10.26. Does NDB Cluster support foreign keys?

NDB Cluster 7.2 does not support foreign key constraints, and ignores foreign keys in CREATE TABLE statements (similarly to how MyISAM treats foreign key syntax).

Foreign key support comparable to that found in the InnoDB storage engine is provided by NDB beginning with NDB 7.3. Applications requiring foreign key support should use NDB Cluster 7.3 or later.

A.10.27. How do I import an existing MySQL database into an NDB Cluster?

You can import databases into NDB Cluster much as you would with any other version of MySQL. Other than the limitations mentioned elsewhere in this FAQ, the only other special requirement is that any tables to be included in the cluster must use the NDB storage engine. This means that the tables must be created with ENGINE=NDB or ENGINE=NDBCLUSTER.
It is also possible to convert existing tables that use other storage engines to NDBCLUSTER using one or more ALTER TABLE statement. However, the definition of the table must be compatible with the NDBCLUSTER storage engine prior to making the conversion. In MySQL 5.5, an additional workaround is also required; see Section 18.1.7, “Known Limitations of NDB Cluster”, for details.

A.10.28 How do NDB Cluster nodes communicate with one another?

Cluster nodes can communicate through any of three different transport mechanisms: TCP/IP, SHM (shared memory), and SCI (Scalable Coherent Interface). Where available, SHM is used by default between nodes residing on the same cluster host; however, this is considered experimental. SCI is a high-speed (1 gigabit per second and higher), high-availability protocol used in building scalable multi-processor systems; it requires special hardware and drivers. See Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”, for more about using SCI as a transport mechanism for NDB Cluster.

A.10.29 What is an arbitrator?

If one or more data nodes in a cluster fail, it is possible that not all cluster data nodes will be able to “see” one another. In fact, it is possible that two sets of data nodes might become isolated from one another in a network partitioning, also known as a “split-brain” scenario. This type of situation is undesirable because each set of data nodes tries to behave as though it is the entire cluster. An arbitrator is required to decide between the competing sets of data nodes.

When all data nodes in at least one node group are alive, network partitioning is not an issue, because no single subset of the cluster can form a functional cluster on its own. The real problem arises when no single node group has all its nodes alive, in which case network partitioning (the “split-brain” scenario) becomes possible. Then an arbitrator is required. All cluster nodes recognize the same node as the arbitrator, which is normally the management server; however, it is possible to configure any of the MySQL Servers in the cluster to act as the arbitrator instead. The arbitrator accepts the first set of cluster nodes to contact it, and tells the remaining set to shut down. Arbitrator selection is controlled by the ArbitrationRank configuration parameter for MySQL Server and management server nodes. You can also use the ArbitrationRank configuration parameter to control the arbitrator selection process. For more information about these parameters, see Section 18.3.3.5, “Defining an NDB Cluster Management Server”.

The role of arbitrator does not in and of itself impose any heavy demands upon the host so designated, and thus the arbitrator host does not need to be particularly fast or to have extra memory especially for this purpose.

A.10.30 What data types are supported by NDB Cluster?

NDB Cluster supports all of the usual MySQL data types, including those associated with MySQL’s spatial extensions; however, the NDB storage engine does not support spatial indexes. (Spatial indexes are supported only by MyISAM; see Section 11.4, “Spatial Data Types”, for more information.) In addition, there are some differences with regard to indexes when used with NDB tables.

**Note**

NDB Cluster Disk Data tables (that is, tables created with TABLESPACE ... STORAGE DISK ENGINE=NDB or TABLESPACE ... STORAGE DISK ENGINE=NDBCLUSTER) have only fixed-width rows. This means that (for example) each Disk Data table record containing a VARCHAR(255) column requires space for 255 characters (as required for the character set and
collation being used for the table), regardless of the actual number of characters stored therein.

See Section 18.1.7, “Known Limitations of NDB Cluster”, for more information about these issues.

**A.10.3** How do I start and stop NDB Cluster?

It is necessary to start each node in the cluster separately, in the following order:

1. Start the management node, using the `ndb_mgmd` command.
   
   You must include the `-f` or `--config-file` option to tell the management node where its configuration file can be found.

2. Start each data node with the `ndbd` command.
   
   Each data node must be started with the `-c` or `--ndb-connectstring` option so that the data node knows how to connect to the management server.

3. Start each MySQL Server (SQL node) using your preferred startup script, such as `mysqld_safe`.
   
   Each MySQL Server must be started with the `--ndbcluster` and `--ndb-connectstring` options. These options cause mysqld to enable NDBCLUSTER storage engine support and how to connect to the management server.

Each of these commands must be run from a system shell on the machine housing the affected node. (You do not have to be physically present at the machine—a remote login shell can be used for this purpose.) You can verify that the cluster is running by starting the NDB management client `ndb_mgm` on the machine housing the management node and issuing the `SHOW` or `ALL STATUS` command.

To shut down a running cluster, issue the command `SHUTDOWN` in the management client. Alternatively, you may enter the following command in a system shell:

```shell
shell> ndb_mgm -e "SHUTDOWN"
```

(The quotation marks in this example are optional, since there are no spaces in the command string following the `-e` option; in addition, the `SHUTDOWN` command, like other management client commands, is not case-sensitive.)

Either of these commands causes the `ndb_mgm`, `ndb_mgm`, and any `ndbd` processes to terminate gracefully. MySQL servers running as SQL nodes can be stopped using `mysqladmin shutdown`.

For more information, see Section 18.5.2, “Commands in the NDB Cluster Management Client”, and Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”.

**A.10.32** What happens to NDB Cluster data when the NDB Cluster is shut down?

The data that was held in memory by the cluster’s data nodes is written to disk, and is reloaded into memory the next time that the cluster is started.

**A.10.33** Is it a good idea to have more than one management node for an NDB Cluster?

It can be helpful as a fail-safe. Only one management node controls the cluster at any given time, but it is possible to configure one management node as primary, and one or more additional management nodes to take over in the event that the primary management node fails.
See Section 18.3.3, “NDB Cluster Configuration Files”, for information on how to configure NDB Cluster management nodes.

A.10.34 Can I mix different kinds of hardware and operating systems in one NDB Cluster?

Yes, as long as all machines and operating systems have the same “endianness” (all big-endian or all little-endian).

It is also possible to use software from different NDB Cluster releases on different nodes. However, we support this only as part of a rolling upgrade procedure (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).

A.10.35 Can I run two data nodes on a single host? Two SQL nodes?

Yes, it is possible to do this. In the case of multiple data nodes, it is advisable (but not required) for each node to use a different data directory. If you want to run multiple SQL nodes on one machine, each instance of mysqld must use a different TCP/IP port.

Running data nodes and SQL nodes together on the same host is possible, but you should be aware that the ndbd (or ndbmtd) and mysqld processes may compete for memory.

A.10.36 Can I use host names with NDB Cluster?

Yes, it is possible to use DNS and DHCP for cluster hosts. However, if your application requires “five nines” availability, you should use fixed (numeric) IP addresses, since making communication between Cluster hosts dependent on services such as DNS and DHCP introduces additional potential points of failure.

A.10.37 Does NDB Cluster support IPv6?

IPv6 is supported for connections between SQL nodes (MySQL servers), but connections between all other types of NDB Cluster nodes must use IPv4.

In practical terms, this means that you can use IPv6 for replication between NDB Clusters, but connections between nodes in the same NDB Cluster must use IPv4. For more information, see Section 18.6.3, “Known Issues in NDB Cluster Replication”.

A.10.38 How do I handle MySQL users in an NDB Cluster having multiple MySQL servers?

MySQL user accounts and privileges are normally not automatically propagated between different MySQL servers accessing the same NDB Cluster. MySQL NDB Cluster provides support for distributed privileges, which you can enable by following a procedure provided in the documentation; see Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”, for more information.

A.10.39 How do I continue to send queries in the event that one of the SQL nodes fails?

MySQL NDB Cluster does not provide any sort of automatic failover between SQL nodes. Your application must be prepared to handle the loss of SQL nodes and to fail over between them.

A.10.40 How do I back up and restore an NDB Cluster?

You can use the NDB Cluster native backup and restore functionality in the NDB management client and the ndb_restore program. See Section 18.5.3, “Online Backup of NDB Cluster”, and Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”.

You can also use the traditional functionality provided for this purpose in mysqldump and the MySQL server. See Section 4.5.4, “mysqldump — A Database Backup Program”, for more information.
A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets

This set of Frequently Asked Questions derives from the experience of MySQL’s Support and Development groups in handling many inquiries about CJK (Chinese-Japanese-Korean) issues.

A.11.1 What CJK character sets are available in MySQL? ................................................................. 3052
A.11.2 I have inserted CJK characters into my table. Why does SELECT display them as “?” characters? .......................................................................................................................... 3054
A.11.3 What problems should I be aware of when working with the Big5 Chinese character set? .... 3056
A.11.4 Why do Japanese character set conversions fail? .............................................................. 3056
A.11.5 What should I do if I want to convert SJIS 81CA to cp932? ............................................... 3057
A.11.6 How does MySQL represent the Yen (¥) sign? ................................................................. 3057
A.11.7 Of what issues should I be aware when working with Korean character sets in MySQL? .... 3057
A.11.8 Why do I get Incorrect string value error messages? ...................................................... 3057
A.11.9 Why does my GUI front end or browser display CJK characters incorrectly in my application using Access, PHP, or another API? ................................................................. 3058
A.11.10 I’ve upgraded to MySQL 5.5. How can I revert to behavior like that in MySQL 4.0 with regard to character sets? ...................................................................................................................... 3059
A.11.11 Why do some LIKE and FULLTEXT searches with CJK characters fail? .......................... 3060
A.11.12 How do I know whether character x is available in all character sets? ............................... 3061
A.11.13 Why do CJK strings sort incorrectly in Unicode? (I) ....................................................... 3062
A.11.14 Why do CJK strings sort incorrectly in Unicode? (II) ..................................................... 3063
A.11.15 Why are my supplementary characters rejected by MySQL? ........................................... 3064
A.11.16 Should “CJK” be “CJKV”? ................................................................................................. 3064
A.11.17 Does MySQL permit CJK characters to be used in database and table names? ............... 3064
A.11.18 Where can I find translations of the MySQL Manual into Chinese, Japanese, and Korean? ... 3064
A.11.19 Where can I get help with CJK and related issues in MySQL? ....................................... 3064

A.11.1 What CJK character sets are available in MySQL?
The list of CJK character sets may vary depending on your MySQL version. For example, the `gb18030` character set is not supported prior to MySQL 5.7.4. However, since the name of the applicable language appears in the `DESCRIPTION` column for every entry in the `INFORMATION_SCHEMA.CHARACTER_SETS` table, you can obtain a current list of all the non-Unicode CJK character sets using this query:

```sql
mysql> SELECT CHARACTER_SET_NAME, DESCRIPTION
FROM INFORMATION_SCHEMA.CHARACTER_SETS
WHERE DESCRIPTION LIKE '%Chin%'
  OR DESCRIPTION LIKE '%Japanese%'
  OR DESCRIPTION LIKE '%Korean%'
ORDER BY CHARACTER_SET_NAME;
```

<table>
<thead>
<tr>
<th>CHARACTER_SET_NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>big5</td>
<td>Big5 Traditional Chinese</td>
</tr>
<tr>
<td>cp932</td>
<td>SJIS for Windows Japanese</td>
</tr>
<tr>
<td>eucjpms</td>
<td>UJIS for Windows Japanese</td>
</tr>
<tr>
<td>euckr</td>
<td>EUC-KR Korean</td>
</tr>
<tr>
<td>gb18030</td>
<td>China National Standard GB18030</td>
</tr>
<tr>
<td>gb2312</td>
<td>GB2312 Simplified Chinese</td>
</tr>
<tr>
<td>gbk</td>
<td>GBK Simplified Chinese</td>
</tr>
<tr>
<td>sjis</td>
<td>Shift-JIS Japanese</td>
</tr>
<tr>
<td>ujis</td>
<td>EUC-JP Japanese</td>
</tr>
</tbody>
</table>

(For more information, see Section 21.2, “The INFORMATION_SCHEMA CHARACTER_SETS Table”.)

MySQL supports three variants of the `GB` (Guojia Biaozhun, or National Standard, or Simplified Chinese) character sets which are official in the People's Republic of China: `gb2312`, `gbk`, and (as of MySQL 5.7.4) `gb18030`.

Sometimes people try to insert `gbk` characters into `gb2312`, and it works most of the time because `gbk` is a superset of `gb2312`. But eventually they try to insert a rarer Chinese character and it does not work. (For an example, see Bug #16072).

Here, we try to clarify exactly what characters are legitimate in `gb2312` or `gbk`, with reference to the official documents. Please check these references before reporting `gb2312` or `gbk` bugs:

- The MySQL `gbk` character set is in reality “Microsoft code page 936”. This differs from the official `gbk` for characters A1A4 (middle dot), A1AA (em dash), A6E0–A6F5, and A8BB–A8C0.

- For a listing of `gbk`/Unicode mappings, see [http://www.unicode.org/Public/MAPPINGS/VENDORS/MICSFT/WINDOWS/CP936.TXT](http://www.unicode.org/Public/MAPPINGS/VENDORS/MICSFT/WINDOWS/CP936.TXT).

It is also possible to store CJK characters in Unicode character sets, although the available collations may not sort characters quite as you expect:

- The `utf8` and `ucs2` character sets support the characters from Unicode Basic Multilingual Plane (BMP). These characters have code point values between `U+0000` and `U+FFFF`.

- The `utf8mb4`, `utf16`, `utf16le`, and `utf32` character sets support BMP characters, as well as supplementary characters that lie outside the BMP. Supplementary characters have code point values between `U+10000` and `U+10FFFF`.

The collation used for a Unicode character set determines the ability to sort (that is, distinguish) characters in the set:
• Collations based on Unicode Collation Algorithm (UCA) 4.0.0 distinguish only BMP characters.
• Collations based on UCA 5.2.0 or 9.0.0 distinguish BMP and supplementary characters.
• Non-UCA collations may not distinguish all Unicode characters. For example, the utf8mb4 default collation is utf8mb4_general_ci, which distinguishes only BMP characters.

Moreover, distinguishing characters is not the same as ordering them per the conventions of a given CJK language. Currently, MySQL has only one CJK-specific UCA collation, gb18030_unicode_520_ci (which requires use of the non-Unicode gb18030 character set).

For information about Unicode collations and their differentiating properties, including collation properties for supplementary characters, see Section 10.10.1, “Unicode Character Sets”.

A.11.2 I have inserted CJK characters into my table. Why does SELECT display them as “?” characters?

This problem is usually due to a setting in MySQL that does not match the settings for the application program or the operating system. Here are some common steps for correcting these types of issues:

• **Be certain of what MySQL version you are using.**

  Use the statement SELECT VERSION(); to determine this.

• **Make sure that the database is actually using the desired character set.**

  People often think that the client character set is always the same as either the server character set or the character set used for display purposes. However, both of these are false assumptions. You can make sure by checking the result of SHOW CREATE TABLE tablename or, better yet, by using this statement:

  ```sql
  SELECT character_set_name, collation_name
  FROM information_schema.columns
  WHERE table_schema = your_database_name
  AND table_name = your_table_name
  AND column_name = your_column_name;
  ```

• **Determine the hexadecimal value of the character or characters that are not being displayed correctly.**

  You can obtain this information for a column column_name in the table table_name using the following query:

  ```sql
  SELECT HEX(column_name)
  FROM table_name;
  ```

  3F is the encoding for the ? character; this means that ? is the character actually stored in the column. This most often happens because of a problem converting a particular character from your client character set to the target character set.
• **Make sure that a round trip is possible. When you select literal (or _introducer hexadecimal-value), do you obtain literal as a result?**

For example, the Japanese Katakana character Pe (ペ) exists in all CJK character sets, and has the code point value (hexadecimal coding) 0x30da. To test a round trip for this character, use this query:

```sql
SELECT 'ペ' AS 'ペ';         /* or SELECT _ucs2 0x30da; */
```

If the result is not also ペ, the round trip failed.

For bug reports regarding such failures, we might ask you to follow up with `SELECT HEX('ペ');`. Then we can determine whether the client encoding is correct.

• **Make sure that the problem is not with the browser or other application, rather than with MySQL.**

Use the `mysql` client program to accomplish this task. If `mysql` displays characters correctly but your application does not, your problem is probably due to system settings.

To determine your settings, use the `SHOW VARIABLES` statement, whose output should resemble what is shown here:

```sql
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | utf8                                   |
| character_set_connection | utf8                                   |
| character_set_database   | latin1                                 |
| character_set_filesystem | binary                                 |
| character_set_results    | utf8                                   |
| character_set_server     | latin1                                 |
| character_set_system     | utf8                                   |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/  |
+--------------------------+----------------------------------------+
```

These are typical character-set settings for an international-oriented client (notice the use of `utf8` Unicode) connected to a server in the West (`latin1` is a West Europe character set).

Although Unicode (usually the `utf8` variant on Unix, and the `ucs2` variant on Windows) is preferable to Latin, it is often not what your operating system utilities support best. Many Windows users find that a Microsoft character set, such as `cp932` for Japanese Windows, is suitable.

If you cannot control the server settings, and you have no idea what setting your underlying computer uses, try changing to a common character set for the country that you’re in (`euckr` = Korea; `gb18030, gb2312 or gbk` = People's Republic of China; `big5` = Taiwan; `sjis, ujis, cp932, or eucjpms` = Japan; `ucs2` or `utf8` = anywhere). Usually it is necessary to change only the client and connection and results settings. The `SET NAMES` statement changes all three at once. For example:

```sql
SET NAMES 'big5';
```

Once the setting is correct, you can make it permanent by editing `my.cnf` or `my.ini`. For example you might add lines looking like these:

```ini
[mysqld]
character-set-server=big5
[client]
```
default-character-set=big5

It is also possible that there are issues with the API configuration setting being used in your application; see Why does my GUI front end or browser not display CJK characters correctly...? for more information.

A.11.3 What problems should I be aware of when working with the Big5 Chinese character set?

MySQL supports the Big5 character set which is common in Hong Kong and Taiwan (Republic of China). The MySQL big5 character set is in reality Microsoft code page 950, which is very similar to the original big5 character set.

A feature request for adding HKSCS extensions has been filed. People who need this extension may find the suggested patch for Bug #13577 to be of interest.

A.11.4 Why do Japanese character set conversions fail?

MySQL supports the sjis, ujis, cp932, and eucjpms character sets, as well as Unicode. A common need is to convert between character sets. For example, there might be a Unix server (typically with sjis or ujis) and a Windows client (typically with cp932).

In the following conversion table, the ucs2 column represents the source, and the sjis, cp932, ujis, and eucjpms columns represent the destinations; that is, the last 4 columns provide the hexadecimal result when we use CONVERT(ucs2) or we assign a ucs2 column containing the value to an sjis, cp932, ujis, or eucjpms column.

<table>
<thead>
<tr>
<th>Character Name</th>
<th>ucs2</th>
<th>sjis</th>
<th>cp932</th>
<th>ujis</th>
<th>eucjpms</th>
</tr>
</thead>
<tbody>
<tr>
<td>BROKEN BAR</td>
<td>00A6</td>
<td>3F</td>
<td>3F</td>
<td>8FA2C3</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH BROKEN BAR</td>
<td>FFE4</td>
<td>3F</td>
<td>FA55</td>
<td>3F</td>
<td>8FA2</td>
</tr>
<tr>
<td>YEN SIGN</td>
<td>00A5</td>
<td>3F</td>
<td>3F</td>
<td>20</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH YEN SIGN</td>
<td>FFE5</td>
<td>818F</td>
<td>818F</td>
<td>A1EF</td>
<td>3F</td>
</tr>
<tr>
<td>TILDE</td>
<td>007E</td>
<td>7E</td>
<td>7E</td>
<td>7E</td>
<td>7E</td>
</tr>
<tr>
<td>OVERLINE</td>
<td>203E</td>
<td>3F</td>
<td>3F</td>
<td>20</td>
<td>3F</td>
</tr>
<tr>
<td>HORIZONTAL BAR</td>
<td>2015</td>
<td>815C</td>
<td>815C</td>
<td>A1BD</td>
<td>A1BD</td>
</tr>
<tr>
<td>EM DASH</td>
<td>2014</td>
<td>3F</td>
<td>3F</td>
<td>3F</td>
<td>3F</td>
</tr>
<tr>
<td>REVERSE SOLIDUS</td>
<td>005C</td>
<td>815F</td>
<td>5C</td>
<td>5C</td>
<td>5C</td>
</tr>
<tr>
<td>FULLWIDTH &quot;&quot;</td>
<td>FF3C</td>
<td>3F</td>
<td>815F</td>
<td>3F</td>
<td>A1C0</td>
</tr>
<tr>
<td>WAVE DASH</td>
<td>301C</td>
<td>8160</td>
<td>3F</td>
<td>A1C1</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH TILDE</td>
<td>FF5E</td>
<td>3F</td>
<td>8160</td>
<td>3F</td>
<td>A1C1</td>
</tr>
<tr>
<td>DOUBLE VERTICAL LINE</td>
<td>2016</td>
<td>8161</td>
<td>3F</td>
<td>A1C2</td>
<td>3F</td>
</tr>
<tr>
<td>PARALLEL TO</td>
<td>2225</td>
<td>3F</td>
<td>8161</td>
<td>3F</td>
<td>A1C2</td>
</tr>
<tr>
<td>MINUS SIGN</td>
<td>2212</td>
<td>817C</td>
<td>3F</td>
<td>A1DD</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH HYPHEN-MINUS</td>
<td>FF0D</td>
<td>3F</td>
<td>817C</td>
<td>3F</td>
<td>A1DD</td>
</tr>
<tr>
<td>CENT SIGN</td>
<td>00A2</td>
<td>8191</td>
<td>3F</td>
<td>A1F1</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH CENT SIGN</td>
<td>FFE0</td>
<td>3F</td>
<td>8191</td>
<td>3F</td>
<td>A1F1</td>
</tr>
<tr>
<td>POUND SIGN</td>
<td>00A3</td>
<td>8192</td>
<td>3F</td>
<td>A1F2</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH POUND SIGN</td>
<td>FFE1</td>
<td>3F</td>
<td>8192</td>
<td>3F</td>
<td>A1F2</td>
</tr>
<tr>
<td>Character Name</td>
<td>ucs2</td>
<td>sjis</td>
<td>cp932</td>
<td>ujis</td>
<td>eucjpms</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------</td>
<td>------</td>
<td>-------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>NOT SIGN</td>
<td>00AC</td>
<td>81CA</td>
<td>3F</td>
<td>A2CC</td>
<td>3F</td>
</tr>
<tr>
<td>FULLWIDTH NOT SIGN</td>
<td>FFE2</td>
<td>3F</td>
<td>81CA</td>
<td>3F</td>
<td>A2CC</td>
</tr>
</tbody>
</table>

Now consider the following portion of the table.

<table>
<thead>
<tr>
<th>ucs2</th>
<th>sjis</th>
<th>cp932</th>
</tr>
</thead>
<tbody>
<tr>
<td>00AC</td>
<td>81CA</td>
<td>3F</td>
</tr>
<tr>
<td>FFE2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This means that MySQL converts the NOT SIGN (Unicode U+00AC) to sjis code point 0x81CA and to cp932 code point 3F. (3F is the question mark (“?”). This is what is always used when the conversion cannot be performed.)

**A.11.5** What should I do if I want to convert SJIS 81CA to cp932?

Our answer is: “?”. There are disadvantages to this, and many people would prefer a “loose” conversion, so that 81CA (NOT SIGN) in sjis becomes 81CA (FULLWIDTH NOT SIGN) in cp932.

**A.11.6** How does MySQL represent the Yen (¥) sign?

A problem arises because some versions of Japanese character sets (both sjis and euc) treat 5C as a reverse solidus (\, also known as a backslash), whereas others treat it as a yen sign (¥).

MySQL follows only one version of the JIS (Japanese Industrial Standards) standard description. In MySQL, \ is always the reverse solidus (\).

**A.11.7** Of what issues should I be aware when working with Korean character sets in MySQL?

In theory, while there have been several versions of the euckr (Extended Unix Code Korea) character set, only one problem has been noted. We use the “ASCII” variant of EUC-KR, in which the code point 0x5c is REVERSE SOLIDUS (\, also known as a backslash), instead of the “KS-Roman” variant of EUC-KR, in which the code point 0x5c is WON SIGN (₩). This means that you cannot convert Unicode U+20A9 to euckr:

```sql
mysql> SELECT
CONVERT('₩' USING euckr) AS euckr,
HEX(CONVERT('₩' USING euckr)) AS hexeuckr;
```

<table>
<thead>
<tr>
<th>euckr</th>
<th>hexeuckr</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>3F</td>
</tr>
</tbody>
</table>

**A.11.8** Why do I get Incorrect string value error messages?

To see the problem, create a table with one Unicode (ucs2) column and one Chinese (gb2312) column.

```sql
mysql> CREATE TABLE ch
(ucs2 CHAR(3) CHARACTER SET ucs2,
 gb2312 CHAR(3) CHARACTER SET gb2312);
```

In nonstrict SQL mode, try to place the rare character ⼤ in both columns.

```sql
mysql> SET sql_mode = '';
mysql> INSERT INTO ch VALUES ('A奄B', 'A奄B');
```
The **INSERT** produces a warning. Use the following statement to see what it is:

```
mysql> SHOW WARNINGS
```

```
******************************** 1. row ***************************
Level: Warning
Code: 1366
Message: Incorrect string value: '\xE6\xB1\x8CB' for column 'gb2312' at row 1
```

So it is a warning about the **gb2312** column only.

```
mysql> SELECT ucs2,HEX(ucs2),gb2312,HEX(gb2312) FROM ch;
```

```
+-------+--------------+--------+-------------+
<table>
<thead>
<tr>
<th>ucs2</th>
<th>HEX(ucs2)</th>
<th>gb2312</th>
<th>HEX(gb2312)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A汌B</td>
<td>00416C4C0042</td>
<td>A?B</td>
<td>413F42</td>
</tr>
</tbody>
</table>
+-------+--------------+--------+-------------+
```

Several things need explanation here:

1. The 汌 character is not in the **gb2312** character set, as described earlier.
2. If you are using an old version of MySQL, you may see a different message.
3. A warning occurs rather than an error because MySQL is not set to use strict SQL mode. In nonstrict mode, MySQL tries to do what it can, to get the best fit, rather than give up. With strict SQL mode, the **Incorrect string value** message occurs as an error rather than a warning, and the **INSERT** fails.

A.11.9 Why does my GUI front end or browser display CJK characters incorrectly in my application using Access, PHP, or another API?

Obtain a direct connection to the server using the **mysql** client, and try the same query there. If **mysql** responds correctly, the trouble may be that your application interface requires initialization. Use **mysql** to tell you what character set or sets it uses with the statement **SHOW VARIABLES LIKE 'char%'**. If you are using Access, you are most likely connecting with Connector/ODBC. In this case, you should check Configuring Connector/ODBC. If, for example, you use **big5**, you would enter **SET NAMES 'big5'**. (In this case, no ; character is required.) If you are using ASP, you might need to add **SET NAMES** in the code. Here is an example that has worked in the past:

```
<% Session.CodePage=0
Dim strConnection
Dim Conn
strConnection="driver={MySQL ODBC 3.51 Driver};server=server;uid=username;" \\
& "pwd=password;database=database;stmt=SET NAMES 'big5';"
Set Conn = Server.CreateObject("ADODB.Connection")
Conn.Open strConnection
%>
```

In much the same way, if you are using any character set other than **latin1** with Connector/NET, you must specify the character set in the connection string. See Connector/NET Connections, for more information.

If you are using PHP, try this:

```
<?php
$link = new mysqli($host, $usr, $pwd, $db);
if( mysqli_connect_errno() )
```

$link->query("SET NAMES 'utf8'");
?>

In this case, we used \texttt{SET NAMES} to change \texttt{character_set_client}, \texttt{character_set_connection}, and \texttt{character_set_results}.

Another issue often encountered in PHP applications has to do with assumptions made by the browser. Sometimes adding or changing a \texttt{<meta>} tag suffices to correct the problem: for example, to insure that the user agent interprets page content as UTF-8, include \texttt{<meta http-equiv="Content-Type" content="text/html; charset=utf-8">} in the \texttt{<head>} section of the HTML page.

If you are using Connector/J, see Using Character Sets and Unicode.

**A.11.10** I've upgraded to MySQL 5.5. How can I revert to behavior like that in MySQL 4.0 with regard to character sets?

In MySQL Version 4.0, there was a single “global” character set for both server and client, and the decision as to which character to use was made by the server administrator. This changed starting with MySQL Version 4.1. What happens now is a “handshake”, as described in Section 10.4, “Connection Character Sets and Collations”:

When a client connects, it sends to the server the name of the character set that it wants to use. The server uses the name to set the \texttt{character_set_client}, \texttt{character_set_results}, and \texttt{character_set_connection} system variables. In effect, the server performs a \texttt{SET NAMES} operation using the character set name.

The effect of this is that you cannot control the client character set by starting \texttt{mysqld} with \texttt{--character-set-server=utf8}. However, some Asian customers prefer the MySQL 4.0 behavior. To make it possible to retain this behavior, we added a \texttt{mysqld} switch, \texttt{--character-set-client-handshake}, which can be turned off with \texttt{--skip-character-set-client-handshake}. If you start \texttt{mysqld} with \texttt{--skip-character-set-client-handshake}, then, when a client connects, it sends to the server the name of the character set that it wants to use. However, the server ignores this request from the client.

By way of example, suppose that your favorite server character set is \texttt{latin1}. Suppose further that the client uses \texttt{utf8} because this is what the client’s operating system supports. Start the server with \texttt{latin1} as its default character set:

\begin{verbatim}
mysqld --character-set-server=latin1
\end{verbatim}

And then start the client with the default character set \texttt{utf8}:

\begin{verbatim}
mysql --default-character-set=utf8
\end{verbatim}

The resulting settings can be seen by viewing the output of \texttt{SHOW VARIABLES}:

\begin{verbatim}
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | utf8                                   |
| character_set_connection | utf8                                   |
+--------------------------+----------------------------------------+
\end{verbatim}
Now stop the client, and stop the server using `mysqladmin`. Then start the server again, but this time tell it to skip the handshake like so:

```
mysqld --character-set-server=utf8 --skip-character-set-client-handshake
```

Start the client with `utf8` once again as the default character set, then display the resulting settings:

```
mysql> SHOW VARIABLES LIKE 'char%';
```

As you can see by comparing the differing results from `SHOW VARIABLES`, the server ignores the client's initial settings if the `--skip-character-set-client-handshake` option is used.

### A.11.1 Why do some LIKE and FULLTEXT searches with CJK characters fail?

For **LIKE** searches, there is a very simple problem with binary string column types such as `BINARY` and `BLOB`: we must know where characters end. With multibyte character sets, different characters might have different octet lengths. For example, in `utf8`, `A` requires one byte but `ペ` requires three bytes, as shown here:

<table>
<thead>
<tr>
<th>OCTET_LENGTH(_utf8 'A')</th>
<th>OCTET_LENGTH(_utf8 'ペ')</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

If we do not know where the first character in a string ends, we do not know where the second character begins, in which case even very simple searches such as **LIKE 'A%'** fail. The solution is to use a nonbinary string column type defined to have the proper CJK character set. For example:

```
mycol TEXT CHARACTER SET sjis
```

Alternatively, convert to a CJK character set before comparing.

This is one reason why MySQL cannot permit encodings of nonexistent characters. If it is not strict about rejecting bad input, it has no way of knowing where characters end.

For **FULLTEXT** searches, we must know where words begin and end. With Western languages, this is rarely a problem because most (if not all) of these use an easy-to-identify word boundary: the space character. However, this is not usually the case with Asian writing. We could use arbitrary halfway measures, like assuming that all Han characters represent words, or (for Japanese) depending on changes from Katakana to Hiragana due to grammatical endings. However, the only sure solution requires a comprehensive word list, which means that we would have to include a dictionary in the server for each Asian language supported. This is simply not feasible.
A.11.12 How do I know whether character x is available in all character sets?

The majority of simplified Chinese and basic nonhalfwidth Japanese Kana characters appear in all CJK character sets. The following stored procedure accepts a UCS–2 Unicode character, converts it to other character sets, and displays the results in hexadecimal.

```sql
CREATE PROCEDURE p_convert(ucs2_char CHAR(1) CHARACTER SET ucs2)
BEGIN
CREATE TABLE tj
    (ucs2 CHAR(1) character set ucs2,
     utf8 CHAR(1) character set utf8,
     big5 CHAR(1) character set big5,
     cp932 CHAR(1) character set cp932,
     eucjpms CHAR(1) character set eucjpms,
     euckr CHAR(1) character set euckr,
     gb2312 CHAR(1) character set gb2312,
     gbk CHAR(1) character set gbk,
     sjis CHAR(1) character set sjis,
     ujis CHAR(1) character set ujis);
INSERT INTO tj (ucs2) VALUES (ucs2_char);
UPDATE tj SET utf8=ucs2,
     big5=ucs2,
     cp932=ucs2,
     eucjpms=ucs2,
     euckr=ucs2,
     gb2312=ucs2,
     gbk=ucs2,
     sjis=ucs2,
     ujis=ucs2;
/* If there are conversion problems, UPDATE produces warnings. */
SELECT hex(ucs2) AS ucs2,
     hex(utf8) AS utf8,
     hex(big5) AS big5,
     hex(cp932) AS cp932,
     hex(eucjpms) AS eucjpms,
     hex(euckr) AS euckr,
     hex(gb2312) AS gb2312,
     hex(gbk) AS gbk,
     hex(sjis) AS sjis,
     hex(ujis) AS ujis
FROM tj;
DROP TABLE tj;
END;
DELIMITER ;
```

The input can be any single ucs2 character, or it can be the code value (hexadecimal representation) of that character. For example, from Unicode's list of ucs2 encodings and names (http://www.unicode.org/Public/UNIDATA/UnicodeData.txt), we know that the Katakana character Pe appears in all CJK character sets, and that its code value is X'30DA'. If we use this value as the argument to p_convert(), the result is as shown here:

```
mysql> CALL p_convert(X'30DA');
+----------+----------+----------+----------+----------+-------+-------+----------+----------+
| ucs2     | utf8     | big5     | cp932    | eucjpms  | euckr | gb2312 | gbk      | sjis     | ujis     |
|----------+----------+----------+----------+----------+-------+-------+----------+----------+----------+
| 3061     | 3061     | 3061     | 3061     | 3061     |       |       | 3061     |         |          |
+----------+----------+----------+----------+----------+-------+-------+----------+----------+----------+
```
Since none of the column values is 3F (that is, the question mark character, ?), we know that every conversion worked.

**A.11.13** Why do CJK strings sort incorrectly in Unicode? (I)

**Note**

The CJK sorting problems described here can occur for MySQL versions prior to MySQL 8.0. As of MySQL 8.0, they can be solved by using the utf8mb4 character set and the utf8mb4_ja_0900_as_cs collation.

Sometimes people observe that the result of a utf8_unicode_ci or ucs2_unicode_ci search, or of an ORDER BY sort is not what they think a native would expect. Although we never rule out the possibility that there is a bug, we have found in the past that many people do not correctly read the standard table of weights for the Unicode Collation Algorithm. MySQL uses the tables found under http://www.unicode.org/Public/UCA/:

- **UCA 4.0.0 table**: http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt
  - This includes xxx_unicode_ci collations with no version number in the collation name.
- **UCA 5.2.0 table**: http://www.unicode.org/Public/UCA/5.2.0/allkeys.txt
  - This includes collations with _520_ in the collation name.
- **UCA 9.0.0 table**: http://www.unicode.org/Public/UCA/9.0.0/allkeys.txt
  - This includes collations with _0900_ in the collation name.

To handle newer UCA versions, we create new collations. We are very wary about changing ordering of existing collations because that affects indexes, which can bring about situations such as that reported in Bug #16526, illustrated as follows:

```
mysql> CREATE TABLE tj (s1 CHAR(1) CHARACTER SET utf8 COLLATE utf8_unicode_ci);
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO tj VALUES ('が'),('か');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM tj WHERE s1 = 'か';
+-----+
| s1  |
| が  |
| か  |
+-----+

The character in the first result row is not the one that we searched for. Why did MySQL retrieve it? First we look for the Unicode code point value, which is possible by reading the hexadecimal number for the ucs2 version of the characters:

```
mysql> SELECT s1, HEX(CONVERT(s1 USING ucs2)) FROM tj;
+-----+-----------------------------+
| s1  | HEX(CONVERT(s1 USING ucs2)) |
| が   | 304C                        |
| か   |                             |
+-----+-----------------------------+
```

Now we search for 304B and 304C in the 4.0.0 allkeys table, and find these lines:

<table>
<thead>
<tr>
<th>か</th>
<th>304B</th>
</tr>
</thead>
</table>

The official Unicode names (following the “#” mark) tell us the Japanese syllabary (Hiragana), the informal classification (letter, digit, or punctuation mark), and the Western identifier (KA or GA, which happen to be voiced and unvoiced components of the same letter pair). More importantly, the primary weight (the first hexadecimal number inside the square brackets) is \texttt{1E57} on both lines. For comparisons in both searching and sorting, MySQL pays attention to the primary weight only, ignoring all the other numbers. This means that we are sorting が and か correctly according to the Unicode specification. If we wanted to distinguish them, we’d have to use a non-UCA (Unicode Collation Algorithm) collation (\texttt{utf8_bin} or \texttt{utf8_general_ci}), or to compare the \texttt{HEX()} values, or use \texttt{ORDER BY CONVERT(s1 USING sjis)}. Being correct “according to Unicode” is not enough, of course: the person who submitted the bug was equally correct. To solve this, we need another collation for Japanese according to the JIS X 4061 standard, in which voiced/unvoiced letter pairs like KA/GA are distinguishable for ordering purposes.

**Why do CJK strings sort incorrectly in Unicode? (II)**

**Note**

The CJK sorting problems described here can occur for MySQL versions prior to MySQL 8.0. As of MySQL 8.0, they can be solved by using the \texttt{utf8mb4} character set and the \texttt{utf8mb4_ja_0900_as_cs} collation.

If you are using Unicode (\texttt{ucs2} or \texttt{utf8}), and you know what the Unicode sort order is (see Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”), but MySQL still seems to sort your table incorrectly, first verify the character set in the table definition:

```sql
mysql> SHOW CREATE TABLE t\G
```

Since the character set for the column \texttt{s1} appears to be correct (\texttt{ucs2}), check what information the \texttt{INFORMATION_SCHEMA.COLUMNS} table can provide about this column:

```sql
mysql> SELECT COLUMN_NAME, CHARACTER_SET_NAME, COLLATION_NAME FROM INFORMATION_SCHEMA.COLUMNS WHERE COLUMN_NAME = 's1' AND TABLE_NAME = 't';
```

(See Section 21.5, “The INFORMATION_SCHEMA COLUMNS Table”, for more information.)

You can see that the collation is \texttt{ucs2_general_ci} instead of \texttt{ucs2_unicode_ci}. The reason why this is so can be found using \texttt{SHOW CHARACTER SET}, as shown here:

```sql
mysql> SHOW CHARSET LIKE 'ucs2%';
```
<table>
<thead>
<tr>
<th>Charset</th>
<th>Description</th>
<th>Default collation</th>
<th>Maxlen</th>
</tr>
</thead>
<tbody>
<tr>
<td>ucs2</td>
<td>UCS-2 Unicode</td>
<td>ucs2_general_ci</td>
<td>2</td>
</tr>
</tbody>
</table>

For `ucs2` and `utf8`, the default collation is “general”. To specify a Unicode UCA collation, use `COLLATE ucs2_unicode_ci`, as shown in the preceding item.

A.11.15 Why are my supplementary characters rejected by MySQL?

Supplementary characters lie outside the Unicode Basic Multilingual Plane / Plane 0. BMP characters have code point values between \u0000 and \uFFFF. Supplementary characters have code point values between \u10000 and \u10FFFF.

To store supplementary characters, you must use a character set that permits them:

- The `utf8` and `ucs2` character sets support BMP characters only.

  The `utf8` character set permits only UTF-8 characters that take up to three bytes. This has led to reports such as that found in Bug #12600, which we rejected as “not a bug”. With `utf8`, MySQL must truncate an input string when it encounters bytes that it does not understand. Otherwise, it is unknown how long the bad multibyte character is.

  One possible workaround is to use `ucs2` instead of `utf8`, in which case the “bad” characters are changed to question marks. However, no truncation takes place. You can also change the data type to `BLOB` or `BINARY`, which perform no validity checking.

- The `utf8mb4`, `utf16`, `utf16le`, and `utf32` character sets support BMP characters, as well as supplementary characters outside the BMP.

A.11.16 Should “CJK” be “CJKV”?

No. The term “CJKV” (Chinese Japanese Korean Vietnamese) refers to Vietnamese character sets which contain Han (originally Chinese) characters. MySQL supports the modern Vietnamese script with Western characters, but does not support the old Vietnamese script using Han characters.

A.11.17 Does MySQL permit CJK characters to be used in database and table names?

Yes.

A.11.18 Where can I find translations of the MySQL Manual into Chinese, Japanese, and Korean?

The Japanese translation of the MySQL 5.6 manual can be downloaded from https://dev.mysql.com/doc/.

A.11.19 Where can I get help with CJK and related issues in MySQL?

The following resources are available:

- A listing of MySQL user groups can be found at https://wikis.oracle.com/display/mysql/List+of+MySQL+User+Groups.

- View feature requests relating to character set issues at http://tinyurl.com/y6xcuf.

A.12 MySQL 5.5 FAQ: Connectors & APIs

For common questions, issues, and answers relating to the MySQL Connectors and other APIs, see the following areas of the Manual:

- Section 23.7.20, “C API Common Issues”
- Common Problems with MySQL and PHP
- Connector/ODBC Notes and Tips
- Connector/NET Programming
- MySQL Connector/J 5.1 Developer Guide

A.13 MySQL 5.5 FAQ: C API, libmysql

Frequently asked questions about MySQL C API and libmysql.

A.13.1 What is “MySQL Native C API”? What are typical benefits and use cases?

libmysql is a C-based API that you can use in C applications to connect with the MySQL database server. It is also itself used as the foundation for drivers for standard database APIs like ODBC, Perl's DBI, and Python's DB API.

A.13.2 Which version of libmysql should I use?

For MySQL 8.0, 5.7, 5.6, and 5.5, we recommend libmysql 8.0.

A.13.3 What if I want to use the “NoSQL” X DevAPI?

For C-language and X DevApi Document Store for MySQL 8.0, we recommend MySQL Connector/C++. Connector/C++ 8.0 has compatible C headers. (This is not applicable to MySQL 5.7 or before.)

A.13.4 How do I download libmysql?

- Linux: The Client Utilities Package is available from the MySQL Community Server download page.
- Repos: The Client Utilities Package is available from the Yum, APT, SuSE repositories.
- Windows: The Client Utilities Package is available from Windows Installer.

A.13.5 Where is the documentation?

See Section 23.7, “MySQL C API”.

A.13.6 How do I report bugs?

Please report any bugs or inconsistencies you observe to our Bugs Database. Select the C API Client as shown.
A.13.7 Is it possible to compile the library myself?

Yes, you can download the libmysqlclient source code and compile it on your own. Here's an example:

```bash
$ git clone --depth 1 https://github.com/mysql/mysql-server
$ cd mysql-server
$ mkdir build
$ cd build
$ cmake .. -GNinja -DDOWNLOAD_BOOST=1 -DWITH_BOOST=/tmp -DCMAKE_BUILD_TYPE=Release -DWITHOUT_SERVER=ON -DWITH_SSL=system
$ ninja libmysqlclient.a
$ ls -la archive_output_directory/libmysqlclient.a
-rw-rw-r-- 1 kg kg 8,5M wrz 5 04:57 archive_output_directory/libmysqlclient.a
```

Note

This example uses https://ninja-build.org/ as a build system instead of make.

A.14 MySQL 5.5 FAQ: Replication

In the following section, we provide answers to questions that are most frequently asked about MySQL Replication.

A.14.1 Must the slave be connected to the master all the time? .......................................................... 3066
A.14.2 Must I enable networking on my master and slave to enable replication? ................................. 3067
A.14.3 How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave? .................................................. 3067
A.14.4 How do I force the master to block updates until the slave catches up? .................................... 3067
A.14.5 What issues should I be aware of when setting up two-way replication? .................................. 3067
A.14.6 How can I use replication to improve performance of my system? .............................................. 3068
A.14.7 What should I do to prepare client code in my own applications to use performance-enhancing replication? .................................................................................. 3068
A.14.8 When and how much can MySQL replication improve the performance of my system? .............. 3068
A.14.9 How can I use replication to provide redundancy or high availability? ........................................ 3069
A.14.10 How do I tell whether a master server is using statement-based or row-based binary logging format? ........................................................................................................... 3069
A.14.11 How do I tell a slave to use row-based replication? ................................................................. 3069
A.14.12 How do I prevent GRANT and REVOKE statements from replicating to slave machines? ........ 3069
A.14.13 Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on OS X and Windows)? ................................................................. 3070
A.14.14 Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)? .................................................. 3070

A.14.1 Must the slave be connected to the master all the time?

No, it does not. The slave can go down or stay disconnected for hours or even days, and then reconnect and catch up on updates. For example, you can set up a master/slave relationship over a dial-up link where the link is up only sporadically and for short periods of time. The implication of this is that, at any given time, the slave is not guaranteed to be in synchonry with the master unless you take some special measures.

To ensure that catchup can occur for a slave that has been disconnected, you must not remove binary log files from the master that contain information that has not yet been replicated to the
slaves. Asynchronous replication can work only if the slave is able to continue reading the binary log from the point where it last read events.

**A.14.2** Must I enable networking on my master and slave to enable replication?

Yes, networking must be enabled on the master and slave. If networking is not enabled, the slave cannot connect to the master and transfer the binary log. Verify that the `skip_networking` system variable has not been enabled in the configuration file for either server.

**A.14.3** How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave?

Check the `Seconds_Behind_Master` column in the output from `SHOW SLAVE STATUS`. See Section 17.1.4.1, “Checking Replication Status”.

When the slave SQL thread executes an event read from the master, it modifies its own time to the event timestamp. (This is why `TIMESTAMP` is well replicated.) In the `Time` column in the output of `SHOW PROCESSLIST`, the number of seconds displayed for the slave SQL thread is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. You can use this to determine the date of the last replicated event. Note that if your slave has been disconnected from the master for one hour, and then reconnects, you may immediately see large `Time` values such as 3600 for the slave SQL thread in `SHOW PROCESSLIST`. This is because the slave is executing statements that are one hour old. See Section 17.2.1, “Replication Implementation Details”.

**A.14.4** How do I force the master to block updates until the slave catches up?

Use the following procedure:

1. On the master, execute these statements:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   mysql> SHOW MASTER STATUS;
   ```

   Record the replication coordinates (the current binary log file name and position) from the output of the `SHOW` statement.

2. On the slave, issue the following statement, where the arguments to the `MASTER_POS_WAIT()` function are the replication coordinate values obtained in the previous step:

   ```
   mysql> SELECT MASTER_POS_WAIT('log_name', log_pos);
   ```

   The `SELECT` statement blocks until the slave reaches the specified log file and position. At that point, the slave is in synchrony with the master and the statement returns.

3. On the master, issue the following statement to enable the master to begin processing updates again:

   ```
   mysql> UNLOCK TABLES;
   ```

**A.14.5** What issues should I be aware of when setting up two-way replication?

MySQL replication currently does not support any locking protocol between master and slave to guarantee the atomicity of a distributed (cross-server) update. In other words, it is possible for client A to make an update to co-master 1, and in the meantime, before it propagates to co-master 2, client B could make an update to co-master 2 that makes the update of client A work differently than it did on co-master 1. Thus, when the update of client A makes it to co-master 2, it produces tables that are different from what you have on co-master 1, even after all the updates from co-master
2 have also propagated. This means that you should not chain two servers together in a two-way replication relationship unless you are sure that your updates can safely happen in any order, or unless you take care of mis-ordered updates somehow in the client code.

You should also realize that two-way replication actually does not improve performance very much (if at all) as far as updates are concerned. Each server must do the same number of updates, just as you would have a single server do. The only difference is that there is a little less lock contention because the updates originating on another server are serialized in one slave thread. Even this benefit might be offset by network delays.

**A.14.6 How can I use replication to improve performance of my system?**

Set up one server as the master and direct all writes to it. Then configure as many slaves as you have the budget and rackspace for, and distribute the reads among the master and the slaves. You can also start the slaves with the --skip-innodb option, enable the low_priority_updates system variable, and set the delay_key_write system variable to ALL to get speed improvements on the slave end. In this case, the slave uses nontransactional MyISAM tables instead of InnoDB tables to get more speed by eliminating transactional overhead.

**A.14.7 What should I do to prepare client code in my own applications to use performance-enhancing replication?**

See the guide to using replication as a scale-out solution, Section 17.3.3, “Using Replication for Scale-Out”.

**A.14.8 When and how much can MySQL replication improve the performance of my system?**

MySQL replication is most beneficial for a system that processes frequent reads and infrequent writes. In theory, by using a single-master/multiple-slave setup, you can scale the system by adding more slaves until you either run out of network bandwidth, or your update load grows to the point that the master cannot handle it.

To determine how many slaves you can use before the added benefits begin to level out, and how much you can improve performance of your site, you must know your query patterns, and determine empirically by benchmarking the relationship between the throughput for reads and writes on a typical master and a typical slave. The example here shows a rather simplified calculation of what you can get with replication for a hypothetical system. Let reads and writes denote the number of reads and writes per second, respectively.

Let's say that system load consists of 10% writes and 90% reads, and we have determined by benchmarking that reads is 1200 - 2 * writes. In other words, the system can do 1,200 reads per second with no writes, the average write is twice as slow as the average read, and the relationship is linear. Suppose that the master and each slave have the same capacity, and that we have one master and \( N \) slaves. Then we have for each server (master or slave):

\[
\text{reads} = 1200 - 2 \times \text{writes}
\]

\[
\text{reads} = 9 \times \text{writes} / (N + 1) \text{ (reads are split, but writes replicated to all slaves)}
\]

\[
9 \times \text{writes} / (N + 1) + 2 \times \text{writes} = 1200
\]

\[
\text{writes} = 1200 / (2 + 9/(N + 1))
\]

The last equation indicates the maximum number of writes for \( N \) slaves, given a maximum possible read rate of 1,200 per second and a ratio of nine reads per write.

This analysis yields the following conclusions:
If \( N = 0 \) (which means we have no replication), our system can handle about \( \frac{1200}{11} = 109 \) writes per second.

If \( N = 1 \), we get up to 184 writes per second.

If \( N = 8 \), we get up to 400 writes per second.

If \( N = 17 \), we get up to 480 writes per second.

Eventually, as \( N \) approaches infinity (and our budget negative infinity), we can get very close to 600 writes per second, increasing system throughput about 5.5 times. However, with only eight servers, we increase it nearly four times.

These computations assume infinite network bandwidth and neglect several other factors that could be significant on your system. In many cases, you may not be able to perform a computation similar to the one just shown that accurately predicts what will happen on your system if you add \( N \) replication slaves. However, answering the following questions should help you decide whether and by how much replication will improve the performance of your system:

- What is the read/write ratio on your system?
- How much more write load can one server handle if you reduce the reads?
- For how many slaves do you have bandwidth available on your network?

**A.14.9 How can I use replication to provide redundancy or high availability?**

How you implement redundancy is entirely dependent on your application and circumstances. High-availability solutions (with automatic failover) require active monitoring and either custom scripts or third party tools to provide the failover support from the original MySQL server to the slave.

To handle the process manually, you should be able to switch from a failed master to a pre-configured slave by altering your application to talk to the new server or by adjusting the DNS for the MySQL server from the failed server to the new server.

For more information and some example solutions, see Section 17.3.6, “Switching Masters During Failover”.

**A.14.10 How do I tell whether a master server is using statement-based or row-based binary logging format?**

Check the value of the `binlog_format` system variable:

```sql
mysql> SHOW VARIABLES LIKE 'binlog_format';
```

The value shown will be one of `STATEMENT`, `ROW`, or `MIXED`. For `MIXED` mode, statement-based logging is used by default but replication switches automatically to row-based logging under certain conditions, such as unsafe statements. For information about when this may occur, see Section 5.4.4.3, “Mixed Binary Logging Format”.

**A.14.11 How do I tell a slave to use row-based replication?**

Slaves automatically know which format to use.

**A.14.12 How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines?**

Start the server with the `--replicate-wild-ignore-table=mysql.%` option to ignore replication for tables in the `mysql` database.
**A.14.1** Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on OS X and Windows)?

Yes.

**A.14.2** Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)?

Yes.

---

## A.15 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool

**A.15.1** What is the Thread Pool and what problem does it solve?

The MySQL Thread Pool is a MySQL server plugin that extends the default connection-handling capabilities of the MySQL server to limit the number of concurrently executing statements/queries and transactions to ensure that each has sufficient CPU and memory resources to fulfill its task. For MySQL 5.5, the Thread Pool plugin is included in MySQL Enterprise Edition, a commercial product.

The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. The Thread Pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The Thread Pool plugin increases server performance by efficiently managing statement execution threads for large numbers of client connections, especially on modern multi-CPU/Core systems.

For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

**A.15.2** How does the Thread Pool limit and manage concurrent sessions and transactions for optimal performance and throughput?

The Thread Pool uses a “divide and conquer” approach to limiting and balancing concurrency. Unlike the default connection handling of the MySQL Server, the Thread Pool separates connections and threads, so there is no fixed relationship between connections and the threads that execute statements received from those connections. The Thread Pool then manages client connections within configurable thread groups, where they are prioritized and queued based on the nature of the work they were submitted to accomplish.

For more information, see Section 5.5.3.3, “Thread Pool Operation”.

**A.15.3** How is the Thread Pool different from the client side Connection Pool?

The MySQL Connection Pool operates on the client side to ensure that a MySQL client does not constantly connect to and disconnect from the MySQL server. It is designed to cache idle connections in the MySQL client for use by other users as they are needed. This minimizes the overhead and expense of establishing and tearing down connections as queries are submitted to the MySQL server. The MySQL Connection Pool has no visibility as to the query handling capabilities or load of the back-end MySQL server. By contrast, the Thread Pool operates on the MySQL server side and is designed to manage the execution of inbound concurrent connections...
and queries as they are received from the client connections accessing the back-end MySQL database. Because of the separation of duties, the MySQL Connection Pool and Thread Pool are orthogonal and can be used independent of each other.

MySQL Connection Pooling via the MySQL Connectors is covered in Chapter 23, Connectors and APIs.

A.15.4 When should I use the Thread Pool?

There are a few rules of thumb to consider for optimal Thread Pool use cases:

The MySQL Threads_running variable keeps track of the number of concurrent statements currently executing in the MySQL Server. If this variable consistently exceeds a region where the server won’t operate optimally (usually going beyond 40 for InnoDB workloads), the Thread Pool will be beneficial, especially in extreme parallel overload situations.

If you are using the innodb_thread_concurrency to limit the number of concurrently executing statements, you will find the Thread Pool solves the same problem, only better, by assigning connections to thread groups, then queuing executions based on transactional content, user defined designations, and so forth.

Lastly, if your workload comprises mainly short queries, the Thread Pool will be beneficial.

To learn more, see Section 5.5.3.4, “Thread Pool Tuning”.

A.15.5 Are there recommended Thread Pool configurations?

The Thread Pool has a number of user case driven configuration parameters that affect its performance. To learn about these and tips on tuning, see Section 5.5.3.4, “Thread Pool Tuning”.

A.16 MySQL 5.5 FAQ: InnoDB Change Buffer

A.16.1 What types of operations modify secondary indexes and result in change buffering? ............... 3071
A.16.2 What is the benefit of the InnoDB change buffer? ................................................................. 3071
A.16.3 Does the change buffer support other types of indexes? .................................................. 3071
A.16.4 How much space does InnoDB use for the change buffer? .............................................. 3072
A.16.5 How do I determine the current size of the change buffer? .............................................. 3072
A.16.6 When does change buffer merging occur? .......................................................... 3072
A.16.7 When is the change buffer flushed? .......................................................... 3072
A.16.8 When should the change buffer be used? .......................................................... 3072
A.16.9 When should the change buffer not be used? .......................................................... 3073
A.16.10 Where can I find additional information about the change buffer? ................................ 3073

A.16.1 What types of operations modify secondary indexes and result in change buffering?

INSERT, UPDATE, and DELETE operations can modify secondary indexes. If an affected index page is not in the buffer pool, the changes can be buffered in the change buffer.

A.16.2 What is the benefit of the InnoDB change buffer?

Buffering secondary index changes when secondary index pages are not in the buffer pool avoids expensive random access I/O operations that would be required to immediately read in affected index pages from disk. Buffered changes can be applied later, in batches, as pages are read into the buffer pool by other read operations.

A.16.3 Does the change buffer support other types of indexes?
No. The change buffer only supports secondary indexes. Clustered indexes, full-text indexes, and spatial indexes are not supported. Full-text indexes have their own caching mechanism.

A.16.4 How much space does InnoDB use for the change buffer?

The maximum size of the on-disk change buffer in the system tablespace is 1/3 of the InnoDB buffer pool size. InnoDB does not buffer an operation if it would cause the on-disk change buffer to exceed this limit.

Change buffer pages are not required to persist in the buffer pool and may be evicted by LRU operations.

A.16.5 How do I determine the current size of the change buffer?

The current size of the change buffer is reported by `SHOW ENGINE INNODB STATUS \G`, under the `INSERT BUFFER AND ADAPTIVE HASH INDEX` heading. For example:

```
INSERT BUFFER AND ADAPTIVE HASH INDEX
-----------------------------
Ibuf: size 1, free list len 0, seg size 2, 0 merges
```

Relevant data points include:

- **size**: The number of pages used within the change buffer. Change buffer size is equal to `seg size - (1 + free list len)`. The 1 + value represents the change buffer header page.
- **seg size**: The size of the change buffer, in pages.

For information about monitoring change buffer status, see Section 14.8.2, “Change Buffer”.

A.16.6 When does change buffer merging occur?

- When a page is read into the buffer pool, buffered changes are merged upon completion of the read, before the page is made available.
- Change buffer merging is performed as a background task. The `innodb_io_capacity` parameter sets an upper limit on the I/O activity performed by InnoDB background tasks such as merging data from the change buffer.
- A change buffer merge is performed during crash recovery. Changes are applied from the change buffer (in the system tablespace) to leaf pages of secondary indexes as index pages are read into the buffer pool.
- The change buffer is fully durable and will survive a system crash. Upon restart, change buffer merge operations resume as part of normal operations.
- A full merge of the change buffer can be forced as part of a slow server shutdown using `--innodb-fast-shutdown=0`.

A.16.7 When is the change buffer flushed?

Updated pages are flushed by the same flushing mechanism that flushes the other pages that occupy the buffer pool.

A.16.8 When should the change buffer be used?

The change buffer is a feature designed to reduce random I/O to secondary indexes as indexes grow larger and no longer fit in the InnoDB buffer pool. Generally, the change buffer should be used
when the entire data set does not fit into the buffer pool, when there is substantial DML activity that modifies secondary index pages, or when there are lots of secondary indexes that are regularly changed by DML activity.

**A.16.9 When should the change buffer not be used?**

You might consider disabling the change buffer if the entire data set fits within the InnoDB buffer pool, if you have relatively few secondary indexes, or if you are using solid-state storage, where random reads are about as fast as sequential reads. Before making configuration changes, it is recommended that you run tests using a representative workload to determine if disabling the change buffer provides any benefit.

**A.16.10 Where can I find additional information about the change buffer?**

See Section 14.8.2, “Change Buffer”.

### A.17 MySQL 5.5 FAQ: Virtualization Support

**A.17.1 Is MySQL supported on virtualized environments such as Oracle VM, VMWare, Docker, Microsoft Hyper-V, or others?**

MySQL is supported on virtualized environments, but is certified only for Oracle VM. Contact Oracle Support for more information.

Be aware of potential problems when using virtualization software. The usual ones are related to performance, performance degradations, slowness, or unpredictability of disk, I/O, network, and memory.
Appendix B Errors, Error Codes, and Common Problems

Table of Contents

B.1 Error Message Sources and Components ............................................................ 3075
B.2 Error Information Interfaces .................................................................................. 3077
B.3 Error Message Reference ....................................................................................... 3078
   B.3.1 Server Error Message Reference ................................................................. 3079
   B.3.2 Client Error Message Reference ................................................................. 3134
   B.3.3 Global Error Message Reference ................................................................. 3139
B.4 Problems and Common Errors .............................................................................. 3141
   B.4.1 How to Determine What Is Causing a Problem ............................................ 3141
   B.4.2 Common Errors When Using MySQL Programs ......................................... 3143
   B.4.3 Administration-Related Issues ..................................................................... 3157
   B.4.4 Query-Related Issues ................................................................................. 3165
   B.4.5 Optimizer-Related Issues ........................................................................... 3173
   B.4.6 Table Definition-Related Issues ................................................................. 3173
   B.4.7 Known Issues in MySQL ............................................................................ 3174

This appendix describes the types of error information MySQL provides and how to obtain information about them. It also lists the error messages that the MySQL server and MySQL client programs generate. The final section is for troubleshooting. It describes common problems and errors that may occur and potential resolutions.

Additional Resources

Other sections that discuss error-related topics include:

- Information about configuring where and how the server writes the error log: Section 5.4.2, “The Error Log”
- Information about the character set used for error messages: Section 10.6, “Error Message Character Set”
- Information about the language used for error messages: Section 10.12, “Setting the Error Message Language”
- Information about errors related to InnoDB: Section 14.23.4, “InnoDB Error Handling”

B.1 Error Message Sources and Components

This section discusses how error messages originate within MySQL and the components they contain.

- Error Message Sources
- Error Message Components

Error Message Sources

Error messages can originate on the server side or the client side:

- On the server side, error messages may occur during the startup and shutdown processes, as a result of issues that occur during SQL statement execution, and so forth.
Error Message Components

- The MySQL server writes some error messages to its error log. These indicate issues of interest to database administrators or that require DBA action.

- The server sends other error messages to client programs. These indicate issues pertaining only to a particular client. The MySQL client library takes errors received from the server and makes them available to the host client program.

- Client-side error messages are generated from within the MySQL client library, usually involving problems communicating with the server.

Example server-side error messages written to the error log:

- This message produced during the startup process provides a status or progress indicator:

  ```
  181009 7:43:37 [Note] Event Scheduler: scheduler thread started with id 1
  ```

- This message indicates an issue that requires DBA action:

  ```
  181009 3:20:39 [ERROR] Can't open the mysql.plugin table. Please run mysql_upgrade to create it.
  ```

Example server-side error message sent to client programs, as displayed by the `mysql` client:

```
mysql> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
``` 

Example client-side error message originating from within the client library, as displayed by the `mysql` client:

```
shell> mysql -h no-such-host
ERROR 2005 (HY000): Unknown MySQL server host 'no-such-host' (0)
``` 

Whether an error originates from within the client library or is received from the server, a MySQL client program may respond in varying ways. As just illustrated, the client may display the error message so the user can take corrective measures. The client may instead internally attempt to resolve or retry a failed operation, or take other action.

Error Message Components

When an error occurs, error information includes several components: an error code, SQLSTATE value, and message string. These components have the following characteristics:

- Error code: This value is numeric. It is MySQL-specific and is not portable to other database systems.
  - Each error number has a corresponding symbolic value. Examples:
    - The symbol for server error number 1146 is `ER_NO_SUCH_TABLE`.
    - The symbol for client error number 2005 is `ER_UNKNOWN_HOST`.
  - Error codes are stable across General Availability (GA) releases of a given MySQL series. Before a series reaches GA status, new codes may still be under development and are subject to change.

- SQLSTATE value: This value is a five-character string (for example, '42S02'). SQLSTATE values are taken from ANSI SQL and ODBC and are more standardized than the numeric error codes. The first two characters of an SQLSTATE value indicate the error class:
  - Class = '00' indicates success.
Error Information Interfaces

- Class = '01' indicates a warning.

- Class = '02' indicates “not found.” This is relevant within the context of cursors and is used to
  control what happens when a cursor reaches the end of a data set. This condition also occurs for
  \texttt{SELECT ... INTO var\_list} statements that retrieve no rows.

- Class > '02' indicates an exception.

For server-side errors, not all MySQL error numbers have corresponding SQLSTATE values. In these
cases, 'HY000' (general error) is used.

For client-side errors, the SQLSTATE value is always 'HY000' (general error), so it is not meaningful
for distinguishing one client error from another.

- Message string: This string provides a textual description of the error.

B.2 Error Information Interfaces

Error messages can originate on the server side or the client side, and each error message includes an
error code, SQLSTATE value, and message string, as described in Section B.1, “Error Message Sources
and Components”. For lists of server-side, client-side, and global (shared between server and clients)
errors, see Section B.3, “Error Message Reference”.

For error checking from within programs, use error code numbers or symbols, not error message strings.
Message strings do not change often, but it is possible. Also, if the database administrator changes the
language setting, that affects the language of message strings; see Section 10.12, “Setting the Error
Message Language”.

Error information in MySQL is available in the server error log, at the SQL level, from within client
programs, and at the command line.

- Error Log
- SQL Error Message Interface
- Client Error Message Interface
- Command-Line Error Message Interface

Error Log

On the server side, some messages are intended for the error log. For information about configuring where
and how the server writes the log, see Section 5.4.2, “The Error Log”.

Other server error messages are intended to be sent to client programs and are available as described in
Client Error Message Interface.

SQL Error Message Interface

At the SQL level, there are several sources of error information in MySQL:

- SQL statement warning and error information is available through the \texttt{SHOW WARNINGS} and \texttt{SHOW ERRORS} statements. The \texttt{warning\_count} system variable indicates the number of errors, warnings,
  and notes (with notes excluded if the \texttt{sql\_notes} system variable is disabled). The \texttt{error\_count}
  system variable indicates the number of errors. Its value excludes warnings and notes.
Client Error Message Interface

Client programs receive errors from two sources:

- Errors that originate on the client side from within the MySQL client library.
- Errors that originate on the server side and are sent to the client by the server. These are received within the client library, which makes them available to the host client program.

Regardless of whether an error originates from within the client library or is received from the server, a MySQL client program obtains the error code, SQLSTATE value, message string, and other related information by calling C API functions in the client library:

- `mysql_errno()` returns the MySQL error code.
- `mysql_sqlstate()` returns the SQLSTATE value.
- `mysql_error()` returns the message string.
- `mysql_stmt_errno()`, `mysql_stmt_sqlstate()`, and `mysql_stmt_error()` are the corresponding error functions for prepared statements.
- `mysql_warning_count()` returns the number of errors, warnings, and notes for the most recent statement.

For descriptions of the client library error functions, see Section 23.7, “MySQL C API”.

A MySQL client program may respond to an error in varying ways. The client may display the error message so the user can take corrective measures, internally attempt to resolve or retry a failed operation, or take other action. For example, (using the `mysql` client), a failure to connect to the server might result in this message:

```
shell> mysql -h no-such-host
ERROR 2005 (HY000): Unknown MySQL server host 'no-such-host' (0)
```

Command-Line Error Message Interface

The `perror` program provides information from the command line about error numbers. See Section 4.8.1, “perror — Display MySQL Error Message Information”.

```
shell> perror 1231
MySQL error code 1231 (ER_WRONG_VALUE_FOR_VAR): Variable '%-.64s' can't be set to the value of '%-.200s'
```

B.3 Error Message Reference

This section provides a reference for the various types of error messages in MySQL:

- Error messages produced only by the server: Section B.3.1, “Server Error Message Reference”
- Error messages that originate only from within the MySQL client library: Section B.3.2, “Client Error Message Reference”
B.3.1 Server Error Message Reference

The MySQL server writes some error messages to its error log, and sends others to client programs.

Example server-side error messages written to the error log:

```
181009 7:43:37 [Note] Event Scheduler: scheduler thread started with id 1
181009 3:20:39 [ERROR] Can't open the mysql.plugin table. Please run mysql_upgrade to create it.
```

Example server-side error message sent to client programs, as displayed by the `mysql` client:

```
mysql> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Each server error message includes an error code, SQLSTATE value, and message string, as described in Section B.1, “Error Message Sources and Components”. These components are available as described in Section B.2, “Error Information Interfaces”.

In addition to the errors in the following list, the server can also produce error messages that have error codes in the range from 1 to 999. See Section B.3.3, “Global Error Message Reference”

- **Error number:** `1000`; Symbol: `ER_HASHCHK`; SQLSTATE: `HY000`
  
  Message: hashchk
  
  Unused.

- **Error number:** `1001`; Symbol: `ER_NISAMCHK`; SQLSTATE: `HY000`
  
  Message: isamchk
  
  Unused.

- **Error number:** `1002`; Symbol: `ER_NO`; SQLSTATE: `HY000`
  
  Message: NO
  
  Used in the construction of other messages.

- **Error number:** `1003`; Symbol: `ER_YES`; SQLSTATE: `HY000`
  
  Message: YES
  
  Used in the construction of other messages.
  
  Extended `EXPLAIN` format generates Note messages. `ER_YES` is used in the Code column for these messages in subsequent `SHOW WARNINGS` output.

- **Error number:** `1004`; Symbol: `ER_CANT_CREATE_FILE`; SQLSTATE: `HY000`
  
  Message: Can't create file '%s' (errno: %d)
  
  Occurs for failure to create or copy a file needed for some operation.
  
  Possible causes: Permissions problem for source file; destination file already exists but is not writeable.
Server Error Message Reference

• Error number: 1005; Symbol: ER_CANT_CREATE_TABLE; SQLSTATE: HY000
  Message: Can't create table '%s' (errno: %d)
  InnoDB reports this error when a table cannot be created. If the error message refers to error 150, table creation failed because a foreign key constraint was not correctly formed. If the error message refers to error −1, table creation probably failed because the table includes a column name that matched the name of an internal InnoDB table.

• Error number: 1006; Symbol: ER_CANT_CREATE_DB; SQLSTATE: HY000
  Message: Can't create database '%s' (errno: %d)

• Error number: 1007; Symbol: ER_DB_CREATE_EXISTS; SQLSTATE: HY000
  Message: Can't create database '%s'; database exists
  An attempt to create a database failed because the database already exists.
  Drop the database first if you really want to replace an existing database, or add an IF NOT EXISTS clause to the CREATE DATABASE statement if to retain an existing database without having the statement produce an error.

• Error number: 1008; Symbol: ER_DB_DROP_EXISTS; SQLSTATE: HY000
  Message: Can't drop database '%s'; database doesn't exist

• Error number: 1009; Symbol: ER_DB_DROP_DELETE; SQLSTATE: HY000
  Message: Error dropping database (can't delete '%s', errno: %d)

• Error number: 1010; Symbol: ER_DB_DROP_RMDIR; SQLSTATE: HY000
  Message: Error dropping database (can't rmdir '%s', errno: %d)

• Error number: 1011; Symbol: ER_CANT_DELETE_FILE; SQLSTATE: HY000
  Message: Error on delete of '%s' (errno: %d)

• Error number: 1012; Symbol: ER_CANT_FIND_SYSTEM_REC; SQLSTATE: HY000
  Message: Can't read record in system table
  Returned by InnoDB for attempts to access InnoDB INFORMATION_SCHEMA tables when InnoDB is unavailable.

• Error number: 1013; Symbol: ER_CANT_GET_STAT; SQLSTATE: HY000
  Message: Can't get status of '%s' (errno: %d)

• Error number: 1014; Symbol: ER_CANT_GET_WD; SQLSTATE: HY000
  Message: Can't get working directory (errno: %d)

• Error number: 1015; Symbol: ER_CANT_LOCK; SQLSTATE: HY000
  Message: Can't lock file (errno: %d)

• Error number: 1016; Symbol: ER_CANT_OPEN_FILE; SQLSTATE: HY000
Message: Can't open file: '%s' (errno: %d)

*InnoDB* reports this error when the table from the *InnoDB data files* cannot be found, even though the `.frm` file for the table exists. See Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”.

- **Error number: 1017; Symbol: ER_FILE_NOT_FOUND; SQLSTATE: HY000**
  Message: Can't find file: '%s' (errno: %d)
- **Error number: 1018; Symbol: ER_CANT_READ_DIR; SQLSTATE: HY000**
  Message: Can't read dir of '%s' (errno: %d)
- **Error number: 1019; Symbol: ER_CANT_SET_WD; SQLSTATE: HY000**
  Message: Can't change dir to '%s' (errno: %d)
- **Error number: 1020; Symbol: ER_CHECKREAD; SQLSTATE: HY000**
  Message: Record has changed since last read in table '%s'
- **Error number: 1021; Symbol: ER_DISK_FULL; SQLSTATE: HY000**
  Message: Disk full (%s); waiting for someone to free some space...
- **Error number: 1022; Symbol: ER_DUP_KEY; SQLSTATE: 23000**
  Message: Can't write; duplicate key in table '%s'
- **Error number: 1023; Symbol: ER_ERROR_ON_CLOSE; SQLSTATE: HY000**
  Message: Error on close of '%s' (errno: %d)
- **Error number: 1024; Symbol: ER_ERROR_ON_READ; SQLSTATE: HY000**
  Message: Error reading file '%s' (errno: %d)
- **Error number: 1025; Symbol: ER_ERROR_ON_RENAME; SQLSTATE: HY000**
  Message: Error on rename of '%s' to '%s' (errno: %d)

*InnoDB* reports this error if you attempt to drop the last index that can enforce a particular referential constraint. As of MySQL 5.5, this error message is replaced by ERROR 1553.

- **Error number: 1026; Symbol: ER_ERROR_ON_WRITE; SQLSTATE: HY000**
  Message: Error writing file '%s' (errno: %d)
- **Error number: 1027; Symbol: ER_FILE_USED; SQLSTATE: HY000**
  Message: '%s' is locked against change
- **Error number: 1028; Symbol: ER_FILSORT_ABORT; SQLSTATE: HY000**
  Message: Sort aborted
- **Error number: 1029; Symbol: ER_FORM_NOT_FOUND; SQLSTATE: HY000**
  Message: View '%s' doesn't exist for '%s'
• Error number: **1030**; Symbol: **ER_GET_ERRNO**; SQLSTATE: **HY000**
Message: Got error %d from storage engine
Check the %d value to see what the OS error means. For example, 28 indicates that you have run out of disk space.

• Error number: **1031**; Symbol: **ER_ILLEGAL_HA**; SQLSTATE: **HY000**
Message: Table storage engine for '%s' doesn't have this option

• Error number: **1032**; Symbol: **ER_KEY_NOT_FOUND**; SQLSTATE: **HY000**
Message: Can't find record in '%s'

• Error number: **1033**; Symbol: **ER_NOT_FORM_FILE**; SQLSTATE: **HY000**
Message: Incorrect information in file: '%s'

• Error number: **1034**; Symbol: **ER_NOT_KEYFILE**; SQLSTATE: **HY000**
Message: Incorrect key file for table '%s'; try to repair it

• Error number: **1035**; Symbol: **ER_OLD_KEYFILE**; SQLSTATE: **HY000**
Message: Old key file for table '%s'; repair it!

• Error number: **1036**; Symbol: **ER_OPEN_AS_READONLY**; SQLSTATE: **HY000**
Message: Table '%s' is read only

• Error number: **1037**; Symbol: **ER_OUTOFMEMORY**; SQLSTATE: **HY001**
Message: Out of memory; restart server and try again (needed %d bytes)

• Error number: **1038**; Symbol: **ER_OUT_OF_SORTMEMORY**; SQLSTATE: **HY001**
Message: Out of sort memory, consider increasing server sort buffer size

• Error number: **1039**; Symbol: **ER_UNEXPECTED_EOF**; SQLSTATE: **HY000**
Message: Unexpected EOF found when reading file '%s' (errno: %d)

• Error number: **1040**; Symbol: **ER_CON_COUNT_ERROR**; SQLSTATE: **08004**
Message: Too many connections

• Error number: **1041**; Symbol: **ER_OUT_OF_RESOURCES**; SQLSTATE: **HY000**
Message: Out of memory; check if mysqld or some other process uses all available memory; if not, you may have to use 'ulimit' to allow mysqld to use more memory or you can add more swap space

• Error number: **1042**; Symbol: **ER_BAD_HOST_ERROR**; SQLSTATE: **08S01**
Message: Can't get hostname for your address

• Error number: **1043**; Symbol: **ER_HANDSHAKE_ERROR**; SQLSTATE: **08S01**
Message: Bad handshake
• Error number: 1044; Symbol: ER_DBACCESS_DENIED_ERROR; SQLSTATE: 42000
  Message: Access denied for user '%s'@'%s' to database '%s'
• Error number: 1045; Symbol: ER_ACCESS_DENIED_ERROR; SQLSTATE: 28000
  Message: Access denied for user '%s'@'%s' (using password: %s)
• Error number: 1046; Symbol: ER_NO_DB_ERROR; SQLSTATE: 3D000
  Message: No database selected
• Error number: 1047; Symbol: ER_UNKNOWN_COM_ERROR; SQLSTATE: 08S01
  Message: Unknown command
• Error number: 1048; Symbol: ER_BAD_NULL_ERROR; SQLSTATE: 23000
  Message: Column '%s' cannot be null
• Error number: 1049; Symbol: ER_BAD_DB_ERROR; SQLSTATE: 42000
  Message: Unknown database '%s'
• Error number: 1050; Symbol: ER_TABLE_EXISTS_ERROR; SQLSTATE: 42S01
  Message: Table '%s' already exists
• Error number: 1051; Symbol: ER_BAD_TABLE_ERROR; SQLSTATE: 42S02
  Message: Unknown table '%s'
• Error number: 1052; Symbol: ER_NON_UNIQ_ERROR; SQLSTATE: 23000
  Message: Column '%s' in %s is ambiguous

  %s = column name
  %s = location of column (for example, "field list")

  Likely cause: A column appears in a query without appropriate qualification, such as in a select list or ON clause.

  Examples:
  
  mysql> SELECT i FROM t INNER JOIN t AS t2;
  ERROR 1052 (23000): Column 'i' in field list is ambiguous
  
  mysql> SELECT * FROM t LEFT JOIN t AS t2 ON i = i;
  ERROR 1052 (23000): Column 'i' in on clause is ambiguous

  Resolution:
  
  • Qualify the column with the appropriate table name:
    
    mysql> SELECT t2.i FROM t INNER JOIN t AS t2;
  
  • Modify the query to avoid the need for qualification:
    
    mysql> SELECT * FROM t LEFT JOIN t AS t2 USING (i);
  
  • Error number: 1053; Symbol: ER_SERVER_SHUTDOWN; SQLSTATE: 08S01
Message: Server shutdown in progress

• Error number: 1054; Symbol: ER_BAD_FIELD_ERROR; SQLSTATE: 42S22
  Message: Unknown column '%s' in '%s'

• Error number: 1055; Symbol: ER_WRONG_FIELD_WITH_GROUP; SQLSTATE: 42000
  Message: '%s' isn't in GROUP BY

• Error number: 1056; Symbol: ER_WRONG_GROUP_FIELD; SQLSTATE: 42000
  Message: Can't group on '%s'

• Error number: 1057; Symbol: ER_WRONG_SUM_SELECT; SQLSTATE: 42000
  Message: Statement has sum functions and columns in same statement

• Error number: 1058; Symbol: ER_WRONG_VALUE_COUNT; SQLSTATE: 21S01
  Message: Column count doesn't match value count

• Error number: 1059; Symbol: ER_TOO_LONG_IDENT; SQLSTATE: 42000
  Message: Identifier name '%s' is too long

• Error number: 1060; Symbol: ER_DUP_FIELDNAME; SQLSTATE: 42S21
  Message: Duplicate column name '%s'

• Error number: 1061; Symbol: ER_DUP_KEYNAME; SQLSTATE: 42000
  Message: Duplicate key name '%s'

• Error number: 1062; Symbol: ER_DUP_ENTRY; SQLSTATE: 23000
  Message: Duplicate entry '%s' for key %d

  The message returned with this error uses the format string for ER_DUP_ENTRY_WITH_KEY_NAME.

• Error number: 1063; Symbol: ER_WRONG_FIELD_SPEC; SQLSTATE: 42000
  Message: Incorrect column specifier for column '%s'

• Error number: 1064; Symbol: ER_PARSE_ERROR; SQLSTATE: 42000
  Message: %s near '%s' at line %d

• Error number: 1065; Symbol: ER_EMPTY_QUERY; SQLSTATE: 42000
  Message: Query was empty

• Error number: 1066; Symbol: ER_NONUNIQ_TABLE; SQLSTATE: 42000
  Message: Not unique table/alias: '%s'

• Error number: 1067; Symbol: ER_INVALID_DEFAULT; SQLSTATE: 42000
  Message: Invalid default value for '%s'
• Error number: 1068; Symbol: ER_MULTIPLE_PRI_KEY; SQLSTATE: 42000
  Message: Multiple primary key defined

• Error number: 1069; Symbol: ER_TOO_MANY_KEYS; SQLSTATE: 42000
  Message: Too many keys specified; max %d keys allowed

• Error number: 1070; Symbol: ER_TOO_MANY_KEY_PARTS; SQLSTATE: 42000
  Message: Too many key parts specified; max %d parts allowed

• Error number: 1071; Symbol: ER_TOO_LONG_KEY; SQLSTATE: 42000
  Message: Specified key was too long; max key length is %d bytes

• Error number: 1072; Symbol: ER_KEY_COLUMN_DOES_NOT_EXITS; SQLSTATE: 42000
  Message: Key column '%s' doesn't exist in table

• Error number: 1073; Symbol: ER_BLOB_USED_AS_KEY; SQLSTATE: 42000
  Message: BLOB column '%s' can't be used in key specification with the used table type

• Error number: 1074; Symbol: ER_TOO_BIG_FIELDLENGTH; SQLSTATE: 42000
  Message: Column length too big for column '%s' (max = %lu); use BLOB or TEXT instead

• Error number: 1075; Symbol: ER_WRONG_AUTO_KEY; SQLSTATE: 42000
  Message: Incorrect table definition; there can be only one auto column and it must be defined as a key

• Error number: 1076; Symbol: ER_READY; SQLSTATE: HY000
  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d

• Error number: 1077; Symbol: ER_NORMAL_SHUTDOWN; SQLSTATE: HY000
  Message: %s: Normal shutdown

• Error number: 1078; Symbol: ER_GOT_SIGNAL; SQLSTATE: HY000
  Message: %s: Got signal %d. Aborting!

• Error number: 1079; Symbol: ER_SHUTDOWN_COMPLETE; SQLSTATE: HY000
  Message: %s: Shutdown complete

• Error number: 1080; Symbol: ER_FORCING_CLOSE; SQLSTATE: 08S01
  Message: %s: Forcing close of thread %ld user: '%s'

• Error number: 1081; Symbol: ER_IPSOCK_ERROR; SQLSTATE: 08S01
  Message: Can't create IP socket

• Error number: 1082; Symbol: ER_NO_SUCH_INDEX; SQLSTATE: 42S12
  Message: Table '%s' has no index like the one used in CREATE INDEX; recreate the table

• Error number: 1083; Symbol: ER_WRONG_FIELD_TERMINATORS; SQLSTATE: 42000
Message: Field separator argument is not what is expected; check the manual

- **Error number:** 1084; **Symbol:** ER_BLOBS_AND_NO_TERMINATED; **SQLSTATE:** 42000
  Message: You can't use fixed rowlength with BLOBs; please use 'fields terminated by'

- **Error number:** 1085; **Symbol:** ER_TEXTFILE_NOT_READABLE; **SQLSTATE:** HY000
  Message: The file '%s' must be in the database directory or be readable by all

- **Error number:** 1086; **Symbol:** ER_FILE_EXISTS_ERROR; **SQLSTATE:** HY000
  Message: File '%s' already exists

- **Error number:** 1087; **Symbol:** ER_LOAD_INFO; **SQLSTATE:** HY000
  Message: Records: %ld Deleted: %ld Skipped: %ld Warnings: %ld

- **Error number:** 1088; **Symbol:** ER_ALTER_INFO; **SQLSTATE:** HY000
  Message: Records: %ld Duplicates: %ld

- **Error number:** 1089; **Symbol:** ER_WRONG_SUB_KEY; **SQLSTATE:** HY000
  Message: Incorrect prefix key; the used key part isn't a string, the used length is longer than the key part, or the storage engine doesn't support unique prefix keys

- **Error number:** 1090; **Symbol:** ER_CANT_REMOVE_ALL_FIELDS; **SQLSTATE:** 42000
  Message: You can't delete all columns with ALTER TABLE; use DROP TABLE instead

- **Error number:** 1091; **Symbol:** ER_CANT_DROP_FIELD_OR_KEY; **SQLSTATE:** 42000
  Message: Can't DROP '%s'; check that column/key exists

- **Error number:** 1092; **Symbol:** ER_INSERT_INFO; **SQLSTATE:** HY000
  Message: Records: %ld Duplicates: %ld Warnings: %ld

- **Error number:** 1093; **Symbol:** ER_UPDATE_TABLE_USED; **SQLSTATE:** HY000
  Message: You can't specify target table '%s' for update in FROM clause
  This error occurs for attempts to select from and modify the same table within a single statement. See Section 13.2.10.12, “Restrictions on Subqueries”.

- **Error number:** 1094; **Symbol:** ER_NO_SUCH_THREAD; **SQLSTATE:** HY000
  Message: Unknown thread id: %lu

- **Error number:** 1095; **Symbol:** ER_KILL_DENIED_ERROR; **SQLSTATE:** HY000
  Message: You are not owner of thread %lu

- **Error number:** 1096; **Symbol:** ER_NO_TABLES_USED; **SQLSTATE:** HY000
  Message: No tables used

- **Error number:** 1097; **Symbol:** ER_TOO_BIG_SET; **SQLSTATE:** HY000
Server Error Message Reference

Message: Too many strings for column %s and SET
• Error number: 1098; Symbol: ER_NO_UNIQUE_LOGFILE; SQLSTATE: HY000
  Message: Can't generate a unique log-filename %s.(1-999)
• Error number: 1099; Symbol: ER_TABLE_NOT_LOCKED_FOR_WRITE; SQLSTATE: HY000
  Message: Table '%s' was locked with a READ lock and can't be updated
• Error number: 1100; Symbol: ER_TABLE_NOT_LOCKED; SQLSTATE: HY000
  Message: Table '%s' was not locked with LOCK TABLES
• Error number: 1101; Symbol: ER_BLOB_CANT_HAVE_DEFAULT; SQLSTATE: 42000
  Message: BLOB/TEXT column '%s' can't have a default value
• Error number: 1102; Symbol: ER_WRONG_DB_NAME; SQLSTATE: 42000
  Message: Incorrect database name '%s'
• Error number: 1103; Symbol: ER_WRONG_TABLE_NAME; SQLSTATE: 42000
  Message: Incorrect table name '%s'
• Error number: 1104; Symbol: ER_TOO_BIG_SELECT; SQLSTATE: 42000
  Message: The SELECT would examine more than MAX_JOIN_SIZE rows; check your WHERE and use SET SQL_BIG_SELECTS=1 or SET MAX_JOIN_SIZE=# if the SELECT is okay
• Error number: 1105; Symbol: ER_UNKNOWN_ERROR; SQLSTATE: HY000
  Message: Unknown error
• Error number: 1106; Symbol: ER_UNKNOWN_PROCEDURE; SQLSTATE: 42000
  Message: Unknown procedure '%s'
• Error number: 1107; Symbol: ER_WRONG_PARAMCOUNT_TOPROCEDURE; SQLSTATE: 42000
  Message: Incorrect parameter count to procedure '%s'
• Error number: 1108; Symbol: ER_WRONGPARAMETERS_TOPROCEDURE; SQLSTATE: HY000
  Message: Incorrect parameters to procedure '%s'
• Error number: 1109; Symbol: ER_UNKNOWN_TABLE; SQLSTATE: 42S02
  Message: Unknown table '%s' in %s
• Error number: 1110; Symbol: ER_FIELD_SPECIFIED_TWICE; SQLSTATE: 42000
  Message: Column '%s' specified twice
• Error number: 1111; Symbol: ER_INVALID_GROUP_FUNC_USE; SQLSTATE: HY000
  Message: Invalid use of group function
• Error number: 1112; Symbol: ER_UNSUPPORTED_EXTENSION; SQLSTATE: 42000
Message: Table '%s' uses an extension that doesn't exist in this MySQL version

•   Error number: 1113; Symbol: ER_TABLE_MUST_HAVE_COLUMNS; SQLSTATE: 42000

Message: A table must have at least 1 column

•   Error number: 1114; Symbol: ER_RECORD_FILE_FULL; SQLSTATE: HY000

Message: The table '%s' is full

InnoDB reports this error when the system tablespace runs out of free space. Reconfigure the system tablespace to add a new data file.

•   Error number: 1115; Symbol: ER_UNKNOWN_CHARACTER_SET; SQLSTATE: 42000

Message: Unknown character set: '%s'

•   Error number: 1116; Symbol: ER_TOO_MANY_TABLES; SQLSTATE: HY000

Message: Too many tables; MySQL can only use %d tables in a join

•   Error number: 1117; Symbol: ER_TOO_MANY_FIELDS; SQLSTATE: HY000

Message: Too many columns

•   Error number: 1118; Symbol: ER_TOO_BIG_ROWSIZE; SQLSTATE: 42000

Message: Row size too large. The maximum row size for the used table type, not counting BLOBs, is %ld. You have to change some columns to TEXT or BLOBs

•   Error number: 1119; Symbol: ER_STACK_OVERRUN; SQLSTATE: HY000

Message: Thread stack overrun: Used: %ld of a %ld stack. Use 'mysqld --thread_stack=#' to specify a bigger stack if needed

•   Error number: 1120; Symbol: ER_WRONG_OUTER_JOIN; SQLSTATE: 42000

Message: Cross dependency found in OUTER JOIN; examine your ON conditions

•   Error number: 1121; Symbol: ER_NULL_COLUMN_IN_INDEX; SQLSTATE: 42000

Message: Table handler doesn't support NULL in given index. Please change column '%s' to be NOT NULL or use another handler

•   Error number: 1122; Symbol: ER_CANT_FIND_UDF; SQLSTATE: HY000

Message: Can't load function '%s'

•   Error number: 1123; Symbol: ER_CANT_INITIALIZE_UDF; SQLSTATE: HY000

Message: Can't initialize function '%s'; %s

•   Error number: 1124; Symbol: ER_UDF_NO_PATHS; SQLSTATE: HY000

Message: No paths allowed for shared library

•   Error number: 1125; Symbol: ER_UDF_EXISTS; SQLSTATE: HY000

Message: Function '%s' already exists
Server Error Message Reference

- Error number: 1126; Symbol: ER_CANT_OPEN_LIBRARY; SQLSTATE: HY000
  Message: Can't open shared library '%s' (errno: %d %s)

- Error number: 1127; Symbol: ER_CANT_FIND_DL_ENTRY; SQLSTATE: HY000
  Message: Can't find symbol '%s' in library

- Error number: 1128; Symbol: ER_FUNCTION_NOT_DEFINED; SQLSTATE: HY000
  Message: Function '%s' is not defined

- Error number: 1129; Symbol: ER_HOST_IS_BLOCKED; SQLSTATE: HY000
  Message: Host '%s' is blocked because of many connection errors; unblock with 'mysqladmin flush-hosts'

- Error number: 1130; Symbol: ER_HOST_NOT_PRIVILEGED; SQLSTATE: HY000
  Message: Host '%s' is not allowed to connect to this MySQL server

- Error number: 1131; Symbol: ER_PASSWORD_ANONYMOUS_USER; SQLSTATE: 42000
  Message: You are using MySQL as an anonymous user and anonymous users are not allowed to change passwords

- Error number: 1132; Symbol: ER_PASSWORD_NOT_ALLOWED; SQLSTATE: 42000
  Message: You must have privileges to update tables in the mysql database to be able to change passwords for others

- Error number: 1133; Symbol: ER_PASSWORD_NO_MATCH; SQLSTATE: 42000
  Message: Can't find any matching row in the user table

- Error number: 1134; Symbol: ER_UPDATE_INFO; SQLSTATE: HY000
  Message: Rows matched: %ld Changed: %ld Warnings: %ld

- Error number: 1135; Symbol: ER_CANT_CREATE_THREAD; SQLSTATE: HY000
  Message: Can't create a new thread (errno %d); if you are not out of available memory, you can consult the manual for a possible OS-dependent bug

- Error number: 1136; Symbol: ER_WRONG_VALUE_COUNT_ON_ROW; SQLSTATE: 21S01
  Message: Column count doesn't match value count at row %ld

- Error number: 1137; Symbol: ER_CANT_REOPEN_TABLE; SQLSTATE: HY000
  Message: Can't reopen table: '%s'

- Error number: 1138; Symbol: ER_INVALID_USE_OF_NULL; SQLSTATE: 22004
  Message: Invalid use of NULL value

- Error number: 1139; Symbol: ER_REGEXP_ERROR; SQLSTATE: 42000
  Message: Got error '%s' from regexp
• Error number: 1140; Symbol: ER_MIX_OF_GROUP_FUNC_AND_FIELDS; SQLSTATE: 42000
Message: Mixing of GROUP columns (MIN(), MAX(), COUNT(), ...) with no GROUP columns is illegal if there is no GROUP BY clause

• Error number: 1141; Symbol: ER_NONEXISTING_GRANT; SQLSTATE: 42000
Message: There is no such grant defined for user '%s' on host '%s'

• Error number: 1142; Symbol: ER_TABLEACCESS_DENIED_ERROR; SQLSTATE: 42000
Message: %s command denied to user '%s'@'%s' for table '%s'

• Error number: 1143; Symbol: ER_COLUMNACCESS_DENIED_ERROR; SQLSTATE: 42000
Message: %s command denied to user '%s'@'%s' for column '%s' in table '%s'

• Error number: 1144; Symbol: ER_ILLEGAL_GRANT_FOR_TABLE; SQLSTATE: 42000
Message: Illegal GRANT/REVOKE command; please consult the manual to see which privileges can be used

• Error number: 1145; Symbol: ER_GRANT_WRONG_HOST_OR_USER; SQLSTATE: 42000
Message: The host or user argument to GRANT is too long

• Error number: 1146; Symbol: ER_NO_SUCH_TABLE; SQLSTATE: 42S02
Message: Table '%s.%s' doesn't exist

• Error number: 1147; Symbol: ER_NONEXISTING_TABLE_GRANT; SQLSTATE: 42000
Message: There is no such grant defined for user '%s' on host '%s' on table '%s'

• Error number: 1148; Symbol: ER_NOT_ALLOWED_COMMAND; SQLSTATE: 42000
Message: The used command is not allowed with this MySQL version

• Error number: 1149; Symbol: ER_SYNTAX_ERROR; SQLSTATE: 42000
Message: You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use

• Error number: 1150; Symbol: ER_DELAYED_CANT_CHANGE_LOCK; SQLSTATE: HY000
Message: Delayed insert thread couldn't get requested lock for table %s

• Error number: 1151; Symbol: ER_TOO_MANY_DELAYED_THREADS; SQLSTATE: HY000
Message: Too many delayed threads in use

• Error number: 1152; Symbol: ER_ABORTING_CONNECTION; SQLSTATE: 08S01
Message: Aborted connection %ld to db: '%s' user: '%s' (%s)

• Error number: 1153; Symbol: ER_NET_PACKET_TOO_LARGE; SQLSTATE: 08S01
Message: Got a packet bigger than 'max_allowed_packet' bytes

• Error number: 1154; Symbol: ER_NET_READ_ERROR_FROM_PIPE; SQLSTATE: 08S01
Message: Got a read error from the connection pipe

• Error number: 1155; Symbol: ER_NET_FCNTL_ERROR; SQLSTATE: 08S01
  Message: Got an error from fcntl()

• Error number: 1156; Symbol: ER_NET_PACKETS_OUT_OF_ORDER; SQLSTATE: 08S01
  Message: Got packets out of order

• Error number: 1157; Symbol: ER_NET_UNCOMPRESS_ERROR; SQLSTATE: 08S01
  Message: Couldn't uncompress communication packet

• Error number: 1158; Symbol: ER_NET_READ_ERROR; SQLSTATE: 08S01
  Message: Got an error reading communication packets

• Error number: 1159; Symbol: ER_NET_READ_INTERRUPTED; SQLSTATE: 08S01
  Message: Got timeout reading communication packets

• Error number: 1160; Symbol: ER_NET_ERROR_ON_WRITE; SQLSTATE: 08S01
  Message: Got an error writing communication packets

• Error number: 1161; Symbol: ER_NET_WRITE_INTERRUPTED; SQLSTATE: 08S01
  Message: Got timeout writing communication packets

• Error number: 1162; Symbol: ER_TOO_LONG_STRING; SQLSTATE: 42000
  Message: Result string is longer than 'max_allowed_packet' bytes

• Error number: 1163; Symbol: ER_TABLE_CANT_HANDLE_BLOB; SQLSTATE: 42000
  Message: The used table type doesn't support BLOB/TEXT columns

• Error number: 1164; Symbol: ER_TABLE_CANT_HANDLE_AUTO_INCREMENT; SQLSTATE: 42000
  Message: The used table type doesn't support AUTO_INCREMENT columns

• Error number: 1165; Symbol: ER_DELAYED_INSERT_TABLE_LOCKED; SQLSTATE: HY000
  Message: INSERT DELAYED can't be used with table '%s' because it is locked with LOCK TABLES

• Error number: 1166; Symbol: ER_WRONG_COLUMN_NAME; SQLSTATE: 42000
  Message: Incorrect column name '%s'

• Error number: 1167; Symbol: ER_WRONG_KEY_COLUMN; SQLSTATE: 42000
  Message: The used storage engine can't index column '%s'

• Error number: 1168; Symbol: ER_WRONG_MRG_TABLE; SQLSTATE: HY000
  Message: Unable to open underlying table which is differently defined or of non-MyISAM type or doesn't exist

• Error number: 1169; Symbol: ER_DUP_UNIQUE; SQLSTATE: 23000
Message: Can't write, because of unique constraint, to table '%s'

- Error number: 1170; Symbol: ER_BLOB_KEY_WITHOUT_LENGTH; SQLSTATE: 42000
  Message: BLOB/TEXT column '%s' used in key specification without a key length

- Error number: 1171; Symbol: ER_PRIMARY_CANT_HAVE_NULL; SQLSTATE: 42000
  Message: All parts of a PRIMARY KEY must be NOT NULL; if you need NULL in a key, use UNIQUE instead

- Error number: 1172; Symbol: ER_TOO_MANY_ROWS; SQLSTATE: 42000
  Message: Result consisted of more than one row

- Error number: 1173; Symbol: ER_REQUIRES_PRIMARY_KEY; SQLSTATE: 42000
  Message: This table type requires a primary key

  **InnoDB** reports this error when you attempt to drop an implicit clustered index (the first UNIQUE NOT NULL index) if the table did not contain a PRIMARY KEY.

  **InnoDB** should no longer report this error as of MySQL 5.5. For tables without an explicit PRIMARY KEY, **InnoDB** creates an implicit clustered index using the first columns of the table that are declared UNIQUE and NOT NULL. When you drop such an index, **InnoDB** now automatically copies the table and rebuilds the index using a different UNIQUE NOT NULL group of columns or a system-generated key. Since this operation changes the primary key, it uses the slow method of copying the table and re-creating the index, rather than the Fast Index Creation technique from Section 14.16.3, "Implementation Details of Fast Index Creation".

- Error number: 1174; Symbol: ER_NO_RAID_COMPILED; SQLSTATE: HY000
  Message: This version of MySQL is not compiled with RAID support

- Error number: 1175; Symbol: ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE; SQLSTATE: HY000
  Message: You are using safe update mode and you tried to update a table without a WHERE that uses a KEY column

- Error number: 1176; Symbol: ER_KEY_DOES_NOT_EXISTS; SQLSTATE: 42000
  Message: Key '%s' doesn't exist in table '%s'

- Error number: 1177; Symbol: ER_CHECK_NO_SUCH_TABLE; SQLSTATE: 42000
  Message: Can't open table

- Error number: 1178; Symbol: ER_CHECK_NOT_IMPLEMENTED; SQLSTATE: 42000
  Message: The storage engine for the table doesn't support %s

- Error number: 1179; Symbol: ER_CANT_DO_THIS_DURING_AN_TRANSACTION; SQLSTATE: 25000
  Message: You are not allowed to execute this command in a transaction

- Error number: 1180; Symbol: ER_ERROR_DURING_COMMIT; SQLSTATE: HY000
  Message: Got error %d during COMMIT
- Error number: 1181; Symbol: `ER_ERROR_DURING_ROLLBACK`; SQLSTATE: HY000
  Message: Got error %d during ROLLBACK
- Error number: 1182; Symbol: `ER_ERROR_DURING_FLUSH_LOGS`; SQLSTATE: HY000
  Message: Got error %d during FLUSH_LOGS
- Error number: 1183; Symbol: `ER_ERROR_DURING_CHECKPOINT`; SQLSTATE: HY000
  Message: Got error %d during CHECKPOINT
- Error number: 1184; Symbol: `ER_NEW_ABORTING_CONNECTION`; SQLSTATE: 08S01
  Message: Aborted connection %ld to db: '%s' user: '%s' host: '%s' (%s)
- Error number: 1185; Symbol: `ER_DUMP_NOT_IMPLEMENTED`; SQLSTATE: HY000
  Message: The storage engine for the table does not support binary table dump
- Error number: 1186; Symbol: `ER_FLUSH_MASTER_BINLOG_CLOSED`; SQLSTATE: HY000
  Message: Binlog closed, cannot RESET MASTER
- Error number: 1187; Symbol: `ER_INDEX_REBUILD`; SQLSTATE: HY000
  Message: Failed rebuilding the index of dumped table '%s'
- Error number: 1188; Symbol: `ER_MASTER`; SQLSTATE: HY000
  Message: Error from master: '%s'
- Error number: 1189; Symbol: `ER_MASTER_NET_READ`; SQLSTATE: 08S01
  Message: Net error reading from master
- Error number: 1190; Symbol: `ER_MASTER_NET_WRITE`; SQLSTATE: 08S01
  Message: Net error writing to master
- Error number: 1191; Symbol: `ER_FT_MATCHING_KEY_NOT_FOUND`; SQLSTATE: HY000
  Message: Can't find FULLTEXT index matching the column list
- Error number: 1192; Symbol: `ER_LOCK_OR_ACTIVE_TRANSACTION`; SQLSTATE: HY000
  Message: Can't execute the given command because you have active locked tables or an active transaction
- Error number: 1193; Symbol: `ER_UNKNOWN_SYSTEM_VARIABLE`; SQLSTATE: HY000
  Message: Unknown system variable '%s'
- Error number: 1194; Symbol: `ER_CRASHED_ON_USAGE`; SQLSTATE: HY000
  Message: Table '%s' is marked as crashed and should be repaired
- Error number: 1195; Symbol: `ER_CRASHED_ON_REPAIR`; SQLSTATE: HY000
  Message: Table '%s' is marked as crashed and last (automatic?) repair failed
• Error number: **1196**; Symbol: **ERWARNING NOT COMPLETE ROLLBACK**; SQLSTATE: **HY000**
Message: Some non-transactional changed tables couldn’t be rolled back

• Error number: **1197**; Symbol: **ER_TRANS_CACHE_FULL**; SQLSTATE: **HY000**
Message: Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage; increase this mysqld variable and try again

• Error number: **1198**; Symbol: **ER_SLAVE MUST STOP**; SQLSTATE: **HY000**
Message: This operation cannot be performed with a running slave; run STOP SLAVE first

• Error number: **1199**; Symbol: **ER_SLAVE NOT RUNNING**; SQLSTATE: **HY000**
Message: This operation requires a running slave; configure slave and do START SLAVE

• Error number: **1200**; Symbol: **ER_BAD_SLAVE**; SQLSTATE: **HY000**
Message: The server is not configured as slave; fix in config file or with CHANGE MASTER TO

• Error number: **1201**; Symbol: **ER_MASTER_INFO**; SQLSTATE: **HY000**
Message: Could not initialize master info structure; more error messages can be found in the MySQL error log

• Error number: **1202**; Symbol: **ER_SLAVE_THREAD**; SQLSTATE: **HY000**
Message: Could not create slave thread; check system resources

• Error number: **1203**; Symbol: **ER_TOO_MANY_USER_CONNECTIONS**; SQLSTATE: **42000**
Message: User %s already has more than 'max_user_connections' active connections

• Error number: **1204**; Symbol: **ER_SET_CONSTANTS_ONLY**; SQLSTATE: **HY000**
Message: You may only use constant expressions with SET

• Error number: **1205**; Symbol: **ER_LOCK_WAIT_TIMEOUT**; SQLSTATE: **HY000**
Message: Lock wait timeout exceeded; try restarting transaction

  InnoDB reports this error when lock wait timeout expires. The statement that waited too long was rolled back (not the entire transaction). You can increase the value of the innodb_lock_wait_timeout configuration option if SQL statements should wait longer for other transactions to complete, or decrease it if too many long-running transactions are causing locking problems and reducing concurrency on a busy system.

• Error number: **1206**; Symbol: **ER_LOCK_TABLE_FULL**; SQLSTATE: **HY000**
Message: The total number of locks exceeds the lock table size

  InnoDB reports this error when the total number of locks exceeds the amount of memory devoted to managing locks. To avoid this error, increase the value of innodb_buffer_pool_size. Within an individual application, a workaround may be to break a large operation into smaller pieces. For example, if the error occurs for a large INSERT, perform several smaller INSERT operations.

• Error number: **1207**; Symbol: **ER_READ ONLY TRANSACTION**; SQLSTATE: **25000**
Server Error Message Reference

Message: Update locks cannot be acquired during a READ UNCOMMITTED transaction

• Error number: 1208; Symbol: ER_DROP_DB_WITH_READ_LOCK; SQLSTATE: HY000
Message: DROP DATABASE not allowed while thread is holding global read lock

• Error number: 1209; Symbol: ER_CREATE_DB_WITH_READ_LOCK; SQLSTATE: HY000
Message: CREATE DATABASE not allowed while thread is holding global read lock

• Error number: 1210; Symbol: ER_WRONG_ARGUMENTS; SQLSTATE: HY000
Message: Incorrect arguments to %s

• Error number: 1211; Symbol: ER_NO_PERMISSION_TO_CREATE_USER; SQLSTATE: 42000
Message: '%s'@'%s' is not allowed to create new users

• Error number: 1212; Symbol: ER_UNION_TABLES_IN_DIFFERENT_DIR; SQLSTATE: HY000
Message: Incorrect table definition; all MERGE tables must be in the same database

• Error number: 1213; Symbol: ER_LOCK_DEADLOCK; SQLSTATE: 40001
Message: Deadlock found when trying to get lock; try restarting transaction

InnoDB reports this error when a transaction encounters a deadlock and is automatically rolled back so that your application can take corrective action. To recover from this error, run all the operations in this transaction again. A deadlock occurs when requests for locks arrive in inconsistent order between transactions. The transaction that was rolled back released all its locks, and the other transaction can now get all the locks it requested. Thus, when you re-run the transaction that was rolled back, it might have to wait for other transactions to complete, but typically the deadlock does not recur. If you encounter frequent deadlocks, make the sequence of locking operations (LOCK TABLES, SELECT ... FOR UPDATE, and so on) consistent between the different transactions or applications that experience the issue. See Section 14.10.5, “Deadlocks in InnoDB” for details.

• Error number: 1214; Symbol: ER_TABLE_CANT_HANDLE_FT; SQLSTATE: HY000
Message: The used table type doesn't support FULLTEXT indexes

• Error number: 1215; Symbol: ER_CANT_ADD_FOREIGN; SQLSTATE: HY000
Message: Cannot add foreign key constraint

• Error number: 1216; Symbol: ER_NO_REFERENCED_ROW; SQLSTATE: 23000
Message: Cannot add or update a child row: a foreign key constraint fails

InnoDB reports this error when you try to add a row but there is no parent row, and a foreign key constraint fails. Add the parent row first.

• Error number: 1217; Symbol: ER_ROW_IS_REFERENCED; SQLSTATE: 23000
Message: Cannot delete or update a parent row: a foreign key constraint fails

InnoDB reports this error when you try to delete a parent row that has children, and a foreign key constraint fails. Delete the children first.
Server Error Message Reference

- **Error number: 1218; Symbol: ER_CONNECT_TO_MASTER; SQLSTATE: 08S01**
  Message: Error connecting to master: %s

- **Error number: 1219; Symbol: ER_QUERY_ON_MASTER; SQLSTATE: HY000**
  Message: Error running query on master: %s

- **Error number: 1220; Symbol: ER_ERROR_WHEN_EXECUTING_COMMAND; SQLSTATE: HY000**
  Message: Error when executing command %s: %s

- **Error number: 1221; Symbol: ER_WRONG_USAGE; SQLSTATE: HY000**
  Message: Incorrect usage of %s and %s

- **Error number: 1222; Symbol: ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT; SQLSTATE: 21000**
  Message: The used SELECT statements have a different number of columns

- **Error number: 1223; Symbol: ER_CANT_UPDATE_WITH_READLOCK; SQLSTATE: HY000**
  Message: Can't execute the query because you have a conflicting read lock

- **Error number: 1224; Symbol: ER_MIXING_NOT_ALLOWED; SQLSTATE: HY000**
  Message: Mixing of transactional and non-transactional tables is disabled

- **Error number: 1225; Symbol: ER_DUP_ARGUMENT; SQLSTATE: HY000**
  Message: Option '%s' used twice in statement

- **Error number: 1226; Symbol: ER_USER_LIMIT_REACHED; SQLSTATE: 42000**
  Message: User '%s' has exceeded the '%s' resource (current value: %ld)

- **Error number: 1227; Symbol: ER_SPECIFIC_ACCESS_DENIED_ERROR; SQLSTATE: 42000**
  Message: Access denied; you need (at least one of) the %s privilege(s) for this operation

- **Error number: 1228; Symbol: ER_LOCAL_VARIABLE; SQLSTATE: HY000**
  Message: Variable '%s' is a SESSION variable and can't be used with SET GLOBAL

- **Error number: 1229; Symbol: ER_GLOBAL_VARIABLE; SQLSTATE: HY000**
  Message: Variable '%s' is a GLOBAL variable and should be set with SET GLOBAL

- **Error number: 1230; Symbol: ER_NO_DEFAULT; SQLSTATE: 42000**
  Message: Variable '%s' doesn't have a default value

- **Error number: 1231; Symbol: ER_WRONG_VALUE_FOR_VAR; SQLSTATE: 42000**
  Message: Variable '%s' can't be set to the value of '%s'

- **Error number: 1232; Symbol: ER_WRONG_TYPE_FOR_VAR; SQLSTATE: 42000**
  Message: Incorrect argument type to variable '%s'
• Error number: 1233; Symbol: ER_VAR_CANT_BE_READ; SQLSTATE: HY000
  Message: Variable '%s' can only be set, not read
• Error number: 1234; Symbol: ER_CANT_USE_OPTION_HERE; SQLSTATE: 42000
  Message: Incorrect usage/placement of '%s'
• Error number: 1235; Symbol: ER_NOT_SUPPORTED_YET; SQLSTATE: 42000
  Message: This version of MySQL doesn't yet support '%s'
• Error number: 1236; Symbol: ER_MASTER_FATAL_ERROR_READING_BINLOG; SQLSTATE: HY000
  Message: Got fatal error %d from master when reading data from binary log: '%s'
• Error number: 1237; Symbol: ER_SLAVE_IGNORED_TABLE; SQLSTATE: HY000
  Message: Slave SQL thread ignored the query because of replicate-*-table rules
• Error number: 1238; Symbol: ER_INCORRECT_GLOBAL_LOCAL_VAR; SQLSTATE: HY000
  Message: Variable '%s' is a %s variable
• Error number: 1239; Symbol: ER_WRONG_FK_DEF; SQLSTATE: 42000
  Message: Incorrect foreign key definition for '%s': %s
• Error number: 1240; Symbol: ER_KEY_REF_DO_NOT_MATCH_TABLE_REF; SQLSTATE: HY000
  Message: Key reference and table reference don't match
• Error number: 1241; Symbol: ER_OPERAND_COLUMNS; SQLSTATE: 21000
  Message: Operand should contain %d column(s)
• Error number: 1242; Symbol: ER_SUBQUERY_NO_1_ROW; SQLSTATE: 21000
  Message: Subquery returns more than 1 row
• Error number: 1243; Symbol: ER_UNKNOWN_STMT_HANDLER; SQLSTATE: HY000
  Message: Unknown prepared statement handler (%.*s) given to %s
• Error number: 1244; Symbol: ER_CORRUPT_HELP_DB; SQLSTATE: HY000
  Message: Help database is corrupt or does not exist
• Error number: 1245; Symbol: ER_CYCLIC_REFERENCE; SQLSTATE: HY000
  Message: Cyclic reference on subqueries
• Error number: 1246; Symbol: ER_AUTO_CONVERT; SQLSTATE: HY000
  Message: Converting column '%s' from %s to %s
• Error number: 1247; Symbol: ER_ILLEGAL_REFERENCE; SQLSTATE: 42S22
  Message: Reference '%s' not supported (%s)
• Error number: 1248; Symbol: ER_DERIVED_MUST_HAVE_ALIAS; SQLSTATE: 42000
  Message: Every derived table must have its own alias
• Error number: 1249; Symbol: ER_SELECT_REduced; SQLSTATE: 01000
  Message: Select %u was reduced during optimization
• Error number: 1250; Symbol: ER_TABLENAME_NOT_ALLOWED_HERE; SQLSTATE: 42000
  Message: Table '%s' from one of the SELECTs cannot be used in %s
• Error number: 1251; Symbol: ER_NOT_SUPPORTED_AUTH_MODE; SQLSTATE: 08004
  Message: Client does not support authentication protocol requested by server; consider upgrading MySQL client
• Error number: 1252; Symbol: ER_SPATIAL_CANT_HAVE_NULL; SQLSTATE: 42000
  Message: All parts of a SPATIAL index must be NOT NULL
• Error number: 1253; Symbol: ER_COLLATION_CHARSET_MISMATCH; SQLSTATE: 42000
  Message: COLLATION '%s' is not valid for CHARACTER SET '%s'
• Error number: 1254; Symbol: ER_SLAVE_WAS_RUNNING; SQLSTATE: HY000
  Message: Slave is already running
• Error number: 1255; Symbol: ER_SLAVE_WAS_NOT_RUNNING; SQLSTATE: HY000
  Message: Slave already has been stopped
• Error number: 1256; Symbol: ER_TOO_BIG_FOR_UNCOMPRESS; SQLSTATE: HY000
  Message: Uncompressed data size too large; the maximum size is %d (probably, length of uncompressed data was corrupted)
• Error number: 1257; Symbol: ER_ZLIB_Z_MEM_ERROR; SQLSTATE: HY000
  Message: ZLIB: Not enough memory
• Error number: 1258; Symbol: ER_ZLIB_Z_BUF_ERROR; SQLSTATE: HY000
  Message: ZLIB: Not enough room in the output buffer (probably, length of uncompressed data was corrupted)
• Error number: 1259; Symbol: ER_ZLIB_Z_DATA_ERROR; SQLSTATE: HY000
  Message: ZLIB: Input data corrupted
• Error number: 1260; Symbol: ER_CUT_VALUE_GROUP_CONCAT; SQLSTATE: HY000
  Message: Row %u was cut by GROUP_CONCAT()
• Error number: 1261; Symbol: ER_WARN_TOO_Few_RECORDS; SQLSTATE: 01000
  Message: Row %ld doesn't contain data for all columns
• Error number: 1262; Symbol: ER_WARN_TOO_MANY_RECORDS; SQLSTATE: 01000
Message: Row %ld was truncated; it contained more data than there were input columns

- Error number: 1263; Symbol: ER_WARN_NULL_TO_NOTNULL; SQLSTATE: 22004
  Message: Column set to default value; NULL supplied to NOT NULL column '%s' at row %ld

- Error number: 1264; Symbol: ER_WARN_DATA_OUT_OF_RANGE; SQLSTATE: 22003
  Message: Out of range value for column '%s' at row %ld

- Error number: 1265; Symbol: WARN_DATA_TRUNCATED; SQLSTATE: 01000
  Message: Data truncated for column '%s' at row %ld

- Error number: 1266; Symbol: ER_WARN_USING_OTHER_HANDLER; SQLSTATE: HY000
  Message: Using storage engine %s for table '%s'

- Error number: 1267; Symbol: ER_CANT_AGGREGATE_2COLLATIONS; SQLSTATE: HY000
  Message: Illegal mix of collations (%s,%s) and (%s,%s) for operation '%s'

- Error number: 1268; Symbol: ER_DROP_USER; SQLSTATE: HY000
  Message: Cannot drop one or more of the requested users

- Error number: 1269; Symbol: ER_REVOKE_GRANTS; SQLSTATE: HY000
  Message: Can't revoke all privileges for one or more of the requested users

- Error number: 1270; Symbol: ER_CANT_AGGREGATE_3COLLATIONS; SQLSTATE: HY000
  Message: Illegal mix of collations (%s,%s), (%s,%s), (%s,%s) for operation '%s'

- Error number: 1271; Symbol: ER_CANT_AGGREGATE_NCOLLATIONS; SQLSTATE: HY000
  Message: Illegal mix of collations for operation '%s'

- Error number: 1272; Symbol: ER_VARIABLE_IS_NOT_STRUCT; SQLSTATE: HY000
  Message: Variable '%s' is not a variable component (can't be used as XXXX.variable_name)

- Error number: 1273; Symbol: ER_UNKNOWN_COLLATION; SQLSTATE: HY000
  Message: Unknown collation: '%s'

- Error number: 1274; Symbol: ER_SLAVE_ignored_SSL_PARAMS; SQLSTATE: HY000
  Message: SSL parameters in CHANGE MASTER are ignored because this MySQL slave was compiled without SSL support; they can be used later if MySQL slave with SSL is started

- Error number: 1275; Symbol: ER_SERVER_IS_IN_SECURE_AUTH_MODE; SQLSTATE: HY000
  Message: Server is running in --secure-auth mode, but '%s'@'%s' has a password in the old format; please change the password to the new format

- Error number: 1276; Symbol: ER_WARN_FIELD_RESOLVED; SQLSTATE: HY000
  Message: Field or reference '%s%s%s%s%s%s' of SELECT #%d was resolved in SELECT #%d
•  Error number: 1277; Symbol: ER_BAD_SLAVE_UNTIL_COND; SQLSTATE: HY000
Message: Incorrect parameter or combination of parameters for START SLAVE UNTIL

•  Error number: 1278; Symbol: ER_MISSING_SKIP_SLAVE; SQLSTATE: HY000
Message: It is recommended to use --skip-slave-start when doing step-by-step replication with START SLAVE UNTIL; otherwise, you will get problems if you get an unexpected slave's mysqld restart

•  Error number: 1279; Symbol: ER_UNTIL_COND_IGNORED; SQLSTATE: HY000
Message: SQL thread is not to be started so UNTIL options are ignored

•  Error number: 1280; Symbol: ER_WRONG_NAME_FOR_INDEX; SQLSTATE: 42000
Message: Incorrect index name '%s'

•  Error number: 1281; Symbol: ER_WRONG_NAME_FOR_CATALOG; SQLSTATE: 42000
Message: Incorrect catalog name '%s'

•  Error number: 1282; Symbol: ER_WARN_QC_RESIZE; SQLSTATE: HY000
Message: Query cache failed to set size %lu; new query cache size is %lu

•  Error number: 1283; Symbol: ER_BAD_FT_COLUMN; SQLSTATE: HY000
Message: Column '%s' cannot be part of FULLTEXT index

•  Error number: 1284; Symbol: ER_UNKNOWN_KEY_CACHE; SQLSTATE: HY000
Message: Unknown key cache '%s'

•  Error number: 1285; Symbol: ER_WARN_HOSTNAME_WONT_WORK; SQLSTATE: HY000
Message: MySQL is started in --skip-name-resolve mode; you must restart it without this switch for this grant to work

•  Error number: 1286; Symbol: ER_UNKNOWN_STORAGE_ENGINE; SQLSTATE: 42000
Message: Unknown storage engine '%s'

•  Error number: 1287; Symbol: ER_WARN_DEPRECATED_SYNTAX; SQLSTATE: HY000
Message: '%s' is deprecated and will be removed in a future release. Please use %s instead

•  Error number: 1288; Symbol: ER_NON_UPDATABLE_TABLE; SQLSTATE: HY000
Message: The target table %s of the %s is not updatable

•  Error number: 1289; Symbol: ER_FEATURE_DISABLED; SQLSTATE: HY000
Message: The '%s' feature is disabled; you need MySQL built with '%s' to have it working

•  Error number: 1290; Symbol: ER_OPTION_PREVENTS_STATEMENT; SQLSTATE: HY000
Message: The MySQL server is running with the %s option so it cannot execute this statement

•  Error number: 1291; Symbol: ER_DUPLICATED_VALUE_IN_TYPE; SQLSTATE: HY000
Message: Column '%s' has duplicated value '%s' in %s

• Error number: 1292; Symbol: ER_TRUNCATED_WRONG_VALUE; SQLSTATE: 22007
  Message: Truncated incorrect %s value: '%s'

• Error number: 1293; Symbol: ER_TOO MUCH_AUTO_TIMESTAMP_COLS; SQLSTATE: HY000
  Message: Incorrect table definition; there can be only one TIMESTAMP column with CURRENT_TIMESTAMP in DEFAULT or ON UPDATE clause

• Error number: 1294; Symbol: ER_INVALID_ON_UPDATE; SQLSTATE: HY000
  Message: Invalid ON UPDATE clause for '%s' column

• Error number: 1295; Symbol: ER_UNSUPPORTED_PS; SQLSTATE: HY000
  Message: This command is not supported in the prepared statement protocol yet

• Error number: 1296; Symbol: ER_GET_ERRMSG; SQLSTATE: HY000
  Message: Got error %d '%s' from %s

• Error number: 1297; Symbol: ER_GET_TEMPORARY_ERRMSG; SQLSTATE: HY000
  Message: Got temporary error %d '%s' from %s

• Error number: 1298; Symbol: ER_UNKNOWN_TIME_ZONE; SQLSTATE: HY000
  Message: Unknown or incorrect time zone: '%s'

• Error number: 1299; Symbol: ER_WARN_INVALID_TIMESTAMP; SQLSTATE: HY000
  Message: Invalid TIMESTAMP value in column '%s' at row %ld

• Error number: 1300; Symbol: ER_INVALID_CHARACTER_STRING; SQLSTATE: HY000
  Message: Invalid %s character string: '%s'

• Error number: 1301; Symbol: ER_WARN_ALLOWED_PACKET_OVERFLOWED; SQLSTATE: HY000
  Message: Result of %s() was larger than max_allowed_packet (%ld) - truncated

• Error number: 1302; Symbol: ER_CONFLICTING_DECLARATIONS; SQLSTATE: HY000
  Message: Conflicting declarations: '%s%s' and '%s%s'

• Error number: 1303; Symbol: ER_SP_NO_RECURSIVE_CREATE; SQLSTATE: 2F003
  Message: Can't create a %s from within another stored routine

• Error number: 1304; Symbol: ER_SP_ALREADY_EXISTS; SQLSTATE: 42000
  Message: %s %s already exists

• Error number: 1305; Symbol: ER_SP DOES NOT_EXIST; SQLSTATE: 42000
  Message: %s %s does not exist

• Error number: 1306; Symbol: ER_SP DROP FAILED; SQLSTATE: HY000
Message: Failed to DROP %s %s
•   Error number: 1307; Symbol: ER_SP_STORE_FAILED; SQLSTATE: HY000
Message: Failed to CREATE %s %s
•   Error number: 1308; Symbol: ER_SP_LILABEL_MISMATCH; SQLSTATE: 42000
Message: %s with no matching label: %s
•   Error number: 1309; Symbol: ER_SP_LABEL_REDEFINE; SQLSTATE: 42000
Message: Redefining label %s
•   Error number: 1310; Symbol: ER_SP_LABEL_MISMATCH; SQLSTATE: 42000
Message: End-label %s without match
•   Error number: 1311; Symbol: ER_SP_UNINIT_VAR; SQLSTATE: 01000
Message: Referring to uninitialized variable %s
•   Error number: 1312; Symbol: ER_SP_BADSELECT; SQLSTATE: 0A000
Message: PROCEDURE %s can't return a result set in the given context
•   Error number: 1313; Symbol: ER_SP_BADRETURN; SQLSTATE: 42000
Message: RETURN is only allowed in a FUNCTION
•   Error number: 1314; Symbol: ER_SP_BADSTATEMENT; SQLSTATE: 0A000
Message: %s is not allowed in stored procedures
•   Error number: 1315; Symbol: ER_UPDATE_LOG_DEPRECATED_IGNORED; SQLSTATE: 42000
Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been ignored. This option will be removed in MySQL 5.6.
•   Error number: 1316; Symbol: ER_UPDATE_LOG_DEPRECATED_TRANSLATED; SQLSTATE: 42000
Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been translated to SET SQL_LOG_BIN. This option will be removed in MySQL 5.6.
•   Error number: 1317; Symbol: ER_QUERY_INTERRUPTED; SQLSTATE: 70100
Message: Query execution was interrupted
•   Error number: 1318; Symbol: ER_SP_WRONG_NO_OF_ARGS; SQLSTATE: 42000
Message: Incorrect number of arguments for %s %s; expected %u, got %u
•   Error number: 1319; Symbol: ER_SP_COND_MISMATCH; SQLSTATE: 42000
Message: Undefined CONDITION: %s
•   Error number: 1320; Symbol: ER_SP_NORETURN; SQLSTATE: 42000
Message: No RETURN found in FUNCTION %s
Server Error Message Reference

- Error number: 1321; Symbol: ER_SP_NORETURNEND; SQLSTATE: 2F005
  Message: FUNCTION %s ended without RETURN
- Error number: 1322; Symbol: ER_SP_BAD_CURSOR_QUERY; SQLSTATE: 42000
  Message: Cursor statement must be a SELECT
- Error number: 1323; Symbol: ER_SP_BAD_CURSOR_SELECT; SQLSTATE: 42000
  Message: Cursor SELECT must not have INTO
- Error number: 1324; Symbol: ER_SP_CURSOR_MISMATCH; SQLSTATE: 42000
  Message: Undefined CURSOR: %s
- Error number: 1325; Symbol: ER_SP_CURSOR_ALREADY_OPEN; SQLSTATE: 24000
  Message: Cursor is already open
- Error number: 1326; Symbol: ER_SP_CURSOR_NOT_OPEN; SQLSTATE: 24000
  Message: Cursor is not open
- Error number: 1327; Symbol: ER_SP_UNDECLARED_VAR; SQLSTATE: 42000
  Message: Undeclared variable: %s
- Error number: 1328; Symbol: ER_SP_WRONG_NO_OF_FETCH_ARGS; SQLSTATE: HY000
  Message: Incorrect number of FETCH variables
- Error number: 1329; Symbol: ER_SP_FETCH_NO_DATA; SQLSTATE: 02000
  Message: No data - zero rows fetched, selected, or processed
- Error number: 1330; Symbol: ER_SP_DUP_PARAM; SQLSTATE: 42000
  Message: Duplicate parameter: %s
- Error number: 1331; Symbol: ER_SP_DUP_VAR; SQLSTATE: 42000
  Message: Duplicate variable: %s
- Error number: 1332; Symbol: ER_SP_DUP_COND; SQLSTATE: 42000
  Message: Duplicate condition: %s
- Error number: 1333; Symbol: ER_SP_DUP_CURS; SQLSTATE: 42000
  Message: Duplicate cursor: %s
- Error number: 1334; Symbol: ER_SP_CANT_ALTER; SQLSTATE: HY000
  Message: Failed to ALTER %s %s
- Error number: 1335; Symbol: ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG; SQLSTATE: 0A000
  Message: Subquery value not supported
- Error number: 1336; Symbol: ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG; SQLSTATE: 0A000
Server Error Message Reference

Message: %s is not allowed in stored function or trigger
  • Error number: 1337; Symbol: ER_SP_VARCOND_AFTER_CURSHNDLR; SQLSTATE: 42000
  Message: Variable or condition declaration after cursor or handler declaration

Message: Cursor declaration after handler declaration
  • Error number: 1338; Symbol: ER_SP_CURSOR_AFTER_HANDLER; SQLSTATE: 42000

Message: Case not found for CASE statement
  • Error number: 1339; Symbol: ER_SP_CASE_NOT_FOUND; SQLSTATE: 20000

Message: Configuration file '%s' is too big
  • Error number: 1340; Symbol: ER_FPARSER_TOO_BIG_FILE; SQLSTATE: HY000

Message: Malformed file type header in file '%s'
  • Error number: 1341; Symbol: ER_FPARSER_BAD_HEADER; SQLSTATE: HY000

Message: Unexpected end of file while parsing comment '%s'
  • Error number: 1342; Symbol: ER_FPARSER_EOF_IN_COMMENT; SQLSTATE: HY000

Message: Error while parsing parameter '%s' (line: '%s')
  • Error number: 1343; Symbol: ER_FPARSER_ERROR_IN_PARAMETER; SQLSTATE: HY000

Message: Unexpected end of file while skipping unknown parameter '%s'
  • Error number: 1344; Symbol: ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER; SQLSTATE: HY000

Message: EXPLAIN/SHOW can not be issued; lacking privileges for underlying table
  • Error number: 1345; Symbol: ER_VIEW_NO_EXPLAIN; SQLSTATE: HY000

Message: File '%s' has unknown type '%s' in its header
  • Error number: 1347; Symbol: ER_WRONG_OBJECT; SQLSTATE: HY000

Message: '%s.%s' is not %s
  The named object is incorrect for the type of operation attempted on it. It must be an object of the named type.

Message: Column '%s' is not updatable
  • Error number: 1348; Symbol: ER_NONUPDATEABLE_COLUMN; SQLSTATE: HY000

Message: View's SELECT contains a subquery in the FROM clause
  • Error number: 1349; Symbol: ER_VIEW_SELECT_DERIVED; SQLSTATE: HY000

Message: View's SELECT contains a '%s' clause
  • Error number: 1350; Symbol: ER_VIEW_SELECT_CLAUSE; SQLSTATE: HY000
• Error number: 1351; Symbol: ER_VIEW_SELECT_VARIABLE; SQLSTATE: HY000
  Message: View's SELECT contains a variable or parameter
• Error number: 1352; Symbol: ER_VIEW_SELECT_TMPTABLE; SQLSTATE: HY000
  Message: View's SELECT refers to a temporary table '%s'
• Error number: 1353; Symbol: ER_VIEW_WRONG_LIST; SQLSTATE: HY000
  Message: View's SELECT and view's field list have different column counts
• Error number: 1354; Symbol: ER_WARN_VIEW_MERGE; SQLSTATE: HY000
  Message: View merge algorithm can't be used here for now (assumed undefined algorithm)
• Error number: 1355; Symbol: ER_WARN_VIEW_WITHOUT_KEY; SQLSTATE: HY000
  Message: View being updated does not have complete key of underlying table in it
• Error number: 1356; Symbol: ER_VIEW_INVALID; SQLSTATE: HY000
  Message: View '%s.%s' references invalid table(s) or column(s) or function(s) or definer/invoker of view lack rights to use them
• Error number: 1357; Symbol: ER_SP_NO_DROP_SP; SQLSTATE: HY000
  Message: Can't drop or alter a %s from within another stored routine
• Error number: 1358; Symbol: ER_SP_GOTO_IN_HNDLR; SQLSTATE: HY000
  Message: GOTO is not allowed in a stored procedure handler
• Error number: 1359; Symbol: ER_TRG_ALREADY_EXISTS; SQLSTATE: HY000
  Message: Trigger already exists
• Error number: 1360; Symbol: ER_TRG_DOES_NOT_EXIST; SQLSTATE: HY000
  Message: Trigger does not exist
• Error number: 1361; Symbol: ER_TRG_ON_VIEW_OR_TEMP_TABLE; SQLSTATE: HY000
  Message: Trigger's '%s' is view or temporary table
• Error number: 1362; Symbol: ER_TRG_CANT_CHANGE_ROW; SQLSTATE: HY000
  Message: Updating of %s row is not allowed in %strigger
• Error number: 1363; Symbol: ER_TRG_NO_SUCH_ROW_IN_TRG; SQLSTATE: HY000
  Message: There is no %s row in %s trigger
• Error number: 1364; Symbol: ER_NO_DEFAULT_FOR_FIELD; SQLSTATE: HY000
  Message: Field '%s' doesn't have a default value
• Error number: 1365; Symbol: ER_DIVISION_BY_ZERO; SQLSTATE: 22012
  Message: Division by 0
• Error number: 1366; Symbol: ER_TRUNCATED_WRONG_VALUE_FOR_FIELD; SQLSTATE: HY000
  Message: Incorrect %s value: '%s' for column '%s' at row %ld
• Error number: 1367; Symbol: ER_ILLEGAL_VALUE_FOR_TYPE; SQLSTATE: 22007
  Message: Illegal %s '%s' value found during parsing
• Error number: 1368; Symbol: ER_VIEW_NONUPD_CHECK; SQLSTATE: HY000
  Message: CHECK OPTION on non-updatable view '%s.%s'
• Error number: 1369; Symbol: ER_VIEW_CHECK_FAILED; SQLSTATE: HY000
  Message: CHECK OPTION failed '%s.%s'
• Error number: 1370; Symbol: ER_PROCACCESS_DENIED_ERROR; SQLSTATE: 42000
  Message: %s command denied to user '%s'@'%s' for routine '%s'
• Error number: 1371; Symbol: ER_RELAY_LOG_FAIL; SQLSTATE: HY000
  Message: Failed purging old relay logs: %s
• Error number: 1372; Symbol: ER_PASSWD_LENGTH; SQLSTATE: HY000
  Message: Password hash should be a %d-digit hexadecimal number
• Error number: 1373; Symbol: ER_UNKNOWN_TARGET_BINLOG; SQLSTATE: HY000
  Message: Target log not found in binlog index
• Error number: 1374; Symbol: ER_IO_ERR_LOG_INDEX_READ; SQLSTATE: HY000
  Message: I/O error reading log index file
• Error number: 1375; Symbol: ER_BINLOG_PURGE_PROHIBITED; SQLSTATE: HY000
  Message: Server configuration does not permit binlog purge
• Error number: 1376; Symbol: ER_FSEEK_FAIL; SQLSTATE: HY000
  Message: Failed on fseek()
• Error number: 1377; Symbol: ER_BINLOG_PURGE_FATAL_ERR; SQLSTATE: HY000
  Message: Fatal error during log purge
• Error number: 1378; Symbol: ER_LOG_IN_USE; SQLSTATE: HY000
  Message: A purgeable log is in use, will not purge
• Error number: 1379; Symbol: ER_LOG_PURGE_UNKNOWN_ERR; SQLSTATE: HY000
  Message: Unknown error during log purge
• Error number: 1380; Symbol: ER_RELAY_LOG_INIT; SQLSTATE: HY000
  Message: Failed initializing relay log position: %s
• Error number: 1381; Symbol: ER_NO_BINARY_LOGGING; SQLSTATE: HY000
  Message: You are not using binary logging
• Error number: 1382; Symbol: ER_RESERVED_SYNTAX; SQLSTATE: HY000
  Message: The ‘%s’ syntax is reserved for purposes internal to the MySQL server
• Error number: 1383; Symbol: ER_WSAS_FAILED; SQLSTATE: HY000
  Message: WSAStartup Failed
• Error number: 1384; Symbol: ER_DIFF_GROUPS_PROC; SQLSTATE: HY000
  Message: Can't handle procedures with different groups yet
• Error number: 1385; Symbol: ER_NO_GROUP_FOR_PROC; SQLSTATE: HY000
  Message: Select must have a group with this procedure
• Error number: 1386; Symbol: ER_ORDER_WITH_PROC; SQLSTATE: HY000
  Message: Can't use ORDER clause with this procedure
• Error number: 1387; Symbol: ER_LOGGING_PROHIBIT_CHANGING_OF; SQLSTATE: HY000
  Message: Binary logging and replication forbid changing the global server %s
• Error number: 1388; Symbol: ER_NO_FILE_MAPPING; SQLSTATE: HY000
  Message: Can't map file: %s, errno: %d
• Error number: 1389; Symbol: ER_WRONG_MAGIC; SQLSTATE: HY000
  Message: Wrong magic in %s
• Error number: 1390; Symbol: ER_PS_MANY_PARAM; SQLSTATE: HY000
  Message: Prepared statement contains too many placeholders
• Error number: 1391; Symbol: ER_KEY_PART_0; SQLSTATE: HY000
  Message: Key part '%s' length cannot be 0
• Error number: 1392; Symbol: ER_VIEW_CHECKSUM; SQLSTATE: HY000
  Message: View text checksum failed
• Error number: 1393; Symbol: ER_VIEW_MULTIUPDATE; SQLSTATE: HY000
  Message: Can not modify more than one base table through a join view '%s.%s'
• Error number: 1394; Symbol: ER_VIEW_NO_INSERT_FIELD_LIST; SQLSTATE: HY000
  Message: Can not insert into join view '%s.%s' without fields list
• Error number: 1395; Symbol: ER_VIEW_DELETE_MERGE_VIEW; SQLSTATE: HY000
  Message: Can not delete from join view '%s.%s'
Server Error Message Reference

- **Error number:** 1396; Symbol: ER_CANNOT_USER; SQLSTATE: HY000
  Message: Operation %%s failed for %s

- **Error number:** 1397; Symbol: ER_XAER_NOTA; SQLSTATE: XAE04
  Message: XAER_NOTA: Unknown XID

- **Error number:** 1398; Symbol: ER_XAER_INVAL; SQLSTATE: XAE05
  Message: XAER_INVAL: Invalid arguments (or unsupported command)

- **Error number:** 1399; Symbol: ER_XAER_RMFAIL; SQLSTATE: XAE07
  Message: XAER_RMFAIL: The command cannot be executed when global transaction is in the %s state

- **Error number:** 1400; Symbol: ER_XAER_OUTSIDE; SQLSTATE: XAE09
  Message: XAER_OUTSIDE: Some work is done outside global transaction

- **Error number:** 1401; Symbol: ER_XAER_RMERR; SQLSTATE: XAE03
  Message: XAER_RMERR: Fatal error occurred in the transaction branch - check your data for consistency

- **Error number:** 1402; Symbol: ER_XA_RBROLLBACK; SQLSTATE: XA100
  Message: XA_RBROLLBACK: Transaction branch was rolled back

- **Error number:** 1403; Symbol: ER_NONEXISTING_PROC_GRANT; SQLSTATE: 42000
  Message: There is no such grant defined for user '%s' on host '%s' on routine '%s'

- **Error number:** 1404; Symbol: ER_PROC_AUTO_GRANT_FAIL; SQLSTATE: HY000
  Message: Failed to grant EXECUTE and ALTER ROUTINE privileges

- **Error number:** 1405; Symbol: ER_PROC_AUTO_REVOKE_FAIL; SQLSTATE: HY000
  Message: Failed to revoke all privileges to dropped routine

- **Error number:** 1406; Symbol: ER_DATA_TOO_LONG; SQLSTATE: 22001
  Message: Data too long for column '%%s' at row %ld

- **Error number:** 1407; Symbol: ER_SP_BAD_SQLSTATE; SQLSTATE: 42000
  Message: Bad SQLSTATE: '%s'

- **Error number:** 1408; Symbol: ER_STARTUP; SQLSTATE: HY000
  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d %s

- **Error number:** 1409; Symbol: ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR; SQLSTATE: HY000
  Message: Can't load value from file with fixed size rows to variable

- **Error number:** 1410; Symbol: ER_CANT_CREATE_USER_WITH_GRANT; SQLSTATE: 42000
  Message: You are not allowed to create a user with GRANT
Server Error Message Reference

- **Error number: 1411; Symbol: ER_WRONG_VALUE_FOR_TYPE; SQLSTATE: HY000**
  
  Message: Incorrect %s value: '%s' for function %s

- **Error number: 1412; Symbol: ER_TABLE_DEF_CHANGED; SQLSTATE: HY000**
  
  Message: Table definition has changed, please retry transaction

- **Error number: 1413; Symbol: ER_SP_DUP_HANDLER; SQLSTATE: 42000**
  
  Message: Duplicate handler declared in the same block

- **Error number: 1414; Symbol: ER_SP_NOT_VAR_ARG; SQLSTATE: 42000**
  
  Message: OUT or INOUT argument %d for routine %s is not a variable or NEW pseudo-variable in BEFORE trigger

- **Error number: 1415; Symbol: ER_SP_NO_RETSET; SQLSTATE: 0A000**
  
  Message: Not allowed to return a result set from a %s

- **Error number: 1416; Symbol: ER_CANT_CREATE_GEOMETRY_OBJECT; SQLSTATE: 22003**
  
  Message: Cannot get geometry object from data you send to the GEOMETRY field

- **Error number: 1417; Symbol: ER_FAILED_ROUTINE_BREAK_BINLOG; SQLSTATE: HY000**
  
  Message: A routine failed and has neither NO SQL nor READS SQL DATA in its declaration and binary logging is enabled; if non-transactional tables were updated, the binary log will miss their changes

- **Error number: 1418; Symbol: ER_BINLOG_UNSAFE_ROUTINE; SQLSTATE: HY000**
  
  Message: This function has none of DETERMINISTIC, NO SQL, or READS SQL DATA in its declaration and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- **Error number: 1419; Symbol: ER_BINLOG_CREATE_ROUTINE_NEED_SUPER; SQLSTATE: HY000**
  
  Message: You do not have the SUPER privilege and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- **Error number: 1420; Symbol: ER_EXEC_STMT_WITH_OPEN_CURSOR; SQLSTATE: HY000**
  
  Message: You can't execute a prepared statement which has an open cursor associated with it. Reset the statement to re-execute it.

- **Error number: 1421; Symbol: ER_STMT_HAS_NO_OPEN_CURSOR; SQLSTATE: HY000**
  
  Message: The statement (%lu) has no open cursor.

- **Error number: 1422; Symbol: ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG; SQLSTATE: HY000**
  
  Message: Explicit or implicit commit is not allowed in stored function or trigger.

- **Error number: 1423; Symbol: ER_NO_DEFAULT_FOR_VIEW_FIELD; SQLSTATE: HY000**
  
  Message: Field of view '%%.%%' underlying table doesn't have a default value

- **Error number: 1424; Symbol: ER_SP_NO_RECURSION; SQLSTATE: HY000**
Message: Recursive stored functions and triggers are not allowed.

- Error number: 1425; Symbol: ER_TOO_BIG_SCALE; SQLSTATE: 42000
  Message: Too big scale %d specified for column '%s'. Maximum is %lu.
- Error number: 1426; Symbol: ER_TOO_BIG_PRECISION; SQLSTATE: 42000
  Message: Too big precision %d specified for column '%s'. Maximum is %lu.
- Error number: 1427; Symbol: ER_M_BIGGER_THAN_D; SQLSTATE: 42000
  Message: For float(M,D), double(M,D) or decimal(M,D), M must be >= D (column '%s').
- Error number: 1428; Symbol: ER_WRONG_LOCK_OF_SYSTEM_TABLE; SQLSTATE: HY000
  Message: You can't combine write-locking of system tables with other tables or lock types
- Error number: 1429; Symbol: ER_CONNECT_TO_FOREIGN_DATA_SOURCE; SQLSTATE: HY000
  Message: Unable to connect to foreign data source: %s
- Error number: 1430; Symbol: ER_QUERY_ON_FOREIGN_DATA_SOURCE; SQLSTATE: HY000
  Message: There was a problem processing the query on the foreign data source. Data source error: %s
- Error number: 1431; Symbol: ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST; SQLSTATE: HY000
  Message: The foreign data source you are trying to reference does not exist. Data source error: %s
- Error number: 1432; Symbol: ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE; SQLSTATE: HY000
  Message: Can't create federated table. The data source connection string '%s' is not in the correct format
- Error number: 1433; Symbol: ER_FOREIGN_DATA_STRING_INVALID; SQLSTATE: HY000
  Message: The data source connection string '%s' is not in the correct format
- Error number: 1434; Symbol: ER_CANT_CREATE_FEDERATED_TABLE; SQLSTATE: HY000
  Message: Can't create federated table. Foreign data src error: %s
- Error number: 1435; Symbol: ER_TRG_IN_WRONG_SCHEMA; SQLSTATE: HY000
  Message: Trigger in wrong schema
- Error number: 1436; Symbol: ER_STACK_OVERRUN_NEED_MORE; SQLSTATE: HY000
  Message: Thread stack overrun: %ld bytes used of a %ld byte stack, and %ld bytes needed. Use 'mysqld --thread_stack=#' to specify a bigger stack.
- Error number: 1437; Symbol: ER_TOO_LONG_BODY; SQLSTATE: 42000
  Message: Routine body for '%s' is too long
- Error number: 1438; Symbol: ER_WARN_CANT_DROP_DEFAULT_KEYCACHE; SQLSTATE: HY000
Message: Cannot drop default keycache
• Error number: 1439; Symbol: ER_TOO_BIG_DISPLAYWIDTH; SQLSTATE: 42000
  Message: Display width out of range for column '%s' (max = %lu)
• Error number: 1440; Symbol: ER_XAER_DUPID; SQLSTATE: XAE08
  Message: XAER_DUPID: The XID already exists
• Error number: 1441; Symbol: ER_DATETIME_FUNCTION_OVERFLOW; SQLSTATE: 22008
  Message: Datetime function: %s field overflow
• Error number: 1442; Symbol: ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG; SQLSTATE: HY000
  Message: Can't update table '%s' in stored function/trigger because it is already used by statement which invoked this stored function/trigger.
• Error number: 1443; Symbol: ER_VIEW_PREVENT_UPDATE; SQLSTATE: HY000
  Message: The definition of table '%s' prevents operation %s on table '%s'.
• Error number: 1444; Symbol: ER_PS_NO_RECURSION; SQLSTATE: HY000
  Message: The prepared statement contains a stored routine call that refers to that same statement. It's not allowed to execute a prepared statement in such a recursive manner.
• Error number: 1445; Symbol: ER_SP_CANT_SET_AUTOCOMMIT; SQLSTATE: HY000
  Message: Not allowed to set autocommit from a stored function or trigger
• Error number: 1446; Symbol: ER_MALFORMED_DEFINER; SQLSTATE: HY000
  Message: Definer is not fully qualified
• Error number: 1447; Symbol: ER_VIEW_FRM_NO_USER; SQLSTATE: HY000
  Message: View '%s'.'%s' has no definer information (old table format). Current user is used as definer. Please recreate the view!
• Error number: 1448; Symbol: ER_VIEW_OTHER_USER; SQLSTATE: HY000
  Message: You need the SUPER privilege for creation view with '%s'@'%s' definer
• Error number: 1449; Symbol: ER_NO_SUCH_USER; SQLSTATE: HY000
  Message: The user specified as a definer ('%s'@'%s') does not exist
• Error number: 1450; Symbol: ER_FORBID_SCHEMA_CHANGE; SQLSTATE: HY000
  Message: Changing schema from '%s' to '%s' is not allowed.
• Error number: 1451; Symbol: ER_ROW_IS_REFERENCED_2; SQLSTATE: 23000
  Message: Cannot delete or update a parent row: a foreign key constraint fails (%s)
  InnoDB reports this error when you try to delete a parent row that has children, and a foreign key constraint fails. Delete the children first.
Server Error Message Reference

- **Error number:** 1452; **Symbol:** ER_NO_REFERENCED_ROW_2; **SQLSTATE:** 23000
  
  **Message:** Cannot add or update a child row: a foreign key constraint fails (%s)

  **InnoDB** reports this error when you try to add a row but there is no parent row, and a foreign key constraint fails. Add the parent row first.

- **Error number:** 1453; **Symbol:** ER_SP_BAD_VAR_SHADOW; **SQLSTATE:** 42000
  
  **Message:** Variable '%s' must be quoted with `...`, or renamed

- **Error number:** 1454; **Symbol:** ER_TRG_NO_DEFINER; **SQLSTATE:** HY000
  
  **Message:** No definer attribute for trigger '%s'.'%s'. The trigger will be activated under the authorization of the invoker, which may have insufficient privileges. Please recreate the trigger.

- **Error number:** 1455; **Symbol:** ER_OLD_FILE_FORMAT; **SQLSTATE:** HY000
  
  **Message:** '%s' has an old format, you should re-create the '%s' object(s)

- **Error number:** 1456; **Symbol:** ER_SP_RECURSION_LIMIT; **SQLSTATE:** HY000
  
  **Message:** Recursive limit %d (as set by the max_sp_recursion_depth variable) was exceeded for routine %s

- **Error number:** 1457; **Symbol:** ER_SP_PROC_TABLE_CORRUPT; **SQLSTATE:** HY000
  
  **Message:** Failed to load routine %s. The table mysql.proc is missing, corrupt, or contains bad data (internal code %d)

- **Error number:** 1458; **Symbol:** ER_SP_WRONG_NAME; **SQLSTATE:** 42000
  
  **Message:** Incorrect routine name '%s'

- **Error number:** 1459; **Symbol:** ER_TABLE_NEEDS_UPGRADE; **SQLSTATE:** HY000
  
  **Message:** Table upgrade required. Please do "REPAIR TABLE `%s`" or dump/reload to fix it!

- **Error number:** 1460; **Symbol:** ER_SP_NO_AGGREGATE; **SQLSTATE:** 42000
  
  **Message:** AGGREGATE is not supported for stored functions

- **Error number:** 1461; **Symbol:** ER_MAX_PREPARED_STMT_COUNT_REACHED; **SQLSTATE:** 42000
  
  **Message:** Can't create more than max_prepared_stmt_count statements (current value: %lu)

- **Error number:** 1462; **Symbol:** ER_VIEW_RECURSIVE; **SQLSTATE:** HY000
  
  **Message:** `%%s` contains view recursion

- **Error number:** 1463; **Symbol:** ER_NON_GROUPING_FIELD_USED; **SQLSTATE:** 42000
  
  **Message:** Non-grouping field '%s' is used in %s clause

- **Error number:** 1464; **Symbol:** ER_TABLE_CANT_HANDLE_SPKEYS; **SQLSTATE:** HY000
  
  **Message:** The used table type doesn't support SPATIAL indexes

- **Error number:** 1465; **Symbol:** ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA; **SQLSTATE:** HY000
Server Error Message Reference

Message: Triggers can not be created on system tables
• Error number: 1466; Symbol: ER_REMOVED_SPACES; SQLSTATE: HY000
  Message: Leading spaces are removed from name '%s'
• Error number: 1467; Symbol: ER_AUTOINC_READ_FAILED; SQLSTATE: HY000
  Message: Failed to read auto-increment value from storage engine
• Error number: 1468; Symbol: ER_USERNAME; SQLSTATE: HY000
  Message: user name
• Error number: 1469; Symbol: ER_HOSTNAME; SQLSTATE: HY000
  Message: host name
• Error number: 1470; Symbol: ER_WRONG_STRING_LENGTH; SQLSTATE: HY000
  Message: String '%s' is too long for %s (should be no longer than %d)
• Error number: 1471; Symbol: ER_NON_INSERTABLE_TABLE; SQLSTATE: HY000
  Message: The target table %s of the %s is not insertable-into
• Error number: 1472; Symbol: ER_ADMIN_WRONG_MRG_TABLE; SQLSTATE: HY000
  Message: Table '%s' is differently defined or of non-MyISAM type or doesn't exist
• Error number: 1473; Symbol: ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT; SQLSTATE: HY000
  Message: Too high level of nesting for select
• Error number: 1474; Symbol: ER_NAME_BECOMES_EMPTY; SQLSTATE: HY000
  Message: Name '%s' has become ''
• Error number: 1475; Symbol: ER_AMBIGUOUS_FIELD_TERM; SQLSTATE: HY000
  Message: First character of the FIELDS TERMINATED string is ambiguous; please use non-optional and non-empty FIELDS ENCLOSED BY
• Error number: 1476; Symbol: ER_FOREIGN_SERVER_EXISTS; SQLSTATE: HY000
  Message: The foreign server, %s, you are trying to create already exists.
• Error number: 1477; Symbol: ER_FOREIGN_SERVER_DOESNT_EXIST; SQLSTATE: HY000
  Message: The foreign server name you are trying to reference does not exist. Data source error: %s
• Error number: 1478; Symbol: ER_ILLEGAL_HA_CREATE_OPTION; SQLSTATE: HY000
  Message: Table storage engine '%s' does not support the create option '%s'
• Error number: 1479; Symbol: ER_PARTITION_REQUIRES_VALUES_ERROR; SQLSTATE: HY000
  Message: Syntax error: %s PARTITIONING requires definition of VALUES %s for each partition
- Error number: 1480; Symbol: ER_PARTITION_WRONG_VALUES_ERROR; SQLSTATE: HY000
  Message: Only %s PARTITIONING can use VALUES %s in partition definition
- Error number: 1481; Symbol: ER_PARTITION_MAXVALUE_ERROR; SQLSTATE: HY000
  Message: MAXVALUE can only be used in last partition definition
- Error number: 1482; Symbol: ER_PARTITION_SUBPARTITION_ERROR; SQLSTATE: HY000
  Message: Subpartitions can only be hash partitions and by key
- Error number: 1483; Symbol: ER_PARTITION_SUBPART_MIX_ERROR; SQLSTATE: HY000
  Message: Must define subpartitions on all partitions if on one partition
- Error number: 1484; Symbol: ER_PARTITION_WRONG_NO_PART_ERROR; SQLSTATE: HY000
  Message: Wrong number of partitions defined, mismatch with previous setting
- Error number: 1485; Symbol: ER_PARTITION_WRONG_NO_SUBPART_ERROR; SQLSTATE: HY000
  Message: Wrong number of subpartitions defined, mismatch with previous setting
- Error number: 1486; Symbol: ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR; SQLSTATE: HY000
  Message: Constant/Random expression in (sub)partitioning function is not allowed
  In 5.5.1: ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was renamed to
  ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR.
  ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was removed after 5.5.0.
- Error number: 1486; Symbol: ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR; SQLSTATE: HY000
  Message: Constant, random or timezone-dependent expressions in (sub)partitioning function are not
  allowed
  In 5.5.1: ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was renamed to
  ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR.
  ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR was added in 5.5.1.
- Error number: 1487; Symbol: ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR; SQLSTATE: HY000
  Message: Expression in RANGE/LIST VALUES must be constant
- Error number: 1488; Symbol: ER_FIELD_NOT_FOUND_PART_ERROR; SQLSTATE: HY000
  Message: Field in list of fields for partition function not found in table
- Error number: 1489; Symbol: ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR; SQLSTATE: HY000
  Message: List of fields is only allowed in KEY partitions
- Error number: 1490; Symbol: ER_INCONSISTENT_PARTITION_INFO_ERROR; SQLSTATE: HY000
  Message: The partition info in the frm file is not consistent with what can be written into the frm file
• Error number: 1491; Symbol: `ER_PARTITION_FUNC_NOT_ALLOWED_ERROR`; SQLSTATE: `HY000`
Message: The %s function returns the wrong type

• Error number: 1492; Symbol: `ER_PARTITIONS_MUST_BE_DEFINED_ERROR`; SQLSTATE: `HY000`
Message: For %s partitions each partition must be defined

• Error number: 1493; Symbol: `ER_RANGE_NOT_INCREASING_ERROR`; SQLSTATE: `HY000`
Message: VALUES LESS THAN value must be strictly increasing for each partition

• Error number: 1494; Symbol: `ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR`; SQLSTATE: `HY000`
Message: VALUES value must be of same type as partition function

• Error number: 1495; Symbol: `ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR`; SQLSTATE: `HY000`
Message: Multiple definition of same constant in list partitioning

• Error number: 1496; Symbol: `ER_PARTITION_ENTRY_ERROR`; SQLSTATE: `HY000`
Message: Partitioning can not be used stand-alone in query

• Error number: 1497; Symbol: `ER_MIX_HANDLER_ERROR`; SQLSTATE: `HY000`
Message: The mix of handlers in the partitions is not allowed in this version of MySQL

• Error number: 1498; Symbol: `ER_PARTITION_NOT_DEFINED_ERROR`; SQLSTATE: `HY000`
Message: For the partitioned engine it is necessary to define all %s

• Error number: 1499; Symbol: `ER_TOO_MANY_PARTITIONS_ERROR`; SQLSTATE: `HY000`
Message: Too many partitions (including subpartitions) were defined

• Error number: 1500; Symbol: `ER_SUBPARTITION_ERROR`; SQLSTATE: `HY000`
Message: It is only possible to mix RANGE/LIST partitioning with HASH/KEY partitioning for subpartitioning

• Error number: 1501; Symbol: `ER_CANT_CREATE_HANDLER_FILE`; SQLSTATE: `HY000`
Message: Failed to create specific handler file

• Error number: 1502; Symbol: `ER_BLOB_FIELD_IN_PART_FUNC_ERROR`; SQLSTATE: `HY000`
Message: A BLOB field is not allowed in partition function

• Error number: 1503; Symbol: `ER_UNIQUE_KEY_NEED_ALL_FIELDS_IN_PF`; SQLSTATE: `HY000`
Message: A %s must include all columns in the table’s partitioning function

• Error number: 1504; Symbol: `ER_NO_PARTS_ERROR`; SQLSTATE: `HY000`
Message: Number of %s = 0 is not an allowed value

• Error number: 1505; Symbol: `ER_PARTITION_MGMT_ON_NONPARTITIONED`; SQLSTATE: `HY000`
Message: Partition management on a not partitioned table is not possible

- Error number: 1506; Symbol: ER_FOREIGN_KEY_ON_PARTITIONED; SQLSTATE: HY000
Message: Foreign key clause is not yet supported in conjunction with partitioning

- Error number: 1507; Symbol: ER_DROP_PARTITION_NON_EXISTENT; SQLSTATE: HY000
Message: Error in list of partitions to %s

- Error number: 1508; Symbol: ER_DROP_LAST_PARTITION; SQLSTATE: HY000
Message: Cannot remove all partitions, use DROP TABLE instead

- Error number: 1509; Symbol: ER_COALESCE_ONLY_ON_HASH_PARTITION; SQLSTATE: HY000
Message: COALESCE PARTITION can only be used on HASH/KEY partitions

- Error number: 1510; Symbol: ER_REORG_HASH_ONLY_ONSAME_NO; SQLSTATE: HY000
Message: REORGANIZE PARTITION can only be used to reorganize partitions not to change their numbers

- Error number: 1511; Symbol: ER_REORG_NO_PARAM_ERROR; SQLSTATE: HY000
Message: REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH PARTITIONs

- Error number: 1512; Symbol: ER_ONLY_ON_RANGE_LIST_PARTITION; SQLSTATE: HY000
Message: %s PARTITION can only be used on RANGE/LIST partitions

- Error number: 1513; Symbol: ER_ADD_PARTITION_SUBPART_ERROR; SQLSTATE: HY000
Message: Trying to Add partition(s) with wrong number of subpartitions

- Error number: 1514; Symbol: ER_ADD_PARTITION_NO_NEW_PARTITION; SQLSTATE: HY000
Message: At least one partition must be added

- Error number: 1515; Symbol: ER_COALESCE_PARTITION_NO_PARTITION; SQLSTATE: HY000
Message: At least one partition must be coalesced

- Error number: 1516; Symbol: ER_REORG_PARTITION_NOT_EXIST; SQLSTATE: HY000
Message: More partitions to reorganize than there are partitions

- Error number: 1517; Symbol: ER_SAME_NAME_PARTITION; SQLSTATE: HY000
Message: Duplicate partition name %s

- Error number: 1518; Symbol: ER_NO_BINLOG_ERROR; SQLSTATE: HY000
Message: It is not allowed to shut off binlog on this command

- Error number: 1519; Symbol: ER_CONSECUTIVE_REORG_PARTITIONS; SQLSTATE: HY000
Message: When reorganizing a set of partitions they must be in consecutive order
Server Error Message Reference

- Error number: 1520; Symbol: ER_REORG_OUTSIDE_RANGE; SQLSTATE: HY000
  Message: Reorganize of range partitions cannot change total ranges except for last partition where it can extend the range

- Error number: 1521; Symbol: ER_PARTITION_FUNCTION_FAILURE; SQLSTATE: HY000
  Message: Partition function not supported in this version for this handler

- Error number: 1522; Symbol: ER_PART_STATE_ERROR; SQLSTATE: HY000
  Message: Partition state cannot be defined from CREATE/ALTER TABLE

- Error number: 1523; Symbol: ER_LIMITED_PART_RANGE; SQLSTATE: HY000
  Message: The %s handler only supports 32 bit integers in VALUES

- Error number: 1524; Symbol: ER_PLUGIN_IS_NOT_LOADED; SQLSTATE: HY000
  Message: Plugin '%%s' is not loaded

- Error number: 1525; Symbol: ER_WRONG_VALUE; SQLSTATE: HY000
  Message: Incorrect %s value: '%s'

- Error number: 1526; Symbol: ER_NO_PARTITION_FOR_GIVEN_VALUE; SQLSTATE: HY000
  Message: Table has no partition for value %s

- Error number: 1527; Symbol: ER_FILEGROUP_OPTION_ONLY_ONCE; SQLSTATE: HY000
  Message: It is not allowed to specify %s more than once

- Error number: 1528; Symbol: ER_CREATE_FILEGROUP_FAILED; SQLSTATE: HY000
  Message: Failed to create %s

- Error number: 1529; Symbol: ER_DROP_FILEGROUP_FAILED; SQLSTATE: HY000
  Message: Failed to drop %s

- Error number: 1530; Symbol: ER_TABLESPACE_AUTO_EXTEND_ERROR; SQLSTATE: HY000
  Message: The handler doesn't support autoextend of tablespaces

- Error number: 1531; Symbol: ER_WRONG_SIZE_NUMBER; SQLSTATE: HY000
  Message: A size parameter was incorrectly specified, either number or on the form 10M

- Error number: 1532; Symbol: ER_SIZE_OVERFLOW_ERROR; SQLSTATE: HY000
  Message: The size number was correct but we don't allow the digit part to be more than 2 billion

- Error number: 1533; Symbol: ER.Alter_FILEGROUP_FAILED; SQLSTATE: HY000
  Message: Failed to alter: %s

- Error number: 1534; Symbol: ER_BINLOG_ROW_LOGGING_FAILED; SQLSTATE: HY000
  Message: Writing one row to the row-based binary log failed
Server Error Message Reference

- **Error number:** 1535; Symbol: ER_BINLOG_ROW_WRONG_TABLE_DEF; SQLSTATE: HY000
  
  Message: Table definition on master and slave does not match: %s

- **Error number:** 1536; Symbol: ER_BINLOG_ROW_RBR_TO_SBR; SQLSTATE: HY000
  
  Message: Slave running with --log-slave-updates must use row-based binary logging to be able to replicate row-based binary log events

- **Error number:** 1537; Symbol: ER_EVENT_ALREADY_EXISTS; SQLSTATE: HY000
  
  Message: Event '%s' already exists

- **Error number:** 1538; Symbol: ER_EVENT_STORE_FAILED; SQLSTATE: HY000
  
  Message: Failed to store event %s. Error code %d from storage engine.

- **Error number:** 1539; Symbol: ER_EVENT_DOES_NOT_EXIST; SQLSTATE: HY000
  
  Message: Unknown event '%s'

- **Error number:** 1540; Symbol: ER_EVENT_CANT_ALTER; SQLSTATE: HY000
  
  Message: Failed to alter event '%s'

- **Error number:** 1541; Symbol: ER_EVENT_DROP_FAILED; SQLSTATE: HY000
  
  Message: Failed to drop %s

- **Error number:** 1542; Symbol: ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG; SQLSTATE: HY000
  
  Message: INTERVAL is either not positive or too big

- **Error number:** 1543; Symbol: ER_EVENT_ENDS_BEFORE_STARTS; SQLSTATE: HY000
  
  Message: ENDS is either invalid or before STARTS

- **Error number:** 1544; Symbol: ER_EVENT_EXEC_TIME_IN_THE_PAST; SQLSTATE: HY000
  
  Message: Event execution time is in the past. Event has been disabled

- **Error number:** 1545; Symbol: ER_EVENT_OPEN_TABLE_FAILED; SQLSTATE: HY000
  
  Message: Failed to open mysql.event

- **Error number:** 1546; Symbol: ER_EVENT_NEITHER_M_EXPR_NOR_M_AT; SQLSTATE: HY000
  
  Message: No datetime expression provided

- **Error number:** 1547; Symbol: ER_COL_COUNT_DOESNT_MATCH_CORRUPTED; SQLSTATE: HY000
  
  Message: Column count of mysql.%s is wrong. Expected %d, found %d. The table is probably corrupted

- **Error number:** 1548; Symbol: ER_CANNOT_LOAD_FROM_TABLE; SQLSTATE: HY000
  
  Message: Cannot load from mysql.%s. The table is probably corrupted

- **Error number:** 1549; Symbol: ER_EVENT_CANNOT_DELETE; SQLSTATE: HY000
Message: Failed to delete the event from mysql.event

- Error number: 1550; Symbol: ER_EVENT_COMPILE_ERROR; SQLSTATE: HY000
  Message: Error during compilation of event's body

- Error number: 1551; Symbol: ER_EVENTSAME_NAME; SQLSTATE: HY000
  Message: Same old and new event name

- Error number: 1552; Symbol: ER_EVENTDATA_TOO_LONG; SQLSTATE: HY000
  Message: Data for column '%s' too long

- Error number: 1553; Symbol: ER_DROPPINDEX_FK; SQLSTATE: HY000
  Message: Cannot drop index '%s': needed in a foreign key constraint

  InnoDB reports this error when you attempt to drop the last index that can enforce a particular referential constraint.

For optimal performance with DML statements, InnoDB requires an index to exist on foreign key columns, so that UPDATE and DELETE operations on a parent table can easily check whether corresponding rows exist in the child table. MySQL creates or drops such indexes automatically when needed, as a side-effect of CREATE TABLE, CREATE INDEX, and ALTER TABLE statements.

When you drop an index, InnoDB checks if the index is used for checking a foreign key constraint. It is still OK to drop the index if there is another index that can be used to enforce the same constraint. InnoDB prevents you from dropping the last index that can enforce a particular referential constraint.

- Error number: 1554; Symbol: ER_WARN_DEPRECATED_SYNTAX_WITH_VER; SQLSTATE: HY000
  Message: The syntax '%s' is deprecated and will be removed in MySQL %. Please use %s instead

- Error number: 1555; Symbol: ER_CANT_WRITE_LOCK_LOG_TABLE; SQLSTATE: HY000
  Message: You can't write-lock a log table. Only read access is possible

- Error number: 1556; Symbol: ER_CANT_LOCK_LOG_TABLE; SQLSTATE: HY000
  Message: You can't use locks with log tables.

- Error number: 1557; Symbol: ER_FOREIGN_DUPLICATE_KEY; SQLSTATE: 23000
  Message: Upholding foreign key constraints for table '%s', entry '%s', key %d would lead to a duplicate entry

- Error number: 1558; Symbol: ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE; SQLSTATE: HY000
  Message: Column count of mysql.%s is wrong. Expected %d, found %d. Created with MySQL %d, now running %d. Please use mysql_upgrade to fix this error.

- Error number: 1559; Symbol: ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR; SQLSTATE: HY000
  Message: Cannot switch out of the row-based binary log format when the session has open temporary tables
• Error number: 1560; Symbol: ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT; SQLSTATE: HY000
  Message: Cannot change the binary logging format inside a stored function or trigger
• Error number: 1561; Symbol: ER_NDB_CANT_SWITCH_BINLOG_FORMAT; SQLSTATE: HY000
  Message: The NDB cluster engine does not support changing the binlog format on the fly yet
• Error number: 1562; Symbol: ER_PARTITION_NO_TEMPORARY; SQLSTATE: HY000
  Message: Cannot create temporary table with partitions
• Error number: 1563; Symbol: ER_PARTITION_CONST_DOMAIN_ERROR; SQLSTATE: HY000
  Message: Partition constant is out of partition function domain
• Error number: 1564; Symbol: ER_PARTITION_FUNCTION_IS_NOT_ALLOWED; SQLSTATE: HY000
  Message: This partition function is not allowed
• Error number: 1565; Symbol: ER_DDL_LOG_ERROR; SQLSTATE: HY000
  Message: Error in DDL log
• Error number: 1566; Symbol: ER_NULL_IN_VALUES_LESS_THAN; SQLSTATE: HY000
  Message: Not allowed to use NULL value in VALUES LESS THAN
• Error number: 1567; Symbol: ER_WRONG_PARTITION_NAME; SQLSTATE: HY000
  Message: Incorrect partition name
• Error number: 1568; Symbol: ER_CANT_CHANGE_TX_ISOLATION; SQLSTATE: 25001
  Message: Transaction isolation level can’t be changed while a transaction is in progress
• Error number: 1569; Symbol: ER_DUP_ENTRY_AUTOINCREMENT_CASE; SQLSTATE: HY000
  Message: ALTER TABLE causes auto_increment resequencing, resulting in duplicate entry ’%s’ for key ’%s’
• Error number: 1570; Symbol: ER_EVENT_MODIFY_QUEUE_ERROR; SQLSTATE: HY000
  Message: Internal scheduler error %d
• Error number: 1571; Symbol: ER_EVENT_SET_VAR_ERROR; SQLSTATE: HY000
  Message: Error during starting/stopping of the scheduler. Error code %u
• Error number: 1572; Symbol: ER_PARTITION_MERGE_ERROR; SQLSTATE: HY000
  Message: Engine cannot be used in partitioned tables
• Error number: 1573; Symbol: ER_CANT_ACTIVATE_LOG; SQLSTATE: HY000
  Message: Cannot activate ’%s’ log
• Error number: 1574; Symbol: ER_RBR_NOT_AVAILABLE; SQLSTATE: HY000
Server Error Message Reference

Message: The server was not built with row-based replication

• Error number: 1575; Symbol: ER_BASE64_DECODE_ERROR; SQLSTATE: HY000
  Message: Decoding of base64 string failed

• Error number: 1576; Symbol: ER_EVENT_RECURSION_FORBIDDEN; SQLSTATE: HY000
  Message: Recursion of EVENT DDL statements is forbidden when body is present

• Error number: 1577; Symbol: ER_EVENTS_DB_ERROR; SQLSTATE: HY000
  Message: Cannot proceed because system tables used by Event Scheduler were found damaged at server start
  To address this issue, try running mysql_upgrade.

• Error number: 1578; Symbol: ER_ONLY_INTEGERS_ALLOWED; SQLSTATE: HY000
  Message: Only integers allowed as number here

• Error number: 1579; Symbol: ER_UNSUPORTED_LOG_ENGINE; SQLSTATE: HY000
  Message: This storage engine cannot be used for log tables"

• Error number: 1580; Symbol: ER_BAD_LOG_STATEMENT; SQLSTATE: HY000
  Message: You cannot '%s' a log table if logging is enabled

• Error number: 1581; Symbol: ER_CANT_RENAME_LOG_TABLE; SQLSTATE: HY000
  Message: Cannot rename '%s'. When logging enabled, rename to/from log table must rename two tables: the log table to an archive table and another table back to '%s'

• Error number: 1582; Symbol: ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT; SQLSTATE: 42000
  Message: Incorrect parameter count in the call to native function '%s'

• Error number: 1583; Symbol: ER_WRONG_PARAMETERS_TO_NATIVE_FCT; SQLSTATE: 42000
  Message: Incorrect parameters in the call to native function '%s'

• Error number: 1584; Symbol: ER_WRONG_PARAMETERS_TO_STORED_FCT; SQLSTATE: 42000
  Message: Incorrect parameters in the call to stored function '%s'

• Error number: 1585; Symbol: ER_NATIVE_FCT_NAME_COLLISION; SQLSTATE: HY000
  Message: This function '%s' has the same name as a native function

• Error number: 1586; Symbol: ER_DUP_ENTRY_WITH_KEY_NAME; SQLSTATE: 23000
  Message: Duplicate entry '%s' for key '%s'
  The format string for this error is also used with ER_DUP_ENTRY.

• Error number: 1587; Symbol: ER_BINLOG_PURGE_EMFILE; SQLSTATE: HY000
  Message: Too many files opened, please execute the command again
• Error number: 1588; Symbol: ER_EVENT_CANNOT_CREATE_IN_THE_PAST; SQLSTATE: HY000
Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

• Error number: 1589; Symbol: ER_EVENT_CANNOT_ALTER_IN_THE_PAST; SQLSTATE: HY000
Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

• Error number: 1590; Symbol: ER_SLAVE_INCIDENT; SQLSTATE: HY000
Message: The incident %s occurred on the master. Message: %s

• Error number: 1591; Symbol: ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT; SQLSTATE: HY000
Message: Table has no partition for some existing values

• Error number: 1592; Symbol: ER_BINLOG_UNSAFE_STATEMENT; SQLSTATE: HY000
Message: Unsafe statement written to the binary log using statement format since BINLOG_FORMAT = STATEMENT. %s

• Error number: 1593; Symbol: ER_SLAVE_FATAL_ERROR; SQLSTATE: HY000
Message: Fatal error: %s

• Error number: 1594; Symbol: ER_SLAVE_RELAY_LOG_READ_FAILURE; SQLSTATE: HY000
Message: Relay log read failure: %s

• Error number: 1595; Symbol: ER_SLAVE_RELAY_LOG_WRITE_FAILURE; SQLSTATE: HY000
Message: Relay log write failure: %s

• Error number: 1596; Symbol: ER_SLAVE_CREATE_EVENT_FAILURE; SQLSTATE: HY000
Message: Failed to create %s

• Error number: 1597; Symbol: ER_SLAVE_MASTER_COM_FAILURE; SQLSTATE: HY000
Message: Master command %s failed: %s

• Error number: 1598; Symbol: ER_BINLOG_LOGGING_IMPOSSIBLE; SQLSTATE: HY000
Message: Binary logging not possible. Message: %s

• Error number: 1599; Symbol: ER_VIEW_NO_CREATION_CTX; SQLSTATE: HY000
Message: View `%s`.`%s` has no creation context

• Error number: 1600; Symbol: ER_VIEW_INVALID_CREATION_CTX; SQLSTATE: HY000
Message: Creation context of view `%s`.`%s` is invalid

• Error number: 1601; Symbol: ER_SR_INVALID_CREATION_CTX; SQLSTATE: HY000
Message: Creation context of stored routine `%s`.`%s` is invalid

• Error number: 1602; Symbol: ER_TRG_CORRUPTED_FILE; SQLSTATE: HY000
Message: Corrupted TRG file for table `%s`.`%s`
- Error number: 1603; Symbol: ER_TRG_NO_CREATION_CTX; SQLSTATE: HY000
  Message: Triggers for table `%s`.`%s` have no creation context
- Error number: 1604; Symbol: ER_TRG_INVALID_CREATION_CTX; SQLSTATE: HY000
  Message: Trigger creation context of table `%s`.`%s` is invalid
- Error number: 1605; Symbol: ER_EVENT_INVALID_CREATION_CTX; SQLSTATE: HY000
  Message: Creation context of event `%s`.`%s` is invalid
- Error number: 1606; Symbol: ER_TRG_CANT_OPEN_TABLE; SQLSTATE: HY000
  Message: Cannot open table for trigger `%s`.`%s`
- Error number: 1607; Symbol: ER_CANT_CREATE_SROUTINE; SQLSTATE: HY000
  Message: Cannot create stored routine `%s`. Check warnings
- Error number: 1608; Symbol: ER_SLAVE_AMBIGOUS_EXEC_MODE; SQLSTATE: HY000
  Message: Ambiguous slave modes combination. %s
  In 5.5.3: ER_SLAVE_AMBIGOUS_EXEC_MODE was renamed to ER_NEVER_USED.
  ER_SLAVE_AMBIGOUS_EXEC_MODE was removed after 5.5.2.
- Error number: 1608; Symbol: ER_NEVER_USED; SQLSTATE: HY000
  Message: Ambiguous slave modes combination. %s
  In 5.5.3: ER_SLAVE_AMBIGOUS_EXEC_MODE was renamed to ER_NEVER_USED.
  ER_NEVER_USED was added in 5.5.3.
- Error number: 1609; Symbol: ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT; SQLSTATE: HY000
  Message: The BINLOG statement of type `%s` was not preceded by a format description BINLOG statement.
- Error number: 1610; Symbol: ER_SLAVE_CORRUPT_EVENT; SQLSTATE: HY000
  Message: Corrupted replication event was detected
- Error number: 1611; Symbol: ER_LOAD_DATA_INVALID_COLUMN; SQLSTATE: HY000
  Message: Invalid column reference (%s) in LOAD DATA
- Error number: 1612; Symbol: ER_LOG_PURGE_NO_FILE; SQLSTATE: HY000
  Message: Being purged log %s was not found
- Error number: 1613; Symbol: ER_XA_RBTIMEOUT; SQLSTATE: XA106
  Message: XA_RBTIMEOUT: Transaction branch was rolled back: took too long
Server Error Message Reference

- **Error number:** 1614; **Symbol:** ER_XA_RBDEADLOCK; **SQLSTATE:** XA102
  Message: XA_RBDEADLOCK: Transaction branch was rolled back: deadlock was detected

- **Error number:** 1615; **Symbol:** ER_NEED_REPREPARE; **SQLSTATE:** HY000
  Message: Prepared statement needs to be re-prepared

- **Error number:** 1616; **Symbol:** ER_DELAYED_NOT_SUPPORTED; **SQLSTATE:** HY000
  Message: DELAYED option not supported for table '%s'

- **Error number:** 1617; **Symbol:** WARN_NO_MASTER_INFO; **SQLSTATE:** HY000
  Message: The master info structure does not exist

- **Error number:** 1618; **Symbol:** WARN_OPTION_IGNORED; **SQLSTATE:** HY000
  Message: <%s> option ignored

- **Error number:** 1619; **Symbol:** WARN_PLUGIN_DELETE_BUILTIN; **SQLSTATE:** HY000
  Message: Built-in plugins cannot be deleted

- **Error number:** 1620; **Symbol:** WARN_PLUGIN_BUSY; **SQLSTATE:** HY000
  Message: Plugin is busy and will be uninstalled on shutdown

- **Error number:** 1621; **Symbol:** ER_VARIABLE_IS_READONLY; **SQLSTATE:** HY000
  Message: %s variable '%s' is read-only. Use SET %s to assign the value

- **Error number:** 1622; **Symbol:** ER_WARN_ENGINE_TRANSACTION_ROLLBACK; **SQLSTATE:** HY000
  Message: Storage engine %s does not support rollback for this statement. Transaction rolled back and must be restarted

- **Error number:** 1623; **Symbol:** ER_SLAVE_HEARTBEAT_FAILURE; **SQLSTATE:** HY000
  Message: Unexpected master's heartbeat data: %s

- **Error number:** 1624; **Symbol:** ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE; **SQLSTATE:** HY000
  Message: The requested value for the heartbeat period is either negative or exceeds the maximum allowed (%s seconds).

- **Error number:** 1625; **Symbol:** ER_NDB_REPLICATION_SCHEMA_ERROR; **SQLSTATE:** HY000
  Message: Bad schema for mysql.ndb_replication table. Message: %s

- **Error number:** 1626; **Symbol:** ER_CONFLICT_FN_PARSE_ERROR; **SQLSTATE:** HY000
  Message: Error in parsing conflict function. Message: %s

- **Error number:** 1627; **Symbol:** ER_EXCEPTIONS_WRITE_ERROR; **SQLSTATE:** HY000
  Message: Write to exceptions table failed. Message: %s"

- **Error number:** 1628; **Symbol:** ER_TOO_LONG_TABLE_COMMENT; **SQLSTATE:** HY000
  Message: Comment for table '%s' is too long (max = %lu)
Server Error Message Reference

- Error number: 1629; Symbol: ER_TOO_LONG_FIELD_COMMENT; SQLSTATE: HY000
  Message: Comment for field '%s' is too long (max = %lu)

- Error number: 1630; Symbol: ER_FUNC_INEXISTENT_NAME_COLLISION; SQLSTATE: 42000
  Message: FUNCTION %s does not exist. Check the ‘Function Name Parsing and Resolution’ section in the Reference Manual

- Error number: 1631; Symbol: ER_DATABASE_NAME; SQLSTATE: HY000
  Message: Database

- Error number: 1632; Symbol: ER_TABLE_NAME; SQLSTATE: HY000
  Message: Table

- Error number: 1633; Symbol: ER_PARTITION_NAME; SQLSTATE: HY000
  Message: Partition

- Error number: 1634; Symbol: ER_SUBPARTITION_NAME; SQLSTATE: HY000
  Message: Subpartition

- Error number: 1635; Symbol: ER_TEMPORARY_NAME; SQLSTATE: HY000
  Message: Temporary

- Error number: 1636; Symbol: ER_RENAMED_NAME; SQLSTATE: HY000
  Message: Renamed

- Error number: 1637; Symbol: ER_TOO_MANY_CONCURRENT_TRXS; SQLSTATE: HY000
  Message: Too many active concurrent transactions

- Error number: 1638; Symbol: WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED; SQLSTATE: HY000
  Message: Non-ASCII separator arguments are not fully supported

- Error number: 1639; Symbol: ER_DEBUG_SYNC_TIMEOUT; SQLSTATE: HY000
  Message: debug sync point wait timed out

- Error number: 1640; Symbol: ER_DEBUG_SYNC_HIT_LIMIT; SQLSTATE: HY000
  Message: debug sync point hit limit reached

- Error number: 1641; Symbol: ER_DUP_SIGNAL_SET; SQLSTATE: 42000
  Message: Duplicate condition information item '%s'

- Error number: 1642; Symbol: ER_SIGNAL_WARN; SQLSTATE: 01000
  Message: Unhandled user-defined warning condition

- Error number: 1643; Symbol: ER_SIGNAL_NOT_FOUND; SQLSTATE: 02000
  Message: Unhandled user-defined not found condition
• Error number: 1644; Symbol: ER_SIGNAL_EXCEPTION; SQLSTATE: HY000
  Message: Unhandled user-defined exception condition

• Error number: 1645; Symbol: ER_RESIGNAL_WITHOUT_ACTIVE_HANDLER; SQLSTATE: 0K000
  Message: RESIGNAL when handler not active

• Error number: 1646; Symbol: ER_SIGNAL_BAD_CONDITION_TYPE; SQLSTATE: HY000
  Message: SIGNAL/RESIGNAL can only use a CONDITION defined with SQLSTATE

• Error number: 1647; Symbol: WARN_COND_ITEM_TRUNCATED; SQLSTATE: HY000
  Message: Data truncated for condition item '%s'

• Error number: 1648; Symbol: ER_COND_ITEM_TOO_LONG; SQLSTATE: HY000
  Message: Data too long for condition item '%s'

• Error number: 1649; Symbol: ER_UNKNOWN_LOCALE; SQLSTATE: HY000
  Message: Unknown locale: '%s'

• Error number: 1650; Symbol: ER_SLAVE_IGNORE_SERVER_IDS; SQLSTATE: HY000
  Message: The requested server id %d clashes with the slave startup option --replicate-same-server-id

• Error number: 1651; Symbol: ER_QUERY_CACHE_DISABLED; SQLSTATE: HY000
  Message: Query cache is disabled; restart the server with query_cache_type=1 to enable it

• Error number: 1652; Symbol: ERSAME_NAME_PARTITION_FIELD; SQLSTATE: HY000
  Message: Duplicate partition field name '%s'

• Error number: 1653; Symbol: ER_PARTITION_COLUMN_LIST_ERROR; SQLSTATE: HY000
  Message: Inconsistency in usage of column lists for partitioning

• Error number: 1654; Symbol: ER_WRONG_TYPE_COLUMN_VALUE_ERROR; SQLSTATE: HY000
  Message: Partition column values of incorrect type

• Error number: 1655; Symbol: ER_TOO_MANY_PARTITION_FUNC_FIELDS_ERROR; SQLSTATE: HY000
  Message: Too many fields in '%s'

• Error number: 1656; Symbol: ER_MAXVALUE_IN_VALUES_IN; SQLSTATE: HY000
  Message: Cannot use MAXVALUE as value in VALUES IN

• Error number: 1657; Symbol: ER_TOO_MANY_VALUES_ERROR; SQLSTATE: HY000
  Message: Cannot have more than one value for this type of %s partitioning

• Error number: 1658; Symbol: ER_ROW_SINGLE_PARTITION_FIELD_ERROR; SQLSTATE: HY000
  Message: Row expressions in VALUES IN only allowed for multi-field column partitioning
Server Error Message Reference

- **Error number: 1659; Symbol: ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD; SQLSTATE: HY000**
  Message: Field '%s' is of a not allowed type for this type of partitioning

- **Error number: 1660; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: The total length of the partitioning fields is too large

- **Error number: 1661; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since both row-incapable engines and statement-incapable engines are involved.
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1662; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since BINLOG_FORMAT = ROW and at least one table uses a storage engine limited to statement-based logging.
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1663; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since statement is unsafe, storage engine is limited to statement-based logging, and BINLOG_FORMAT = MIXED. %s
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1664; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since statement is in row format and at least one table uses a storage engine limited to statement-based logging.
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1665; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since BINLOG_FORMAT = STATEMENT and at least one table uses a storage engine limited to row-based logging.%s
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1666; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since BINLOG_FORMAT = STATEMENT.
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.

- **Error number: 1667; Symbol: ER_PARTITION_FIELDS_TOO_LONG; SQLSTATE: HY000**
  Message: Cannot execute statement: impossible to write to binary log since more than one engine is involved and at least one engine is self-logging.
  
  ER_PARTITION_FIELDS_TOO_LONG was added in 5.5.3.
Server Error Message Reference

- Error number: 1668; Symbol: ER_BINLOG_UNSAFE_LIMIT; SQLSTATE: HY000
  Message: The statement is unsafe because it uses a LIMIT clause. This is unsafe because the set of rows included cannot be predicted.
  ER_BINLOG_UNSAFE_LIMIT was added in 5.5.3.

- Error number: 1669; Symbol: ER_BINLOG_UNSAFE_INSERTDELAYED; SQLSTATE: HY000
  Message: The statement is unsafe because it uses INSERT DELAYED. This is unsafe because the times when rows are inserted cannot be predicted.
  ER_BINLOG_UNSAFE_INSERT_DELAYED was added in 5.5.3.

- Error number: 1670; Symbol: ER_BINLOG_UNSAFE_SYSTEM_TABLE; SQLSTATE: HY000
  Message: The statement is unsafe because it uses the general log, slow query log, or performance_schema table(s). This is unsafe because system tables may differ on slaves.
  ER_BINLOG_UNSAFE_SYSTEM_TABLE was added in 5.5.3.

- Error number: 1671; Symbol: ER_BINLOG_UNSAFE_AUTOINC_COLUMNS; SQLSTATE: HY000
  Message: Statement is unsafe because it invokes a trigger or a stored function that inserts into an AUTO_INCREMENT column. Inserted values cannot be logged correctly.
  ER_BINLOG_UNSAFE_AUTOINC_COLUMNS was added in 5.5.3.

- Error number: 1672; Symbol: ER_BINLOG_UNSAFE_UDF; SQLSTATE: HY000
  Message: Statement is unsafe because it uses a UDF which may not return the same value on the slave.
  ER_BINLOG_UNSAFE_UDF was added in 5.5.3.

- Error number: 1673; Symbol: ER_BINLOG_UNSAFE_SYSTEM_VARIABLE; SQLSTATE: HY000
  Message: Statement is unsafe because it uses a system variable that may have a different value on the slave.
  ER_BINLOG_UNSAFE_SYSTEM_VARIABLE was added in 5.5.3.

- Error number: 1674; Symbol: ER_BINLOG_UNSAFE_SYSTEM_FUNCTION; SQLSTATE: HY000
  Message: Statement is unsafe because it uses a system function that may return a different value on the slave.
  ER_BINLOG_UNSAFE_SYSTEM_FUNCTION was added in 5.5.3.

- Error number: 1675; Symbol: ER_BINLOG_UNSAFE_NONTRANS_AFTERTX; SQLSTATE: HY000
  Message: Statement is unsafe because it accesses a non-transactional table after accessing a transactional table within the same transaction.
  ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS was added in 5.5.3.

- Error number: 1676; Symbol: ER_MESSAGE_AND_STATEMENT; SQLSTATE: HY000
  Message: %s Statement: %s
**ER_MESSAGE_AND_STATEMENT** was added in 5.5.3.

- **Error number: 1677; Symbol: ER_SLAVE_CONVERSION_FAILED; SQLSTATE: HY000**
  
  Message: Column %d of table '%s.%s' cannot be converted from type '%s' to type '%s'

**ER_SLAVE_CONVERSION_FAILED** was added in 5.5.3.

- **Error number: 1678; Symbol: ER_SLAVE_CANT_CREATE_CONVERSION; SQLSTATE: HY000**
  
  Message: Can't create conversion table for table '%s.%s'

**ER_SLAVE_CANT_CREATE_CONVERSION** was added in 5.5.3.

- **Error number: 1679; Symbol: ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT; SQLSTATE: HY000**
  
  Message: Cannot modify @@session.binlog_format inside a transaction

**ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT** was added in 5.5.3.

- **Error number: 1680; Symbol: ER_PATH_LENGTH; SQLSTATE: HY000**
  
  Message: The path specified for %s is too long.

**ER_PATH_LENGTH** was added in 5.5.3.

- **Error number: 1681; Symbol: ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT; SQLSTATE: HY000**
  
  Message: '%s' is deprecated and will be removed in a future release.

**ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT** was added in 5.5.3.

- **Error number: 1682; Symbol: ER_WRONG_NATIVE_TABLE_STRUCTURE; SQLSTATE: HY000**
  
  Message: Native table '%s'.'%s' has the wrong structure

**ER_WRONG_NATIVE_TABLE_STRUCTURE** was added in 5.5.3.

- **Error number: 1683; Symbol: ER_WRONG_PERFSHEMA_USAGE; SQLSTATE: HY000**
  
  Message: Invalid performance_schema usage.

**ER_WRONG_PERFSHEMA_USAGE** was added in 5.5.3.

- **Error number: 1684; Symbol: ER_WARN_I_S_SKIPPED_TABLE; SQLSTATE: HY000**
  
  Message: Table '%s'.'%s' was skipped since its definition is being modified by concurrent DDL statement

**ER_WARN_I_S_SKIPPED_TABLE** was added in 5.5.3.

- **Error number: 1685; Symbol: ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT; SQLSTATE: HY000**
  
  Message: Cannot modify @@session.binlog_direct_non_transactional_updates inside a transaction

**ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT** was added in 5.5.3.
• Error number: 1686; Symbol: ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT; SQLSTATE: HY000
Message: Cannot change the binlog direct flag inside a stored function or trigger
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT was added in 5.5.3.

• Error number: 1687; Symbol: ER_SPATIAL_MUST_HAVE_GEOM_COL; SQLSTATE: 42000
Message: A SPATIAL index may only contain a geometrical type column
ER_SPATIAL_MUST_HAVE_GEOM_COL was added in 5.5.2.

• Error number: 1688; Symbol: ER_TOO_LONG_INDEX_COMMENT; SQLSTATE: HY000
Message: Comment for index '%s' is too long (max = %lu)
ER_TOO_LONG_INDEX_COMMENT was added in 5.5.3.

• Error number: 1689; Symbol: ER_LOCK_ABORTED; SQLSTATE: HY000
Message: Wait on a lock was aborted due to a pending exclusive lock
ER_LOCK_ABORTED was added in 5.5.4.

• Error number: 1690; Symbol: ER_DATA_OUT_OF_RANGE; SQLSTATE: 22003
Message: %s value is out of range in '%s'
ER_DATA_OUT_OF_RANGE was added in 5.5.5.

• Error number: 1691; Symbol: ER_WRONG_SPVAR_TYPE_IN_LIMIT; SQLSTATE: HY000
Message: A variable of a non-integer based type in LIMIT clause
ER_WRONG_SPVAR_TYPE_IN_LIMIT was added in 5.5.5.

• Error number: 1692; Symbol:
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE; SQLSTATE: HY000
Message: Mixing self-logging and non-self-logging engines in a statement is unsafe.
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE was added in 5.5.5.

• Error number: 1693; Symbol: ER_BINLOG_UNSAFE_MIXED_STATEMENT; SQLSTATE: HY000
Message: Statement accesses nontransactional table as well as transactional or temporary table, and writes to any of them.
ER_BINLOG_UNSAFE_MIXED_STATEMENT was added in 5.5.5.

• Error number: 1694; Symbol: ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN; SQLSTATE: HY000
Message: Cannot modify @@session.sql_log_bin inside a transaction
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN was added in 5.5.5.

• Error number: 1695; Symbol: ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN; SQLSTATE: HY000
Message: Cannot change the sql_log_bin inside a stored function or trigger

**ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN** was added in 5.5.5.

- Error number: 1696; Symbol: **ER_FAILED_READ_FROM_PAR_FILE**; SQLSTATE: HY000
  
  Message: Failed to read from the .par file

  **ER_FAILED_READ_FROM_PAR_FILE** was added in 5.5.5.

- Error number: 1697; Symbol: **ER_VALUES_IS_NOT_INT_TYPE_ERROR**; SQLSTATE: HY000
  
  Message: VALUES value for partition "%%s" must have type INT

  **ER_VALUES_IS_NOT_INT_TYPE_ERROR** was added in 5.5.7.

- Error number: 1698; Symbol: **ER_ACCESS_DENIED_NO_PASSWORD_ERROR**; SQLSTATE: 28000
  
  Message: Access denied for user '%s'@'%s'

  **ER_ACCESS_DENIED_NO_PASSWORD_ERROR** was added in 5.5.7.

- Error number: 1699; Symbol: **ER_SET_PASSWORD_AUTH_PLUGIN**; SQLSTATE: HY000
  
  Message: SET PASSWORD has no significance for users authenticating via plugins

- Error number: 1700; Symbol: **ER_GRANT_PLUGIN_USER_EXISTS**; SQLSTATE: HY000
  
  Message: GRANT with IDENTIFIED WITH is illegal because the user %-.*s already exists

- Error number: 1701; Symbol: **ER_TRUNCATE_ILLEGAL_FK**; SQLSTATE: 42000
  
  Message: Cannot truncate a table referenced in a foreign key constraint (%s)

  **ER_TRUNCATE_ILLEGAL_FK** was added in 5.5.7.

- Error number: 1702; Symbol: **ER_PLUGIN_IS_PERMANENT**; SQLSTATE: HY000
  
  Message: Plugin '%s' is force_plus_permanent and can not be unloaded

  **ER_PLUGIN_IS_PERMANENT** was added in 5.5.7.

- Error number: 1703; Symbol: **ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN**; SQLSTATE: HY000
  
  Message: The requested value for the heartbeat period is less than 1 millisecond. The value is reset to 0, meaning that heartbeating will effectively be disabled.

  **ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN** was added in 5.5.7.

- Error number: 1704; Symbol: **ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX**; SQLSTATE: HY000
  
  Message: The requested value for the heartbeat period exceeds the value of `slave_net_timeout' seconds. A sensible value for the period should be less than the timeout.
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX was added in 5.5.7.

- Error number: 1705; Symbol: ER_STMT_CACHE_FULL; SQLSTATE: HY000
  Message: Multi-row statements required more than 'max_binlog_stmt_cache_size' bytes of storage; increase this mysql variable and try again
  ER_STMT_CACHE_FULL was added in 5.5.9.

- Error number: 1706; Symbol: ER_MULTI_UPDATE_KEY_CONFLICT; SQLSTATE: HY000
  Message: Primary key/partition key update is not allowed since the table is updated both as '%s' and '%s'.
  ER_MULTI_UPDATE_KEY_CONFLICT was added in 5.5.11.

- Error number: 1707; Symbol: ER_TABLE_NEEDS_REBUILD; SQLSTATE: HY000
  Message: Table rebuild required. Please do "ALTER TABLE `%s` FORCE" or dump/reload to fix it!
  ER_TABLE_NEEDS_REBUILD was added in 5.5.11.

- Error number: 1708; Symbol: WARN_OPTION_BELOW_LIMIT; SQLSTATE: HY000
  Message: The value of '%s' should be no less than the value of '%s'
  WARN_OPTION_BELOW_LIMIT was added in 5.5.12.

- Error number: 1709; Symbol: ER_INDEX_COLUMN_TOO_LONG; SQLSTATE: HY000
  Message: Index column size too large. The maximum column size is %lu bytes.
  ER_INDEX_COLUMN_TOO_LONG was added in 5.5.14.

- Error number: 1710; Symbol: ER_ERROR_IN_TRIGGER_BODY; SQLSTATE: HY000
  Message: Trigger '%s' has an error in its body: '%s'
  ER_ERROR_IN_TRIGGER_BODY was added in 5.5.15.

- Error number: 1711; Symbol: ER_ERROR_IN_UNKNOWN_TRIGGER_BODY; SQLSTATE: HY000
  Message: Unknown trigger has an error in its body: '%s'
  ER_ERROR_IN_UNKNOWN_TRIGGER_BODY was added in 5.5.15.

- Error number: 1712; Symbol: ER_INDEX_CORRUPT; SQLSTATE: HY000
  Message: Index %s is corrupted
  ER_INDEX_CORRUPT was added in 5.5.17.

- Error number: 1713; Symbol: ER_UNDO_RECORD_TOO_BIG; SQLSTATE: HY000
  Message: Undo log record is too big.
  ER_UNDO_RECORD_TOO_BIG was added in 5.5.17.

- Error number: 1714; Symbol: ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT; SQLSTATE: HY000
Message: INSERT IGNORE... SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT** was added in 5.5.18.

- **Error number:** 1715; **Symbol:** ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE; **SQLSTATE:** HY000

Message: INSERT... SELECT... ON DUPLICATE KEY UPDATE is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are updated. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE** was added in 5.5.18.

- **Error number:** 1716; **Symbol:** ER_BINLOG_UNSAFE_REPLACE_SELECT; **SQLSTATE:** HY000

Message: REPLACE... SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are replaced. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_REPLACE_SELECT** was added in 5.5.18.

- **Error number:** 1717; **Symbol:** ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT; **SQLSTATE:** HY000

Message: CREATE... IGNORE SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT** was added in 5.5.18.

- **Error number:** 1718; **Symbol:** ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT; **SQLSTATE:** HY000

Message: CREATE... REPLACE SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are replaced. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT** was added in 5.5.18.

- **Error number:** 1719; **Symbol:** ER_BINLOG_UNSAFE_UPDATE_IGNORE; **SQLSTATE:** HY000

Message: UPDATE IGNORE is unsafe because the order in which rows are updated determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

**ER_BINLOG_UNSAFE_UPDATE_IGNORE** was added in 5.5.18.

- **Error number:** 1720; **Symbol:** ER_PLUGIN_NO_UNINSTALL; **SQLSTATE:** HY000

Message: Plugin '%s' is marked as not dynamically uninstallable. You have to stop the server to uninstall it.

**ER_PLUGIN_NO_UNINSTALL** was added in 5.5.16.

- **Error number:** 1721; **Symbol:** ER_PLUGIN_NO_INSTALL; **SQLSTATE:** HY000

Message: Plugin '%s' is marked as not dynamically installable. You have to stop the server to install it.

**ER_PLUGIN_NO_INSTALL** was added in 5.5.16.
• Error number: 1722; Symbol: ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT; SQLSTATE: HY000
Message: Statements writing to a table with an auto-increment column after selecting from another table are unsafe because the order in which rows are retrieved determines what (if any) rows will be written. This order cannot be predicted and may differ on master and the slave.

ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT was added in 5.5.22.

• Error number: 1723; Symbol: ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC; SQLSTATE: HY000
Message: CREATE TABLE... SELECT... on a table with an auto-increment column is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are inserted. This order cannot be predicted and may differ on master and the slave.

ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC was added in 5.5.22.

• Error number: 1724; Symbol: ER_BINLOG_UNSAFE_INSERT_TWO_KEYS; SQLSTATE: HY000
Message: INSERT... ON DUPLICATE KEY UPDATE on a table with more than one UNIQUE KEY is unsafe.

ER_BINLOG_UNSAFE_INSERT_TWO_KEYS was added in 5.5.24.

• Error number: 1725; Symbol: ER_TABLE_IN_FK_CHECK; SQLSTATE: HY000
Message: Table is being used in foreign key check.

ER_TABLE_IN_FK_CHECK was added in 5.5.24.

• Error number: 1726; Symbol: ER_UNSUPPORTED_ENGINE; SQLSTATE: HY000
Message: Storage engine '%s' does not support system tables. [%s.%s]

ER_UNSUPPORTED_ENGINE was added in 5.5.24.

• Error number: 1727; Symbol: ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST; SQLSTATE: HY000
Message: INSERT into autoincrement field which is not the first part in the composed primary key is unsafe.

ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST was added in 5.5.25.

B.3.2 Client Error Message Reference

Client error messages originate from within the MySQL client library. Here is an example client error message, as displayed by the mysql client:

shell> mysql -h no-such-host
ERROR 2005 (HY000): Unknown MySQL server host 'no-such-host' (0)

Each client error message includes an error code, SQLSTATE value, and message string, as described in Section B.1, "Error Message Sources and Components". These components are available as described in Section B.2, "Error Information Interfaces". For client errors, the SQLSTATE value is always 'HY000' (general error), so it is not meaningful for distinguishing one client error from another.

The client library also makes available to host client programs any errors that originate on the server side and are received by the client from the server. For a list of server-side errors, see Section B.3.1, "Server Error Message Reference".

In addition to the errors in the following list, the client library can also produce error messages that have error codes in the range from 1 to 999. See Section B.3.3, "Global Error Message Reference"

- **Error number:** 2000; Symbol: `CR_UNKNOWN_ERROR`;
  Message: Unknown MySQL error

- **Error number:** 2001; Symbol: `CR_SOCKET_CREATE_ERROR`;
  Message: Can't create UNIX socket (%d)

- **Error number:** 2002; Symbol: `CR_CONNECTION_ERROR`;
  Message: Can't connect to local MySQL server through socket '%s' (%d)

- **Error number:** 2003; Symbol: `CR_CONN_HOST_ERROR`;
  Message: Can't connect to MySQL server on '%s' (%d)

- **Error number:** 2004; Symbol: `CR_IPSOCK_ERROR`;
  Message: Can't create TCP/IP socket (%d)

- **Error number:** 2005; Symbol: `CR_UNKNOWN_HOST`;
  Message: Unknown MySQL server host '%s' (%d)

- **Error number:** 2006; Symbol: `CR_SERVER_GONE_ERROR`;
  Message: MySQL server has gone away

- **Error number:** 2007; Symbol: `CR_VERSION_ERROR`;
  Message: Protocol mismatch; server version = %d, client version = %d

- **Error number:** 2008; Symbol: `CR_OUT_OF_MEMORY`;
  Message: MySQL client ran out of memory

- **Error number:** 2009; Symbol: `CR_WRONG_HOST_INFO`;
  Message: Wrong host info

- **Error number:** 2010; Symbol: `CR_LOCALHOST_CONNECTION`;
  Message: Localhost via UNIX socket

- **Error number:** 2011; Symbol: `CR_TCP_CONNECTION`;
  Message: %s via TCP/IP

- **Error number:** 2012; Symbol: `CR_SERVER_HANDSHAKE_ERR`;
  Message: Error in server handshake

- **Error number:** 2013; Symbol: `CR_SERVER_LOST`;
  Message: Lost connection to MySQL server during query

- **Error number:** 2014; Symbol: `CR_COMMANDS_OUT_OF_SYNC`;
Message: Commands out of sync; you can't run this command now

Commands were executed in an improper order. This error occurs when a function is called that is not appropriate for the current state of the connection. For example, if `mysql_stmt_fetch()` is not called enough times to read an entire result set (that is, enough times to return `MYSQL_NO_DATA`), this error may occur for the following C API call.

- Error number: 2015; Symbol: `CR_NAMEDPIPE_CONNECTION`;
  Message: Named pipe: %s

- Error number: 2016; Symbol: `CR_NAMEDPIPEWAIT_ERROR`;
  Message: Can't wait for named pipe to host: %s pipe: %s (%lu)

- Error number: 2017; Symbol: `CR_NAMEDPIPEOPEN_ERROR`;
  Message: Can't open named pipe to host: %s pipe: %s (%lu)

- Error number: 2018; Symbol: `CR_NAMEDPIPESETSTATE_ERROR`;
  Message: Can't set state of named pipe to host: %s pipe: %s (%lu)

- Error number: 2019; Symbol: `CR_CANT_READ_CHARSET`;
  Message: Can't initialize character set %s (path: %s)

- Error number: 2020; Symbol: `CR_NET_PACKET_TOO_LARGE`;
  Message: Got packet bigger than 'max_allowed_packet' bytes

- Error number: 2021; Symbol: `CR_EMBEDDED_CONNECTION`;
  Message: Embedded server

- Error number: 2022; Symbol: `CR_PROBE_SLAVE_STATUS`;
  Message: Error on SHOW SLAVE STATUS:

- Error number: 2023; Symbol: `CR_PROBE_SLAVE_HOSTS`;
  Message: Error on SHOW SLAVE HOSTS:

- Error number: 2024; Symbol: `CR_PROBE_SLAVE_CONNECT`;
  Message: Error connecting to slave:

- Error number: 2025; Symbol: `CR_PROBE_MASTER_CONNECT`;
  Message: Error connecting to master:

- Error number: 2026; Symbol: `CR_SSL_CONNECTION_ERROR`;
  Message: SSL connection error: %s

- Error number: 2027; Symbol: `CR_MALFORMED_PACKET`;
  Message: Malformed packet
• Error number: 2028; Symbol: CR_WRONG_LICENSE;
  Message: This client library is licensed only for use with MySQL servers having '%s' license
• Error number: 2029; Symbol: CR_NULL_POINTER;
  Message: Invalid use of null pointer
• Error number: 2030; Symbol: CR_NO_PREPARE_STMT;
  Message: Statement not prepared
• Error number: 2031; Symbol: CR_PARAMS_NOT_BOUND;
  Message: No data supplied for parameters in prepared statement
• Error number: 2032; Symbol: CR_DATA_TRUNCATED;
  Message: Data truncated
• Error number: 2033; Symbol: CR_NO_PARAMETERS_EXISTS;
  Message: No parameters exist in the statement
• Error number: 2034; Symbol: CR_INVALID_PARAMETER_NO;
  Message: Invalid parameter number
  The column number for mysql_stmt_fetch_column() was invalid.
  The parameter number for mysql_stmt_send_long_data() was invalid.
• Error number: 2035; Symbol: CR_INVALID_BUFFER_USE;
  Message: Can't send long data for non-string/non-binary data types (parameter: %d)
• Error number: 2036; Symbol: CR_UNSUPPORTED_PARAM_TYPE;
  Message: Using unsupported buffer type: %d (parameter: %d)
• Error number: 2037; Symbol: CR_SHARED_MEMORY_CONNECTION;
  Message: Shared memory: %s
• Error number: 2038; Symbol: CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR;
  Message: Can't open shared memory; client could not create request event (%lu)
• Error number: 2039; Symbol: CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR;
  Message: Can't open shared memory; no answer event received from server (%lu)
• Error number: 2040; Symbol: CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR;
  Message: Can't open shared memory; server could not allocate file mapping (%lu)
• Error number: 2041; Symbol: CR_SHARED_MEMORY_CONNECT_MAP_ERROR;
  Message: Can't open shared memory; server could not get pointer to file mapping (%lu)
• Error number: 2042; Symbol: CR_SHARED_MEMORY_FILE_MAP_ERROR;
  Message: Can't open shared memory; client could not allocate file mapping (%lu)
• Error number: 2043; Symbol: CR_SHARED_MEMORY_MAP_ERROR;
  Message: Can't open shared memory; client could not get pointer to file mapping (%lu)
• Error number: 2044; Symbol: CR_SHARED_MEMORY_EVENT_ERROR;
  Message: Can't open shared memory; client could not create %s event (%lu)
• Error number: 2045; Symbol: CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR;
  Message: Can't open shared memory; no answer from server (%lu)
• Error number: 2046; Symbol: CR_SHARED_MEMORY_CONNECT_SET_ERROR;
  Message: Can't open shared memory; cannot send request event to server (%lu)
• Error number: 2047; Symbol: CR_CONN_UNKNOWN_PROTOCOL;
  Message: Wrong or unknown protocol
• Error number: 2048; Symbol: CR_INVALID_CONN_HANDLE;
  Message: Invalid connection handle
• Error number: 2049; Symbol: CR_SECURE_AUTH;
  Message: Connection using old (pre-4.1.1) authentication protocol refused (client option 'secure_auth' enabled)
• Error number: 2050; Symbol: CR_FETCH_CANCELED;
  Message: Row retrieval was canceled by mysql_stmt_close() call
• Error number: 2051; Symbol: CR_NO_DATA;
  Message: Attempt to read column without prior row fetch
• Error number: 2052; Symbol: CR_NO_STMT_METADATA;
  Message: Prepared statement contains no metadata
• Error number: 2053; Symbol: CR_NO_RESULT_SET;
  Message: Attempt to read a row while there is no result set associated with the statement
• Error number: 2054; Symbol: CR_NOT_IMPLEMENTED;
  Message: This feature is not implemented yet
• Error number: 2055; Symbol: CR_SERVER_LOST_EXTENDED;
  Message: Lost connection to MySQL server at '%s', system error: %d
• Error number: 2056; Symbol: CR_STMT_CLOSED;
  Message: Statement closed indirectly because of a preceding %s() call
• Error number: **2057**; Symbol: **CR_NEW_STMT_METADATA**;
Message: The number of columns in the result set differs from the number of bound buffers. You must reset the statement, rebind the result set columns, and execute the statement again

• Error number: **2058**; Symbol: **CR_ALREADY_CONNECTED**;
Message: This handle is already connected. Use a separate handle for each connection.

• Error number: **2059**; Symbol: **CR_AUTH_PLUGIN_CANNOT_LOAD**;
Message: Authentication plugin '%s' cannot be loaded: %s
**CR_AUTH_PLUGIN_CANNOT_LOAD** was added in 5.5.7.

### B.3.3 Global Error Message Reference

This section lists global error messages that are shared in the sense that they can be produced by the MySQL server or by MySQL client programs. These errors have error codes in the range from 1 to 999.

Each global error message includes an error code, SQLSTATE value, and message string, as described in Section B.1, “Error Message Sources and Components”. These components are available as described in Section B.2, “Error Information Interfaces”. For global errors, the SQLSTATE value is always 'HY000' (general error), so it is not meaningful for distinguishing one client error from another.

• Error number: **1**; Symbol: **EE_CANTCREATEFILE**;
Message: Can't create/write to file '%s' (Errcode: %d)

• Error number: **2**; Symbol: **EE_READ**;
Message: Error reading file '%s' (Errcode: %d)

• Error number: **3**; Symbol: **EE_WRITE**;
Message: Error writing file '%s' (Errcode: %d)

• Error number: **4**; Symbol: **EE_BADCLOSE**;
Message: Error on close of '%s' (Errcode: %d)

• Error number: **5**; Symbol: **EE_OUTOFMEMORY**;
Message: Out of memory (Needed %u bytes)

• Error number: **6**; Symbol: **EE_DELETE**;
Message: Error on delete of '%s' (Errcode: %d)

• Error number: **7**; Symbol: **EE_LINK**;
Message: Error on rename of '%s' to '%s' (Errcode: %d)

• Error number: **9**; Symbol: **EE_EOFERR**;
Message: Unexpected eof found when reading file '%s' (Errcode: %d)

• Error number: **10**; Symbol: **EE_CANTLOCK**;
Message: Can't lock file (Errcode: %d)
• Error number: 11; Symbol: EE_CANTUNLOCK;
Message: Can't unlock file (Errcode: %d)
• Error number: 12; Symbol: EE_DIR;
Message: Can't read dir of '%s' (Errcode: %d)
• Error number: 13; Symbol: EE_STAT;
Message: Can't get stat of '%s' (Errcode: %d)
• Error number: 14; Symbol: EE_CANT_CHSIZE;
Message: Can't change size of file (Errcode: %d)
• Error number: 15; Symbol: EE_CANT_OPEN_STREAM;
Message: Can't open stream from handle (Errcode: %d)
• Error number: 16; Symbol: EE_GETWD;
Message: Can't get working directory (Errcode: %d)
• Error number: 17; Symbol: EE_SETWD;
Message: Can't change dir to '%s' (Errcode: %d)
• Error number: 18; Symbol: EE_LINK_WARNING;
Message: Warning: '%s' had %d links
• Error number: 19; Symbol: EE_OPEN_WARNING;
Message: Warning: %d files and %d streams is left open
• Error number: 20; Symbol: EE_DISK_FULL;
Message: Disk is full writing '%s' (Errcode: %d). Waiting for someone to free space... (Expect up to %d secs delay for server to continue after freeing disk space)
• Error number: 21; Symbol: EE_CANT_MKDIR;
Message: Can't create directory '%s' (Errcode: %d)
• Error number: 22; Symbol: EE_UNKNOWN_CHARSET;
Message: Character set '%s' is not a compiled character set and is not specified in the '%s' file
• Error number: 23; Symbol: EE_OUT_OF_FILERESOURCES;
Message: Out of resources when opening file '%s' (Errcode: %d)
• Error number: 24; Symbol: EE_CANT_READLINK;
Message: Can't read value for symlink '%s' (Error %d)
B.4 Problems and Common Errors

This section lists some common problems and error messages that you may encounter. It describes how to determine the causes of the problems and what to do to solve them.

B.4.1 How to Determine What Is Causing a Problem

When you run into a problem, the first thing you should do is to find out which program or piece of equipment is causing it:

• If you have one of the following symptoms, then it is probably a hardware problems (such as memory, motherboard, CPU, or hard disk) or kernel problem:
  • The keyboard does not work. This can normally be checked by pressing the Caps Lock key. If the Caps Lock light does not change, you have to replace your keyboard. (Before doing this, you should try to restart your computer and check all cables to the keyboard.)

• Error number: 25; Symbol: EE_CANT_SYMLINK;
  Message: Can't create symlink '%s' pointing at '%s' (Error %d)

• Error number: 26; Symbol: EE_REALPATH;
  Message: Error on realpath() on '%s' (Error %d)

• Error number: 27; Symbol: EE_SYNC;
  Message: Can't sync file '%s' to disk (Errcode: %d)

• Error number: 28; Symbol: EE_UNKNOWN_COLLATION;
  Message: Collation '%s' is not a compiled collation and is not specified in the '%s' file

• Error number: 29; Symbol: EE_FILENOTFOUND;
  Message: File '%s' not found (Errcode: %d)

• Error number: 30; Symbol: EE_FILE_NOT_CLOSED;
  Message: File '%s' (fileno: %d) was not closed

• Error number: 31; Symbol: EE_CHANGE_OWNERSHIP;
  Message: Can't change ownership of the file '%s' (Errcode: %d)

  EE_CHANGE_OWNERSHIP was added in 5.5.6.

• Error number: 32; Symbol: EE_CHANGE_PERMISSIONS;
  Message: Can't change permissions of the file '%s' (Errcode: %d)

  EE_CHANGE_PERMISSIONS was added in 5.5.6.

• Error number: 33; Symbol: EE_CANT_SEEK;
  Message: Can't seek in file '%s' (Errcode: %d)

  EE_CANT_SEEK was added in 5.5.9.
How to Determine What Is Causing a Problem

• The mouse pointer does not move.
• The machine does not answer to a remote machine's pings.
• Other programs that are not related to MySQL do not behave correctly.
• Your system restarted unexpectedly. (A faulty user-level program should never be able to take down your system.)

In this case, you should start by checking all your cables and run some diagnostic tool to check your hardware! You should also check whether there are any patches, updates, or service packs for your operating system that could likely solve your problem. Check also that all your libraries (such as glibc) are up to date.

It is always good to use a machine with ECC memory to discover memory problems early.

• If your keyboard is locked up, you may be able to recover by logging in to your machine from another machine and executing kbd_mode -a.

• Please examine your system log file (/var/log/messages or similar) for reasons for your problem. If you think the problem is in MySQL, you should also examine MySQL’s log files. See Section 5.4, “MySQL Server Logs”.

• If you do not think you have hardware problems, you should try to find out which program is causing problems. Try using top, ps, Task Manager, or some similar program, to check which program is taking all CPU or is locking the machine.

• Use top, df, or a similar program to check whether you are out of memory, disk space, file descriptors, or some other critical resource.

• If the problem is some runaway process, you can always try to kill it. If it does not want to die, there is probably a bug in the operating system.

If you have examined all other possibilities and concluded that the MySQL server or a MySQL client is causing the problem, it is time to create a bug report, see Section 1.6, “How to Report Bugs or Problems”. In the bug report, try to give a complete description of how the system is behaving and what you think is happening. Also state why you think that MySQL is causing the problem. Take into consideration all the situations described in this chapter. State any problems exactly how they appear when you examine your system. Use the “copy and paste” method for any output and error messages from programs and log files.

Try to describe in detail which program is not working and all symptoms you see. We have in the past received many bug reports that state only “the system does not work.” This provides us with no information about what could be the problem.

If a program fails, it is always useful to know the following information:

• Has the program in question made a segmentation fault (did it dump core)?

• Is the program taking up all available CPU time? Check with top. Let the program run for a while, it may simply be evaluating something computationally intensive.

• If the mysqld server is causing problems, can you get any response from it with mysqladmin -u root ping or mysqladmin -u root processlist?

• What does a client program say when you try to connect to the MySQL server? (Try with mysql, for example.) Does the client jam? Do you get any output from the program?
When sending a bug report, you should follow the outline described in Section 1.6, “How to Report Bugs or Problems”.

B.4.2 Common Errors When Using MySQL Programs

This section lists some errors that users frequently encounter when running MySQL programs. Although the problems show up when you try to run client programs, the solutions to many of the problems involves changing the configuration of the MySQL server.

B.4.2.1 Access denied

An Access denied error can have many causes. Often the problem is related to the MySQL accounts that the server permits client programs to use when connecting. See Section 6.2, “Access Control and Account Management”, and Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”.

B.4.2.2 Can't connect to [local] MySQL server

A MySQL client on Unix can connect to the mysql server in two different ways: By using a Unix socket file to connect through a file in the file system (default /tmp/mysql.sock), or by using TCP/IP, which connects through a port number. A Unix socket file connection is faster than TCP/IP, but can be used only when connecting to a server on the same computer. A Unix socket file is used if you do not specify a host name or if you specify the special host name localhost.

If the MySQL server is running on Windows, you can connect using TCP/IP. If the server is started with the named_pipe system variable enabled, you can also connect with named pipes if you run the client on the host where the server is running. The name of the named pipe is MySQL by default. If you do not give a host name when connecting to mysqld, a MySQL client first tries to connect to the named pipe. If that does not work, it connects to the TCP/IP port. You can force the use of named pipes on Windows by using . as the host name.

The error (2002) Can't connect to ... normally means that there is no MySQL server running on the system or that you are using an incorrect Unix socket file name or TCP/IP port number when trying to connect to the server. You should also check that the TCP/IP port you are using has not been blocked by a firewall or port blocking service.

The error (2003) Can't connect to MySQL server on 'server' (10061) indicates that the network connection has been refused. You should check that there is a MySQL server running, that it has network connections enabled, and that the network port you specified is the one configured on the server.

Start by checking whether there is a process named mysqld running on your server host. (Use ps xa | grep mysqld on Unix or the Task Manager on Windows.) If there is no such process, you should start the server. See Section 2.10.2, “Starting the Server”.

If a mysqld process is running, you can check it by trying the following commands. The port number or Unix socket file name might be different in your setup. host_ip represents the IP address of the machine where the server is running.

```
shell> mysqladmin version
shell> mysqladmin variables
shell> mysqladmin -h `hostname` version variables
shell> mysqladmin -h `hostname` --port=3306 version
shell> mysqladmin -h host_ip version
shell> mysqladmin --protocol=SOCKET --socket=/tmp/mysql.sock version
```

Note the use of backticks rather than forward quotation marks with the hostname command; these cause the output of hostname (that is, the current host name) to be substituted into the mysqladmin command. If you have no hostname command or are running on Windows, you can manually type the host name of

3143
Common Errors When Using MySQL Programs

your machine (without backticks) following the \-h option. You can also try \-h 127.0.0.1 to connect with TCP/IP to the local host.

Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with the skip_networking system variable enabled, it will not accept TCP/IP connections at all. If the server was started with \--bind-address=127.0.0.1, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or the Windows XP personal firewall may need to be configured not to block the MySQL port.

Here are some reasons the Can't connect to local MySQL server error might occur:

• mysqld is not running on the local host. Check your operating system’s process list to ensure the mysqld process is present.

• You're running a MySQL server on Windows with many TCP/IP connections to it. If you're experiencing that quite often your clients get that error, you can find a workaround here: Connection to MySQL Server Failing on Windows.

• Someone has removed the Unix socket file that mysqld uses (/tmp/mysql.sock by default). For example, you might have a cron job that removes old files from the /tmp directory. You can always run mysqladmin version to check whether the Unix socket file that mysqladmin is trying to use really exists. The fix in this case is to change the cron job to not remove mysql.sock or to place the socket file somewhere else. See Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”.

• You have started the mysqld server with the \--socket=/path/to/socket option, but forgotten to tell client programs the new name of the socket file. If you change the socket path name for the server, you must also notify the MySQL clients. You can do this by providing the same \--socket option when you run client programs. You also need to ensure that clients have permission to access the mysql.sock file. To find out where the socket file is, you can do:

  shell> netstat -ln | grep mysql

See Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”.

• You are using Linux and one server thread has died (dumped core). In this case, you must kill the other mysqld threads (for example, with kill or with the mysql_zap script) before you can restart the MySQL server. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

• The server or client program might not have the proper access privileges for the directory that holds the Unix socket file or the socket file itself. In this case, you must either change the access privileges for the directory or socket file so that the server and clients can access them, or restart mysqld with a \--socket option that specifies a socket file name in a directory where the server can create it and where client programs can access it.

If you get the error message Can't connect to MySQL server on some_host, you can try the following things to find out what the problem is:

• Check whether the server is running on that host by executing telnet some_host 3306 and pressing the Enter key a couple of times. (3306 is the default MySQL port number. Change the value if your server is listening to a different port.) If there is a MySQL server running and listening to the port, you should get a response that includes the server's version number. If you get an error such as telnet:
Unable to connect to remote host: Connection refused, then there is no server running on the given port.

- If the server is running on the local host, try using `mysqladmin -h localhost variables` to connect using the Unix socket file. Verify the TCP/IP port number that the server is configured to listen to (it is the value of the `port` variable.)

- If you are running under Linux and Security-Enhanced Linux (SELinux) is enabled, see Set SELinux context for MySQL Server.

Set SELinux context for MySQL Server

The MySQL server reads from and writes to many files, and if the SELinux context is not set correctly on these files then the mysqld process may block access to MySQL files. In some cases, this may stop mysqld from logging errors.

Required Tools

The `semanage` binary is used in this guide to manage context; on Enterprise Linux it's part of the `policycoreutils-python` package:

```
shell> yum install policycoreutils-python
```

Note

RHEL 6 with Python 2.6: to use `semanage` with early versions of RHEL 6 with python 2.6, you may need to install a backport of the `OrderedDict` python collection module using `python-pip` from the EPEL repository.

List Current MySQL Context

List them using the following:

```
shell> semanage fcontext -l | grep -i mysql
```

Set MySQL Data Directory Context

The default data directory location is `/var/lib/mysql/`; and the SELinux context used is `mysqld_db_t`.

If you edit the configuration file to use a different location for the data directory, or for any of the files normally in the data directory (such as the binary logs) you may need to set the context for the new location. For example:

```
shell> semanage fcontext -a -t mysqld_db_t "/path/to/my/custom/datadir(/.*)?"
shell> restorecon -Rv /path/to/my/custom/datadir

shell> semanage fcontext -a -t mysqld_db_t "/path/to/my/custom/logdir(/.*)?"
shell> restorecon -Rv /path/to/my/custom/logdir
```

Set MySQL Error Log File Context

The default location for RedHat RPMs is `/var/log/mysqld.log`; and the SELinux context used is `mysqld_log_t`.

If you edit the configuration file to use a different location then you may need to set the context for the new location. For example:

```
shell> semanage fcontext -a -t mysqld_log_t "/path/to/my/custom/error.log"
shell> restorecon -Rv /path/to/my/custom/error.log
```
Common Errors When Using MySQL Programs

Set PID File Context

The default location for the PID file is /var/run/mysqld/mysqld.pid; and the SELinux context used is mysqld_var_run_t.

If you edit the configuration file to use a different location then you may need to set the context for the new location. For example:

```
shell> semanage fcontext -a -t mysqld_var_run_t "/path/to/my/custom/pidfile/directory/.*?"
shell> restorecon -Rv /path/to/my/custom/pidfile/directory
```

Set unix-domain Socket Context

The default location for the unix-domain socket is /var/lib/mysql/mysql.sock; and the SELinux context used is mysqld_var_run_t.

If you edit the configuration file to use a different location then you may need to set the context for the new location. For example:

```
shell> semanage fcontext -a -t mysqld_var_run_t "/path/to/my/custom/mysql.sock"
shell> restorecon -Rv /path/to/my/custom/mysql.sock
```

Set TCP Port Context

The default TCP port is 3306; and the SELinux context used is mysqld_port_t.

If you edit the configuration file to use a different TCP port, or you enable Group Replication which uses an additional port (typically port 13306), you may need to set the context for the new port. For example:

```
shell> semanage port -a -t mysqld_port_t -p tcp 13306
shell> restorecon
```

Set secure_file_priv Directory Context

For MySQL versions since 5.5.53, 5.6.34, 5.7.16, and 8.0.11.

Installing the MySQL server RPM creates a /var/lib/mysql-files/ directory, but does not set the SELinux context on this directory. This directory is intended to be used for operations such as SELECT ... INTO OUTFILE.

If you enabled the use of this directory by setting secure_file_priv, you may need to set the context like so:

```
shell> semanage fcontext -a -t mysqld_db_t "/var/lib/mysql-files/(.*)?"
shell> restorecon -Rv /var/lib/mysql-files
```

Edit this path if you used a different location. For security purposes, this directory should never be within the data directory.

For more information about this variable, see the secure_file_priv documentation.

Connection to MySQL Server Failing on Windows

When you're running a MySQL server on Windows with many TCP/IP connections to it, and you're experiencing that quite often your clients get a Can't connect to MySQL server error, the reason might be that Windows does not allow for enough ephemeral (short-lived) ports to serve those connections.

The purpose of TIME_WAIT is to keep a connection accepting packets even after the connection has been closed. This is because Internet routing can cause a packet to take a slow route to its destination and it
may arrive after both sides have agreed to close. If the port is in use for a new connection, that packet from the old connection could break the protocol or compromise personal information from the original connection. The **TIME_WAIT** delay prevents this by ensuring that the port cannot be reused until after some time has been permitted for those delayed packets to arrive.

It is safe to reduce **TIME_WAIT** greatly on LAN connections because there is little chance of packets arriving at very long delays, as they could through the Internet with its comparatively large distances and latencies.

Windows permits ephemeral (short-lived) TCP ports to the user. After any port is closed it will remain in a **TIME_WAIT** status for 120 seconds. The port will not be available again until this time expires. The default range of port numbers depends on the version of Windows, with a more limited number of ports in older versions:

- Windows through Server 2003: Ports in range 1025–5000

With a small stack of available TCP ports (5000) and a high number of TCP ports being open and closed over a short period of time along with the **TIME_WAIT** status you have a good chance for running out of ports. There are two ways to address this problem:

- Reduce the number of TCP ports consumed quickly by investigating connection pooling or persistent connections where possible
- Tune some settings in the Windows registry (see below)

---

### Important

The following procedure involves modifying the Windows registry. Before you modify the registry, make sure to back it up and make sure that you understand how to restore it if a problem occurs. For information about how to back up, restore, and edit the registry, view the following article in the Microsoft Knowledge Base: [http://support.microsoft.com/kb/256986/EN-US/](http://support.microsoft.com/kb/256986/EN-US/).

1. Start Registry Editor (**Regedt32.exe**).
2. Locate the following key in the registry:

   `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters`

3. On the **Edit** menu, click **Add Value**, and then add the following registry value:

   - **Value Name:** MaxUserPort
   - **Data Type:** REG_DWORD
   - **Value:** 65534

   This sets the number of ephemeral ports available to any user. The valid range is between 5000 and 65534 (decimal). The default value is 0x1388 (5000 decimal).

4. On the **Edit** menu, click **Add Value**, and then add the following registry value:

   - **Value Name:** TcpTimedWaitDelay
   - **Data Type:** REG_DWORD
   - **Value:** 30

   This sets the number of seconds to hold a TCP port connection in **TIME_WAIT** state before closing. The valid range is between 30 and 300 decimal, although you may wish to check with Microsoft for the latest permitted values. The default value is 0x78 (120 decimal).
5. Quit Registry Editor.
6. Reboot the machine.

Note: Undoing the above should be as simple as deleting the registry entries you've created.

B.4.2.3 Lost connection to MySQL server

There are three likely causes for this error message.

Usually it indicates network connectivity trouble and you should check the condition of your network if this error occurs frequently. If the error message includes “during query,” this is probably the case you are experiencing.

Sometimes the “during query” form happens when millions of rows are being sent as part of one or more queries. If you know that this is happening, you should try increasing net_read_timeout from its default of 30 seconds to 60 seconds or longer, sufficient for the data transfer to complete.

More rarely, it can happen when the client is attempting the initial connection to the server. In this case, if your connect_timeout value is set to only a few seconds, you may be able to resolve the problem by increasing it to ten seconds, perhaps more if you have a very long distance or slow connection. You can determine whether you are experiencing this more uncommon cause by using SHOW GLOBAL STATUS LIKE 'Aborted_connects'. It will increase by one for each initial connection attempt that the server aborts. You may see “reading authorization packet” as part of the error message; if so, that also suggests that this is the solution that you need.

If the cause is none of those just described, you may be experiencing a problem with BLOB values that are larger than max_allowed_packet, which can cause this error with some clients. Sometime you may see an ER_NET_PACKET_TOO_LARGE error, and that confirms that you need to increase max_allowed_packet.

B.4.2.4 Client does not support authentication protocol

The current implementation of the authentication protocol uses a password hashing algorithm that is incompatible with that used by older (pre-4.1) clients. Attempts to connect to a 4.1 or higher server with an older client may fail with the following message:

```
shell> mysql
Client does not support authentication protocol requested by server; consider upgrading MySQL client
```

To deal with this problem, the preferred solution is to upgrade all client programs to use a 4.1.1 or higher client library. If that is not possible, use one of the following approaches:

• To connect to the server with a pre-4.1 client program, use an account that still has a pre-4.1-style password.

• Reset the password to pre-4.1 style for each user that needs to use a pre-4.1 client program. This can be done using the SET PASSWORD statement and the OLD_PASSWORD() function:

```
mysql> SET PASSWORD FOR 'some_user'@'some_host' = OLD_PASSWORD('new_password');
```

Substitute the password you want to use for “new_password” in the preceding example. MySQL cannot tell you what the original password was, so you'll need to pick a new one.

• Tell the server to use the older password hashing algorithm by default:
1. Start `mysqld` with the `old_passwords` system variable set to 1.

2. Assign an old-format password to each account that has had its password updated to the longer 4.1 format. You can identify these accounts with the following query:

```sql
mysql> SELECT Host, User, Password FROM mysql.user
       -> WHERE LENGTH(Password) > 16;
```

For each account record displayed by the query, use the `Host` and `User` values and assign a password using one of the methods described previously.

The `Client does not support authentication protocol` error also can occur if multiple versions of MySQL are installed but client programs are dynamically linked and link to an older library. Make sure that clients use the most recent library version with which they are compatible. The procedure to do this will depend on your system.

**Note**

The PHP `mysql` extension does not support the authentication protocol in MySQL 4.1.1 and higher. This is true regardless of the PHP version being used. If you wish to use the `mysql` extension with MySQL 4.1 or higher, you may need to follow one of the options discussed above for configuring MySQL to work with old clients. The `mysqli` extension (stands for “MySQL, Improved”; added in PHP 5) is compatible with the improved password hashing employed in MySQL 4.1 and higher, and no special configuration of MySQL need be done to use this MySQL client library. For more information about the `mysqli` extension, see [http://php.net/mysqli](http://php.net/mysqli).

For additional background on password hashing and authentication, see Section 6.1.2.4, “Password Hashing in MySQL”.

**B.4.2.5 Password Fails When Entered Interactively**

MySQL client programs prompt for a password when invoked with a `--password` or `-p` option that has no following password value:

```shell
shell> mysql -u user_name -p
Enter password:
```

On some systems, you may find that your password works when specified in an option file or on the command line, but not when you enter it interactively at the `Enter password:` prompt. This occurs when the library provided by the system to read passwords limits password values to a small number of characters (typically eight). That is a problem with the system library, not with MySQL. To work around it, change your MySQL password to a value that is eight or fewer characters long, or put your password in an option file.

**B.4.2.6 Host 'host_name' is blocked**

If the following error occurs, it means that `mysqld` has received many connection requests from the given host that were interrupted in the middle:

```
Host 'host_name' is blocked because of many connection errors.
Unblock with 'mysqldadmin flush-hosts'
```

The value of the `max_connect_errors` system variable determines how many successive interrupted connection requests are permitted. After `max_connect_errors` failed requests without a successful
connection, `mysqld` assumes that something is wrong (for example, that someone is trying to break in), and blocks the host from further connections until you flush the host cache by executing a `FLUSH HOSTS` statement or `mysqladmin flush-hosts` command.

To adjust the permitted number of successive connection errors, set `max_connect_errors` at server startup. For example, put these lines in the server `my.cnf` file:

```
[mysqld]
max_connect_errors=10000
```

The value can also be set at runtime:

```
SET GLOBAL max_connect_errors=10000;
```

If you get the `Host 'host_name' is blocked` error message for a given host, you should first verify that there is nothing wrong with TCP/IP connections from that host. If you are having network problems, it does no good to increase the value of `max_connect_errors`.

For more information about how the host cache works, see Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

### B.4.2.7 Too many connections

If clients encounter `Too many connections` errors when attempting to connect to the `mysqld` server, all available connections are in use by other clients.

The permitted number of connections is controlled by the `max_connections` system variable. The default value is 151 to improve performance when MySQL is used with the Apache Web server. To support more connections, set `max_connections` to a larger value.

`mysqld` actually permits `max_connections` + 1 client connections. The extra connection is reserved for use by accounts that have the `SUPER` privilege. By granting the privilege to administrators and not to normal users (who should not need it), an administrator who also has the `PROCESS` privilege can connect to the server and use `SHOW PROCESSLIST` to diagnose problems even if the maximum number of unprivileged clients are connected. See Section 13.7.5.30, “SHOW PROCESSLIST Statement”.

For more information about how the server handles client connections, see Section 8.12.5.1, “How MySQL Handles Client Connections”.

### B.4.2.8 Out of memory

If you issue a query using the `mysql` client program and receive an error like the following one, it means that `mysql` does not have enough memory to store the entire query result:

```
mysql: Out of memory at line 42, 'malloc.c'
mysql: needed 8136 byte (8k), memory in use:  12481367 bytes (12189k)
ERROR 2008: MySQL client ran out of memory
```

To remedy the problem, first check whether your query is correct. Is it reasonable that it should return so many rows? If not, correct the query and try again. Otherwise, you can invoke `mysql` with the `--quick` option. This causes it to use the `mysql_use_result()` C API function to retrieve the result set, which places less of a load on the client (but more on the server).

### B.4.2.9 MySQL server has gone away

This section also covers the related `Lost connection to server during query` error.
The most common reason for the MySQL server has gone away error is that the server timed out and closed the connection. In this case, you normally get one of the following error codes (which one you get is operating system-dependent).

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR_SERVER_GONE_ERROR</td>
<td>The client couldn't send a question to the server.</td>
</tr>
<tr>
<td>CR_SERVER_LOST</td>
<td>The client didn't get an error when writing to the server, but it didn't get a full answer (or any answer) to the question.</td>
</tr>
</tbody>
</table>

By default, the server closes the connection after eight hours if nothing has happened. You can change the time limit by setting the wait_timeout variable when you start mysqld. See Section 5.1.7, “Server System Variables”.

If you have a script, you just have to issue the query again for the client to do an automatic reconnection. This assumes that you have automatic reconnection in the client enabled (which is the default for the mysql command-line client).

Some other common reasons for the MySQL server has gone away error are:

• You (or the db administrator) has killed the running thread with a KILL statement or a mysqladmin kill command.

• You tried to run a query after closing the connection to the server. This indicates a logic error in the application that should be corrected.

• A client application running on a different host does not have the necessary privileges to connect to the MySQL server from that host.

• You got a timeout from the TCP/IP connection on the client side. This may happen if you have been using the commands: mysql_options(..., MYSQL_OPT_READ_TIMEOUT,...) or mysql_options(..., MYSQL_OPT_WRITE_TIMEOUT,...). In this case increasing the timeout may help solve the problem.

• You have encountered a timeout on the server side and the automatic reconnection in the client is disabled (the reconnect flag in the MYSQL structure is equal to 0).

• You are using a Windows client and the server had dropped the connection (probably because wait_timeout expired) before the command was issued.

The problem on Windows is that in some cases MySQL does not get an error from the OS when writing to the TCP/IP connection to the server, but instead gets the error when trying to read the answer from the connection.

The solution to this is to either do a mysql_ping() on the connection if there has been a long time since the last query (this is what Connector/ODBC does) or set wait_timeout on the mysqld server so high that it in practice never times out.

• You can also get these errors if you send a query to the server that is incorrect or too large. If mysqld receives a packet that is too large or out of order, it assumes that something has gone wrong with the client and closes the connection. If you need big queries (for example, if you are working with big BLOB columns), you can increase the query limit by setting the server’s max_allowed_packet variable, which has a default value of 1MB. You may also need to increase the maximum packet size on the client end. More information on setting the packet size is given in Section B.4.2.10, “Packet Too Large”.

An INSERT or REPLACE statement that inserts a great many rows can also cause these sorts of errors. Either one of these statements sends a single request to the server irrespective of the number of rows
to be inserted; thus, you can often avoid the error by reducing the number of rows sent per `INSERT` or `REPLACE`.

- It is also possible to see this error if host name lookups fail (for example, if the DNS server on which your server or network relies goes down). This is because MySQL is dependent on the host system for name resolution, but has no way of knowing whether it is working—from MySQL's point of view the problem is indistinguishable from any other network timeout.

You may also see the `MySQL server has gone away` error if MySQL is started with the `skip_networking` system variable enabled.

Another networking issue that can cause this error occurs if the MySQL port (default 3306) is blocked by your firewall, thus preventing any connections at all to the MySQL server.

- You can also encounter this error with applications that fork child processes, all of which try to use the same connection to the MySQL server. This can be avoided by using a separate connection for each child process.

- You have encountered a bug where the server died while executing the query.

You can check whether the MySQL server died and restarted by executing `mysqladmin version` and examining the server's uptime. If the client connection was broken because `mysqld` crashed and restarted, you should concentrate on finding the reason for the crash. Start by checking whether issuing the query again kills the server again. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

You can obtain more information about lost connections by starting `mysqld` with the `--log-warnings=2` option. This logs some of the disconnected errors in the `hostname.err` file. See Section 5.4.2, “The Error Log”.

If you want to create a bug report regarding this problem, be sure that you include the following information:

- Indicate whether the MySQL server died. You can find information about this in the server error log. See Section B.4.3.3, “What to Do If MySQL Keeps Crashing”.

- If a specific query kills `mysqld` and the tables involved were checked with CHECK TABLE before you ran the query, can you provide a reproducible test case? See Section 24.5, “Debugging and Porting MySQL”.

- What is the value of the `wait_timeout` system variable in the MySQL server? (`mysqladmin variables` gives you the value of this variable.)

- Have you tried to run `mysqld` with the general query log enabled to determine whether the problem query appears in the log? (See Section 5.4.3, “The General Query Log”.)

See also Section B.4.2.11, “Communication Errors and Aborted Connections”, and Section 1.6, “How to Report Bugs or Problems”.

**B.4.2.10 Packet Too Large**

A communication packet is a single SQL statement sent to the MySQL server, a single row that is sent to the client, or a binary log event sent from a master replication server to a slave.

The largest possible packet that can be transmitted to or from a MySQL 5.5 server or client is 1GB.

When a MySQL client or the `mysqld` server receives a packet bigger than `max_allowed_packet` bytes, it issues an `ER_NET_PACKET_TOO_LARGE` error and closes the connection. With some clients, you may
also get a **Lost connection to MySQL server during query** error if the communication packet is too large.

Both the client and the server have their own `max_allowed_packet` variable, so if you want to handle big packets, you must increase this variable both in the client and in the server.

If you are using the `mysql` client program, its default `max_allowed_packet` variable is 16MB. To set a larger value, start `mysql` like this:

```shell
mysql --max_allowed_packet=32M
```

That sets the packet size to 32MB.

The server’s default `max_allowed_packet` value is 1MB. You can increase this if the server needs to handle big queries (for example, if you are working with big BLOB columns). For example, to set the variable to 16MB, start the server like this:

```shell
mysqld --max_allowed_packet=16M
```

You can also use an option file to set `max_allowed_packet`. For example, to set the size for the server to 16MB, add the following lines in an option file:

```ini
[mysqld]
max_allowed_packet=16M
```

It is safe to increase the value of this variable because the extra memory is allocated only when needed. For example, `mysqld` allocates more memory only when you issue a long query or when `mysqld` must return a large result row. The small default value of the variable is a precaution to catch incorrect packets between the client and server and also to ensure that you do not run out of memory by using large packets accidentally.

You can also get strange problems with large packets if you are using large BLOB values but have not given `mysqld` access to enough memory to handle the query. If you suspect this is the case, try adding `ulimit -d 256000` to the beginning of the `mysqld_safe` script and restarting `mysqld`.

### B.4.2.11 Communication Errors and Aborted Connections

If connection problems occur such as communication errors or aborted connections, use these sources of information to diagnose problems:

- The error log. See Section 5.4.2, “The Error Log”.
- The general query log. See Section 5.4.3, “The General Query Log”.
- The Aborted_xxx status variables. See Section 5.1.9, “Server Status Variables”.

If you start the server with the `--log-warnings` option, you might find messages like this in your error log:

```
Aborted connection 854 to db: 'employees' user: 'josh'
```

If a client is unable even to connect, the server increments the `Aborted_connects` status variable. Unsuccessful connection attempts can occur for the following reasons:

- A client attempts to access a database but has no privileges for it.
- A client uses an incorrect password.
Common Errors When Using MySQL Programs

- A connection packet does not contain the right information.

- It takes more than `connect_timeout` seconds to obtain a connect packet. See Section 5.1.7, “Server System Variables”.

If these kinds of things happen, it might indicate that someone is trying to break into your server! If the general query log is enabled, messages for these types of problems are logged to it.

If a client successfully connects but later disconnects improperly or is terminated, the server increments the `Aborted_clients` status variable, and logs an `Aborted connection` message to the error log. The cause can be any of the following:

- The client program did not call `mysql_close()` before exiting.

- The client had been sleeping more than `wait_timeout` or `interactive_timeout` seconds without issuing any requests to the server. See Section 5.1.7, “Server System Variables”.

- The client program ended abruptly in the middle of a data transfer.

Other reasons for problems with aborted connections or aborted clients:

- The `max_allowed_packet` variable value is too small or queries require more memory than you have allocated for `mysqld`. See Section B.4.2.10, “Packet Too Large”.

- Use of Ethernet protocol with Linux, both half and full duplex. Some Linux Ethernet drivers have this bug. You should test for this bug by transferring a huge file using FTP between the client and server machines. If a transfer goes in burst-pause-burst-pause mode, you are experiencing a Linux duplex syndrome. Switch the duplex mode for both your network card and hub/switch to either full duplex or to half duplex and test the results to determine the best setting.

- A problem with the thread library that causes interrupts on reads.

- Badly configured TCP/IP.

- Faulty Ethernets, hubs, switches, cables, and so forth. This can be diagnosed properly only by replacing hardware.

See also Section B.4.2.9, “MySQL server has gone away”.

### B.4.2.12 The table is full

If a table-full error occurs, it may be that the disk is full or that the table has reached its maximum size. The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. See Section 8.4.6, “Limits on Table Size”.

This error can occur sometimes for NDB Cluster tables even when there appears to be more than sufficient data memory available. See the documentation for the `DataMemory` NDB Cluster data node configuration parameter, as well as Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

### B.4.2.13 Can't create/write to file

If you get an error of the following type for some queries, it means that MySQL cannot create a temporary file for the result set in the temporary directory:

```
Can't create/write to file '\sqla3fe_0.ism'.
```
Common Errors When Using MySQL Programs

The preceding error is a typical message for Windows; the Unix message is similar.

One fix is to start `mysqld` with the `--tmpdir` option or to add the option to the [mysqld] section of your option file. For example, to specify a directory of `C:\temp`, use these lines:

```
[mysqld]
tmpdir=C:/temp
```

The `C:\temp` directory must exist and have sufficient space for the MySQL server to write to. See Section 4.2.2.2, "Using Option Files".

Another cause of this error can be permissions issues. Make sure that the MySQL server can write to the `tmpdir` directory.

Check also the error code that you get with `perror`. One reason the server cannot write to a table is that the file system is full:

```
shell> perror 28
OS error code 28:  No space left on device
```

If you get an error of the following type during startup, it indicates that the file system or directory used for storing data files is write protected. Provided that the write error is to a test file, the error is not serious and can be safely ignored.

```
Can't create test file /usr/local/mysql/data/master.lower-test
```

B.4.2.14 Commands out of sync

If you get `Commands out of sync; you can't run this command now` in your client code, you are calling client functions in the wrong order.

This can happen, for example, if you are using `mysql_use_result()` and try to execute a new query before you have called `mysql_free_result()`. It can also happen if you try to execute two queries that return data without calling `mysql_use_result()` or `mysql_store_result()` in between.

B.4.2.15 Ignoring user

If you get the following error, it means that when `mysqld` was started or when it reloaded the grant tables, it found an account in the `user` table that had an invalid password.

```
Found wrong password for user 'some_user'@'some_host'; ignoring user
```

As a result, the account is simply ignored by the permission system.

The following list indicates possible causes of and fixes for this problem:

• You may be running a new version of `mysqld` with an old `user` table. Check whether the `Password` column of that table is shorter than 16 characters. If so, correct this condition by running `mysql_upgrade`.

• The account has an old password (eight characters long). Update the account in the `user` table to have a new password.

• You have specified a password in the `user` table without using the `PASSWORD()` function. Use `mysql` to update the account in the `user` table with a new password, making sure to use the `PASSWORD()` function:

```
mysql> UPDATE user SET Password=PASSWORD('new_password')
```
Common Errors When Using MySQL Programs

B.4.2.16 Table 'tbl_name' doesn't exist

If you get either of the following errors, it usually means that no table exists in the default database with the given name:

<table>
<thead>
<tr>
<th>Table 'tbl_name' doesn't exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can't find file: 'tbl_name' (errno: 2)</td>
</tr>
</tbody>
</table>

In some cases, it may be that the table does exist but that you are referring to it incorrectly:

- Because MySQL uses directories and files to store databases and tables, database and table names are case-sensitive if they are located on a file system that has case-sensitive file names.
- Even for file systems that are not case-sensitive, such as on Windows, all references to a given table within a query must use the same lettercase.

You can check which tables are in the default database with `SHOW TABLES`. See Section 13.7.5, “SHOW Statements”.

B.4.2.17 Can't initialize character set

You might see an error like this if you have character set problems:

MySQL Connection Failed: Can't initialize character set charset_name

This error can have any of the following causes:

- The character set is a multibyte character set and you have no support for the character set in the client. In this case, you need to recompile the client by running `CMake` with the `-DDEFAULT_CHARSET=charset_name` or `-DWITH_EXTRA_CHARSETS=charset_name` option. See Section 2.9.7, “MySQL Source-Configuration Options”.

All standard MySQL binaries are compiled with `-DWITH_EXTRA_CHARSETS=all`, which enables support for all multibyte character sets. See Section 2.9.7, “MySQL Source-Configuration Options”.

- The character set is a simple character set that is not compiled into `mysqlld`, and the character set definition files are not in the place where the client expects to find them.

In this case, you need to use one of the following methods to solve the problem:

- Recompile the client with support for the character set. See Section 2.9.7, “MySQL Source-Configuration Options”.
- Specify to the client the directory where the character set definition files are located. For many clients, you can do this with the `--character-sets-dir` option.
- Copy the character definition files to the path where the client expects them to be.

B.4.2.18 File Not Found and Similar Errors

If you get `ERROR 'file_name' not found (errno: 23), Can't open file: file_name (errno: 24)`, or any other error with `errno` 23 or `errno` 24 from MySQL, it means that you have not allocated enough file descriptors for the MySQL server. You can use the `perror` utility to get a description of what the error number means:

shell> `perror` 23
The problem here is that `mysqld` is trying to keep open too many files simultaneously. You can either tell `mysqld` not to open so many files at once or increase the number of file descriptors available to `mysqld`.

To tell `mysqld` to keep open fewer files at a time, you can make the table cache smaller by reducing the value of the `table_open_cache` system variable (the default value is 64). This may not entirely prevent running out of file descriptors because in some circumstances the server may attempt to extend the cache size temporarily, as described in Section 8.4.3.1, “How MySQL Opens and Closes Tables”. Reducing the value of `max_connections` also reduces the number of open files (the default value is 100).

To change the number of file descriptors available to `mysqld`, you can use the `--open-files-limit` option to `mysqld_safe` or set the `open_files_limit` system variable. See Section 5.1.7, “Server System Variables”. The easiest way to set these values is to add an option to your option file. See Section 4.2.2.2, “Using Option Files”. The easiest way to set these values is to add an option to your option file. See Section 5.1.7, “Server System Variables”. The easiest way to set these values is to add an option to your option file. See Section 4.2.2.2, “Using Option Files”. The easiest way to set these values is to add an option to your option file. See Section 5.1.7, “Server System Variables”. The easiest way to set these values is to add an option to your option file. See Section 4.2.2.2, “Using Option Files”.

`--open-files-limit` and `ulimit` can increase the number of file descriptors, but only up to the limit imposed by the operating system. There is also a “hard” limit that can be overridden only if you start `mysqld_safe` or `mysqld` as root (just remember that you also need to start the server with the `--user` option in this case so that it does not continue to run as root after it starts up). If you need to increase the operating system limit on the number of file descriptors available to each process, consult the documentation for your system.

If you run the `tcsh` shell, `ulimit` does not work! `tcsh` also reports incorrect values when you ask for the current limits. In this case, you should start `mysqld_safe` using `sh`.

### B.4.2.19 Table-Corruption Issues

If you have started `mysqld` with the `myisam_recover_options` system variable set, MySQL automatically checks and tries to repair MyISAM tables if they are marked as ‘not closed properly’ or ‘crashed’. If this happens, MySQL writes an entry in the `hostname.err` file 'Warning: Checking table ...' which is followed by Warning: Repairing table if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further.

As of MySQL 5.5.3, when the server detects MyISAM table corruption, it writes additional information to the error log, such as the name and line number of the source file, and the list of threads accessing the table. Example: Got an error from thread_id=1, mi_dynrec.c:368. This is useful information to include in bug reports.

See also Section 5.1.6, “Server Command Options”, and Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”.

### B.4.3 Administration-Related Issues

#### B.4.3.1 Problems with File Permissions
If you have problems with file permissions, the `UMASK` or `UMASK_DIR` environment variable might be set incorrectly when `mysqld` starts. For example, `mysqld` might issue the following error message when you create a table:

```
ERROR: Can't find file: 'path/with/filename.frm' (Errcode: 13)
```

The default `UMASK` and `UMASK_DIR` values are `0660` and `0700`, respectively. `mysqld` assumes that the value for `UMASK` or `UMASK_DIR` is in octal if it starts with a zero. For example, setting `UMASK=0600` is equivalent to `UMASK=384` because 0600 octal is 384 decimal.

Assuming that you start `mysqld` using `mysqld_safe`, change the default `UMASK` value as follows:

```bash
UMASK=384  # = 600 in octal
export UMASK
mysqld_safe &
```

**Note**

An exception applies for the error log file if you start `mysqld` using `mysqld_safe`, which does not respect `UMASK`: `mysqld_safe` may create the error log file if it does not exist prior to starting `mysqld`, and `mysqld_safe` uses a umask set to a strict value of `0137`. If this is unsuitable, create the error file manually with the desired access mode prior to executing `mysqld_safe`.

By default, `mysqld` creates database directories with an access permission value of `0700`. To modify this behavior, set the `UMASK_DIR` variable. If you set its value, new directories are created with the combined `UMASK` and `UMASK_DIR` values. For example, to give group access to all new directories, start `mysqld_safe` as follows:

```bash
UMASK_DIR=504  # = 770 in octal
export UMASK_DIR
mysqld_safe &
```

For additional details, see Section 4.9, “Environment Variables”.

### B.4.3.2 How to Reset the Root Password

If you have never assigned a root password for MySQL, the server does not require a password at all for connecting as root. However, this is insecure. For instructions on assigning passwords, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

If you know the root password and want to change it, see Section 13.7.1.6, “SET PASSWORD Statement”.

If you assigned a root password previously but have forgotten it, you can assign a new password. The following sections provide instructions for Windows and Unix and Unix-like systems, as well as generic instructions that apply to any system.

**Resetting the Root Password: Windows Systems**

On Windows, use the following procedure to reset the password for the MySQL `root'@'localhost` account. To change the password for a root account with a different host name part, modify the instructions to use that host name.

1. Log on to your system as Administrator.
2. Stop the MySQL server if it is running. For a server that is running as a Windows service, go to the Services manager: From the Start menu, select Control Panel, then Administrative Tools, then Services. Find the MySQL service in the list and stop it. If your server is not running as a service, you may need to use the Task Manager to force it to stop.

3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

   ```sql
   SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
   ```

4. Save the file. This example assumes that you name the file C:\mysql-init.txt.

5. Open a console window to get to the command prompt: From the Start menu, select Run, then enter cmd as the command to be run.

6. Start the MySQL server with the init_file system variable set to name the file (notice that the backslash in the option value is doubled):

   ```
   C:\> cd "C:\Program Files\MySQL\MySQL Server 5.5\bin"
   C:\> mysqld --init-file=C:\mysql-init.txt
   ```

   If you installed MySQL to a different location, adjust the cd command accordingly.

   The server executes the contents of the file named by the init_file system variable at startup, changing the 'root'@'localhost' account password.

   To have server output to appear in the console window rather than in a log file, add the --console option to the mysqld command.

   If you installed MySQL using the MySQL Installation Wizard, you may need to specify a --defaults-file option. For example:

   ```
   C:\> mysqld
   --defaults-file="C:\ProgramData\MySQL\MySQL Server 5.5\my.ini"
   --init-file=C:\mysql-init.txt
   ```

   The appropriate --defaults-file setting can be found using the Services Manager: From the Start menu, select Control Panel, then Administrative Tools, then Services. Find the MySQL service in the list, right-click it, and choose the Properties option. The Path to executable field contains the --defaults-file setting.

7. After the server has started successfully, delete C:\mysql-init.txt.

   You should now be able to connect to the MySQL server as root using the new password. Stop the MySQL server and restart it normally. If you run the server as a service, start it from the Windows Services window. If you start the server manually, use whatever command you normally use.

**Resetting the Root Password: Unix and Unix-Like Systems**

On Unix, use the following procedure to reset the password for the MySQL 'root'@'localhost' account. To change the password for a root account with a different host name part, modify the instructions to use that host name.

The instructions assume that you will start the MySQL server from the Unix login account that you normally use for running it. For example, if you run the server using the mysql login account, you should log in as mysql before using the instructions. Alternatively, you can log in as root, but in this case you **must** start mysqld with the --user=mysql option. If you start the server as root without using --user=mysql, the server may create root-owned files in the data directory, such as log files, and these may cause
permission-related problems for future server startups. If that happens, you will need to either change the ownership of the files to mysql or remove them.

1. Log on to your system as the Unix user that the MySQL server runs as (for example, mysql).

2. Stop the MySQL server if it is running. Locate the .pid file that contains the server’s process ID. The exact location and name of this file depend on your distribution, host name, and configuration. Common locations are /var/lib/mysql/, /var/run/mysqld/, and /usr/local/mysql/data/. Generally, the file name has an extension of .pid and begins with either mysqld or your system’s host name.

Stop the MySQL server by sending a normal kill (not kill -9) to the mysqld process. Use the actual path name of the .pid file in the following command:

```
shell> kill `cat /mysql-data-directory/host_name.pid`
```

Use backticks (not forward quotation marks) with the cat command. These cause the output of cat to be substituted into the kill command.

3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

```
SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
```

4. Save the file. This example assumes that you name the file /home/me/mysql-init. The file contains the password, so do not save it where it can be read by other users. If you are not logged in as mysql (the user the server runs as), make sure that the file has permissions that permit mysql to read it.

5. Start the MySQL server with the init_file system variable set to name the file:

```
shell> mysqld --init-file=/home/me/mysql-init &
```

The server executes the contents of the file named by the init_file system variable at startup, changing the 'root'@'localhost' account password.

Other options may be necessary as well, depending on how you normally start your server. For example, --defaults-file may be needed before the init_file argument.

6. After the server has started successfully, delete /home/me/mysql-init.

You should now be able to connect to the MySQL server as root using the new password. Stop the server and restart it normally.

**Resetting the Root Password: Generic Instructions**

The preceding sections provide password-resetting instructions specifically for Windows and Unix and Unix-like systems. Alternatively, on any platform, you can reset the password using the mysql client (but this approach is less secure):

1. Stop the MySQL server if necessary, then restart it with the --skip-grant-tables option. This enables anyone to connect without a password and with all privileges, and disables account-management statements such as SET PASSWORD. Because this is insecure, you might want to use --skip-grant-tables in conjunction with enabling the skip_networking system variable to prevent remote clients from connecting.

2. Connect to the MySQL server using the mysql client; no password is necessary because the server was started with --skip-grant-tables:

```
shell> mysql
```
3. In the mysql client, tell the server to reload the grant tables so that account-management statements work:

```
mysql> FLUSH PRIVILEGES;
```

Then change the 'root'@'localhost' account password. Replace the password with the password that you want to use. To change the password for a root account with a different host name part, modify the instructions to use that host name.

```
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
```

You should now be able to connect to the MySQL server as root using the new password. Stop the server and restart it normally (without the --skip-grant-tables option and without enabling the skip_networking system variable).

### B.4.3.3 What to Do If MySQL Keeps Crashing

Each MySQL version is tested on many platforms before it is released. This does not mean that there are no bugs in MySQL, but if there are bugs, they should be very few and can be hard to find. If you have a problem, it always helps if you try to find out exactly what crashes your system, because you have a much better chance of getting the problem fixed quickly.

First, you should try to find out whether the problem is that the mysqld server dies or whether your problem has to do with your client. You can check how long your mysqld server has been up by executing `mysqladmin version`. If mysqld has died and restarted, you may find the reason by looking in the server’s error log. See Section 5.4.2, “The Error Log”.

On some systems, you can find in the error log a stack trace of where mysqld died that you can resolve with the `resolve_stack_dump` program. See Section 24.5, “Debugging and Porting MySQL”. Note that the variable values written in the error log may not always be 100% correct.

Many server crashes are caused by corrupted data files or index files. MySQL updates the files on disk with the `write()` system call after every SQL statement and before the client is notified about the result. (This is not true if you are running with the `delay_key_write` system variable enabled, in which case data files are written but not index files.) This means that data file contents are safe even if mysqld crashes, because the operating system ensures that the unflushed data is written to disk. You can force MySQL to flush everything to disk after every SQL statement by starting mysqld with the `--flush` option.

The preceding means that normally you should not get corrupted tables unless one of the following happens:

- The MySQL server or the server host was killed in the middle of an update.
- You have found a bug in mysqld that caused it to die in the middle of an update.
- Some external program is manipulating data files or index files at the same time as mysqld without locking the table properly.
- You are running many mysqld servers using the same data directory on a system that does not support good file system locks (normally handled by the lockd lock manager), or you are running multiple servers with external locking disabled.
- You have a crashed data file or index file that contains very corrupt data that confused mysqld.
- You have found a bug in the data storage code. This isn't likely, but it is at least possible. In this case, you can try to change the storage engine to another engine by using `ALTER TABLE` on a repaired copy of the table.
Because it is very difficult to know why something is crashing, first try to check whether things that work for others crash for you. Please try the following things:

- **Stop the mysql server with** `mysqladmin shutdown`, run `myisamchk --silent --force */*.MYI` from the data directory to check all MyISAM tables, and restart `mysqld`. This ensures that you are running from a clean state. See *Chapter 5, MySQL Server Administration*.

- **Start mysql with the general query log enabled** (see Section 5.4.3, “The General Query Log”). Then try to determine from the information written to the log whether some specific query kills the server. About 95% of all bugs are related to a particular query. Normally, this is one of the last queries in the log file just before the server restarts. See Section 5.4.3, “The General Query Log”. If you can repeatedly kill MySQL with a specific query, even when you have checked all tables just before issuing it, then you have been able to locate the bug and should submit a bug report for it. See Section 1.6, “How to Report Bugs or Problems”.

- **Try to make a test case that we can use to repeat the problem.** See Section 24.5, “Debugging and Porting MySQL”.

- **Try the fork_big.pl script.** (It is located in the tests directory of source distributions.)

- **If you configure MySQL for debugging, it is much easier to gather information about possible errors if something goes wrong.** Reconfigure MySQL with the `--WITH_DEBUG=1` option to `CMake` and then recompile. See Section 24.5, “Debugging and Porting MySQL”.

- **Make sure that you have applied the latest patches for your operating system.**

- **Use the `--skip-external-locking` option to mysql.** On some systems, the `lockd` lock manager does not work properly; the `--skip-external-locking` option tells `mysql` not to use external locking. (This means that you cannot run two `mysql` servers on the same data directory and that you must be careful if you use `myisamchk`. Nevertheless, it may be instructive to try the option as a test.)

- **Have you tried mysqladmin -u root processlist when mysql appears to be running but not responding?** Sometimes `mysql` is not comatose even though you might think so. The problem may be that all connections are in use, or there may be some internal lock problem. mysqladmin -u root processlist usually is able to make a connection even in these cases, and can provide useful information about the current number of connections and their status.

- **Run the command mysqladmin -i 5 status or mysqladmin -i 5 -r status in a separate window to produce statistics while you run your other queries.**

- **Try the following:**
  1. Start `mysql` from `gdb` (or another debugger). See Section 24.5, “Debugging and Porting MySQL”.
  2. Run your test scripts.
  3. Print the backtrace and the local variables at the three lowest levels. In `gdb`, you can do this with the following commands when `mysql` has crashed inside `gdb`:

     ```
     backtrace
     info local
     up
     info local
     up
     info local
     ```

     With `gdb`, you can also examine which threads exist with `info threads` and switch to a specific thread with `thread N`, where `N` is the thread ID.
• Try to simulate your application with a Perl script to force MySQL to crash or misbehave.

• Send a normal bug report. See Section 1.6, “How to Report Bugs or Problems”. Be even more detailed than usual. Because MySQL works for many people, it may be that the crash results from something that exists only on your computer (for example, an error that is related to your particular system libraries).

• If you have a problem with tables containing dynamic-length rows and you are using only VARCHAR columns (not BLOB or TEXT columns), you can try to change all VARCHAR to CHAR with ALTER TABLE. This forces MySQL to use fixed-size rows. Fixed-size rows take a little extra space, but are much more tolerant to corruption.

The current dynamic row code has been in use for several years with very few problems, but dynamic-length rows are by nature more prone to errors, so it may be a good idea to try this strategy to see whether it helps.

• Do not rule out your server hardware when diagnosing problems. Defective hardware can be the cause of data corruption. Particular attention should be paid to your memory and disk subsystems when troubleshooting hardware.

### B.4.3.4 How MySQL Handles a Full Disk

This section describes how MySQL responds to disk-full errors (such as “no space left on device”), and to quota-exceeded errors (such as “write failed” or “user block limit reached”).

This section is relevant for writes to MyISAM tables. It also applies for writes to binary log files and binary log index file, except that references to “row” and “record” should be understood to mean “event.”

When a disk-full condition occurs, MySQL does the following:

• It checks once every minute to see whether there is enough space to write the current row. If there is enough space, it continues as if nothing had happened.

• Every 10 minutes it writes an entry to the log file, warning about the disk-full condition.

To alleviate the problem, you can take the following actions:

• To continue, you only have to free enough disk space to insert all records.

• To abort the thread, you must use `mysqladmin kill`. The thread is aborted the next time it checks the disk (in one minute).

• Other threads might be waiting for the table that caused the disk-full condition. If you have several “locked” threads, killing the one thread that is waiting on the disk-full condition enables the other threads to continue.

Exceptions to the preceding behavior are when you use `REPAIR TABLE` or `OPTIMIZE TABLE` or when the indexes are created in a batch after `LOAD DATA` or after an `ALTER TABLE` statement. All of these statements may create large temporary files that, if left to themselves, would cause big problems for the rest of the system. If the disk becomes full while MySQL is doing any of these operations, it removes the big temporary files and mark the table as crashed. The exception is that for `ALTER TABLE`, the old table is left unchanged.

### B.4.3.5 Where MySQL Stores Temporary Files

On Unix, MySQL uses the value of the `TMPDIR` environment variable as the path name of the directory in which to store temporary files. If `TMPDIR` is not set, MySQL uses the system default, which is usually `/tmp`, `/var/tmp`, or `/usr/tmp`. 
On Windows, MySQL checks in order the values of the `TMPDIR`, `TEMP`, and `TMP` environment variables. For the first one found to be set, MySQL uses it and does not check those remaining. If none of `TMPDIR`, `TEMP`, or `TMP` are set, MySQL uses the Windows system default, which is usually `C:\windows\temp\`.

If the file system containing your temporary file directory is too small, you can use the `mysqld --tmpdir` option to specify a directory in a file system where you have enough space. On replication slaves, you can use the `slave_load_tmpdir` system variable to specify a separate directory for holding temporary files when replicating `LOAD DATA` statements.

The `--tmpdir` option can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters (:) on Unix and semicolon characters (;) on Windows.

**Note**

To spread the load effectively, these paths should be located on different physical disks, not different partitions of the same disk.

If the MySQL server is acting as a replication slave, you should be sure to set `slave_load_tmpdir` not to point to a directory that is on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA` operations. If files in the slave temporary file directory are lost when the server restarts, replication fails.

MySQL arranges that temporary files are removed if `mysqld` is terminated. On platforms that support it (such as Unix), this is done by unlinking the file after opening it. The disadvantage of this is that the name does not appear in directory listings and you do not see a big temporary file that fills up the file system in which the temporary file directory is located. (In such cases, `lsof +L1` may be helpful in identifying large files associated with `mysqld`.)

When sorting (`ORDER BY` or `GROUP BY`), MySQL normally uses one or two temporary files. The maximum disk space required is determined by the following expression:

\[
\text{(length of what is sorted + sizeof(row pointer))} \\
\times \text{number of matched rows} \\
\times 2
\]

The row pointer size is usually four bytes, but may grow in the future for really big tables.

For some statements, MySQL creates temporary SQL tables that are not hidden and have names that begin with `#sql`.

Some `SELECT` queries creates temporary SQL tables to hold intermediate results.

`ALTER TABLE` creates a temporary copy of the original table in the same directory as the original table.

See also [Orphan Temporary Tables](#).

### B.4.3.6 How to Protect or Change the MySQL Unix Socket File

The default location for the Unix socket file that the server uses for communication with local clients is `/tmp/mysql.sock`. (For some distribution formats, the directory might be different, such as `/var/lib/mysql` for RPMs.)

On some versions of Unix, anyone can delete files in the `/tmp` directory or other similar directories used for temporary files. If the socket file is located in such a directory on your system, this might cause problems.
On most versions of Unix, you can protect your `/tmp` directory so that files can be deleted only by their owners or the superuser (`root`). To do this, set the `sticky` bit on the `/tmp` directory by logging in as `root` and using the following command:

```
shell> chmod +t /tmp
```

You can check whether the `sticky` bit is set by executing `ls -ld /tmp`. If the last permission character is `t`, the bit is set.

Another approach is to change the place where the server creates the Unix socket file. If you do this, you should also let client programs know the new location of the file. You can specify the file location in several ways:

- Specify the path in a global or local option file. For example, put the following lines in `/etc/my.cnf`:
  ```
  [mysqld]
  socket=/path/to/socket
  [client]
  socket=/path/to/socket
  ```
  See Section 4.2.2.2, “Using Option Files”.
- Specify a `--socket` option on the command line to `mysqld_safe` and when you run client programs.
- Set the `MYSQL_UNIX_PORT` environment variable to the path of the Unix socket file.
- Recompile MySQL from source to use a different default Unix socket file location. Define the path to the file with the `MYSQL_UNIX_ADDR` option when you run `CMake`. See Section 2.9.7, “MySQL Source-Configuration Options”.

You can test whether the new socket location works by attempting to connect to the server with this command:

```
shell> mysqladmin --socket=/path/to/socket version
```

### B.4.3.7 Time Zone Problems

If you have a problem with `SELECT NOW()` returning values in UTC and not your local time, you have to tell the server your current time zone. The same applies if `UNIX_TIMESTAMP()` returns the wrong value. This should be done for the environment in which the server runs (for example, in `mysqld_safe` or `mysql.server`). See Section 4.9, “Environment Variables”.

You can set the time zone for the server with the `--timezone=timezone_name` option to `mysqld_safe`. You can also set it by setting the `TZ` environment variable before you start `mysqld`.

The permissible values for `--timezone` or `TZ` are system dependent. Consult your operating system documentation to see what values are acceptable.

### B.4.4 Query-Related Issues

#### B.4.4.1 Case Sensitivity in String Searches

For nonbinary strings (`CHAR`, `VARCHAR`, `TEXT`), string searches use the collation of the comparison operands. For binary strings (`BINARY`, `VARBINARY`, `BLOB`), comparisons use the numeric values of the bytes in the operands; this means that for alphabetic characters, comparisons will be case-sensitive.

A comparison between a nonbinary string and binary string is treated as a comparison of binary strings.
Simple comparison operations (>=, >, =, <, <=, sorting, and grouping) are based on each character’s “sort value.” Characters with the same sort value are treated as the same character. For example, if e and é have the same sort value in a given collation, they compare as equal.

The default character set and collation are latin1 and latin1_swedish_ci, so nonbinary string comparisons are case-insensitive by default. This means that if you search with col_name LIKE 'a %', you get all column values that start with A or a. To make this search case-sensitive, make sure that one of the operands has a case-sensitive or binary collation. For example, if you are comparing a column and a string that both have the latin1 character set, you can use the COLLATE operator to cause either operand to have the latin1_general_cs or latin1_bin collation:

```
col_name COLLATE latin1_general_cs LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_general_cs
col_name COLLATE latin1_bin LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_bin
```

If you want a column always to be treated in case-sensitive fashion, declare it with a case-sensitive or binary collation. See Section 13.1.17, “CREATE TABLE Statement”.

To cause a case-sensitive comparison of nonbinary strings to be case-insensitive, use COLLATE to name a case-insensitive collation. The strings in the following example normally are case-sensitive, but COLLATE changes the comparison to be case-insensitive:

```
mysql> SET @s1 = 'MySQL' COLLATE latin1_bin,
   -> @s2 = 'mysql' COLLATE latin1_bin;
mysql> SELECT @s1 = @s2;
+-----------+
| @s1 = @s2 |
+-----------+
|         0 |
mysql> SELECT @s1 COLLATE latin1_swedish_ci = @s2;
+-------------------------------------+
| @s1 COLLATE latin1_swedish_ci = @s2 |
+-------------------------------------+
|                                   1 |
+-------------------------------------+
```

A binary string is case-sensitive in comparisons. To compare the string as case-insensitive, convert it to a nonbinary string and use COLLATE to name a case-insensitive collation:

```
mysql> SET @s = BINARY 'MySQL';
mysql> SELECT @s = 'mysql';
+--------------+
| @s = 'mysql' |
+--------------+
|            0 |
mysql> SELECT CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql';
+--------------------------------------------------------------+
| CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql' |
+--------------------------------------------------------------+
|                                                            1 |
+--------------------------------------------------------------+
```

To determine whether a value will compare as a nonbinary or binary string, use the COLLATION() function. This example shows that VERSION() returns a string that has a case-insensitive collation, so comparisons are case-insensitive:

```
mysql> SELECT COLLATION(VERSION());
+----------------------+
| COLLATION(VERSION()) |
+----------------------+
```
Query-Related Issues

utf8_general_ci

For binary strings, the collation value is binary, so comparisons will be case-sensitive. One context in which you will see binary is for compression functions, which return binary strings as a general rule:

```sql
mysql> SELECT COLLATION(COMPRESS('x'));
+----------------------------------+
| COLLATION(COMPRESS('x'))          |
+----------------------------------+
| binary                           |
+----------------------------------+
```

B.4.4.2 Problems Using DATE Columns

The format of a DATE value is 'YYYY-MM-DD'. According to standard SQL, no other format is permitted. You should use this format in UPDATE expressions and in the WHERE clause of SELECT statements. For example:

```sql
SELECT * FROM t1 WHERE date >= '2003-05-05';
```

As a convenience, MySQL automatically converts a date to a number if the date is used in numeric context and vice versa. MySQL also permits a "relaxed" string format when updating and in a WHERE clause that compares a date to a DATE, DATETIME, or TIMESTAMP column. "Relaxed" format means that any punctuation character may be used as the separator between parts. For example, '2004-08-15' and '2004#08#15' are equivalent. MySQL can also convert a string containing no separators (such as '20040815'), provided it makes sense as a date.

When you compare a DATE, TIME, DATETIME, or TIMESTAMP to a constant string with the <, <=, =, >=, >, or BETWEEN operators, MySQL normally converts the string to an internal long integer for faster comparison (and also for a bit more "relaxed" string checking). However, this conversion is subject to the following exceptions:

- When you compare two columns
- When you compare a DATE, TIME, DATETIME, or TIMESTAMP column to an expression
- When you use any comparison method other than those just listed, such as IN or STRCMP().

For those exceptions, the comparison is done by converting the objects to strings and performing a string comparison.

To be on the safe side, assume that strings are compared as strings and use the appropriate string functions if you want to compare a temporal value to a string.

The special “zero” date '0000-00-00' can be stored and retrieved as '0000-00-00'. When a '0000-00-00' date is used through Connector/ODBC, it is automatically converted to NULL because ODBC cannot handle that kind of date.

Because MySQL performs the conversions just described, the following statements work (assume that `idate` is a DATE column):

```sql
INSERT INTO t1 (idate) VALUES (19970505);
INSERT INTO t1 (idate) VALUES ('19970505');
INSERT INTO t1 (idate) VALUES ('97-05-05');
INSERT INTO t1 (idate) VALUES ('1997.05.05');
INSERT INTO t1 (idate) VALUES ('1997 05 05');
```
INSERT INTO t1 (idate) VALUES ('0000-00-00');
SELECT idate FROM t1 WHERE idate >= '1997-05-05';
SELECT idate FROM t1 WHERE idate >= 19970505;
SELECT MOD(idate,100) FROM t1 WHERE idate >= 19970505;
SELECT idate FROM t1 WHERE idate >= '19970505';

However, the following statement does not work:
SELECT idate FROM t1 WHERE STRCMP(idate,'20030505')=0;

STRCMP() is a string function, so it converts idate to a string in 'YYYY-MM-DD' format and performs a string comparison. It does not convert '20030505' to the date '2003-05-05' and perform a date comparison.

If you enable the ALLOW_INVALID_DATES SQL mode, MySQL permits you to store dates that are given only limited checking: MySQL requires only that the day is in the range from 1 to 31 and the month is in the range from 1 to 12. This makes MySQL very convenient for Web applications where you obtain year, month, and day in three different fields and you want to store exactly what the user inserted (without date validation).

MySQL permits you to store dates where the day or month and day are zero. This is convenient if you want to store a birthdate in a DATE column and you know only part of the date. To disallow zero month or day parts in dates, enable the NO_ZERO_IN_DATE SQL mode.

MySQL permits you to store a “zero” value of '0000-00-00' as a “dummy date.” This is in some cases more convenient than using NULL values. If a date to be stored in a DATE column cannot be converted to any reasonable value, MySQL stores '0000-00-00'. To disallow '0000-00-00', enable the NO_ZERO_DATE SQL mode.

To have MySQL check all dates and accept only legal dates (unless overridden by IGNORE), set the sql_mode system variable to "NO_ZERO_IN_DATE,NO_ZERO_DATE".

B.4.4.3 Problems with NULL Values

The concept of the NULL value is a common source of confusion for newcomers to SQL, who often think that NULL is the same thing as an empty string ' '. This is not the case. For example, the following statements are completely different:

mysql> INSERT INTO my_table (phone) VALUES (NULL);
mysql> INSERT INTO my_table (phone) VALUES ('');

Both statements insert a value into the phone column, but the first inserts a NULL value and the second inserts an empty string. The meaning of the first can be regarded as “phone number is not known” and the meaning of the second can be regarded as “the person is known to have no phone, and thus no phone number.”

To help with NULL handling, you can use the IS NULL and IS NOT NULL operators and the IFNULL() function.

In SQL, the NULL value is never true in comparison to any other value, even NULL. An expression that contains NULL always produces a NULL value unless otherwise indicated in the documentation for the operators and functions involved in the expression. All columns in the following example return NULL:

mysql> SELECT NULL, 1,NULL, CONCAT('Invisible',NULL);

To search for column values that are NULL, you cannot use an expr = NULL test. The following statement returns no rows, because expr = NULL is never true for any expression:
Query-Related Issues

```
mysql> SELECT * FROM my_table WHERE phone = NULL;
```

To look for NULL values, you must use the `IS NULL` test. The following statements show how to find the NULL phone number and the empty phone number:

```
mysql> SELECT * FROM my_table WHERE phone IS NULL;
mysql> SELECT * FROM my_table WHERE phone = ' ';
```

See Section 3.3.4.6, “Working with NULL Values”, for additional information and examples.

You can add an index on a column that can have NULL values if you are using the MyISAM, InnoDB, or MEMORY storage engine. Otherwise, you must declare an indexed column NOT NULL, and you cannot insert NULL into the column.

When reading data with LOAD DATA, empty or missing columns are updated with ' '. To load a NULL value into a column, use `\N` in the data file. The literal word NULL may also be used under some circumstances. See Section 13.2.6, “LOAD DATA Statement”.

When using DISTINCT, GROUP BY, or ORDER BY, all NULL values are regarded as equal.

When using ORDER BY, NULL values are presented first, or last if you specify DESC to sort in descending order.

Aggregate (summary) functions such as COUNT(), MIN(), and SUM() ignore NULL values. The exception to this is COUNT(*), which counts rows and not individual column values. For example, the following statement produces two counts. The first is a count of the number of rows in the table, and the second is a count of the number of non-NULL values in the age column:

```
mysql> SELECT COUNT(*), COUNT(age) FROM person;
```

For some data types, MySQL handles NULL values specially. If you insert NULL into a TIMESTAMP column, the current date and time is inserted. If you insert NULL into an integer or floating-point column that has the AUTO_INCREMENT attribute, the next number in the sequence is inserted.

### B.4.4.4 Problems with Column Aliases

An alias can be used in a query select list to give a column a different name. You can use the alias in GROUP BY, ORDER BY, or HAVING clauses to refer to the column:

```
SELECT SQRT(a*b) AS root FROM tbl_name
GROUP BY root HAVING root > 0;
```

```
SELECT id, COUNT(*) AS cnt FROM tbl_name
GROUP BY id HAVING cnt > 0;
```

```
SELECT id AS 'Customer identity' FROM tbl_name;
```

Standard SQL disallows references to column aliases in a WHERE clause. This restriction is imposed because when the WHERE clause is evaluated, the column value may not yet have been determined. For example, the following query is illegal:

```
SELECT id, COUNT(*) AS cnt FROM tbl_name
WHERE cnt > 0 GROUP BY id;
```

The WHERE clause determines which rows should be included in the GROUP BY clause, but it refers to the alias of a column value that is not known until after the rows have been selected, and grouped by the GROUP BY.

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:
SELECT 1 AS 'one', 2 AS 'two';

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal. For example, this statement groups by the values in column `id`, referenced using the alias `a`:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
GROUP BY `a`;
```

But this statement groups by the literal string 'a' and will not work as expected:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
GROUP BY 'a';
```

**B.4.4.5 Rollback Failure for Nontransactional Tables**

If you receive the following message when trying to perform a **ROLLBACK**, it means that one or more of the tables you used in the transaction do not support transactions:

*Warning: Some non-transactional changed tables couldn't be rolled back*

These nontransactional tables are not affected by the **ROLLBACK** statement.

If you were not deliberately mixing transactional and nontransactional tables within the transaction, the most likely cause for this message is that a table you thought was transactional actually is not. This can happen if you try to create a table using a transactional storage engine that is not supported by your **mysql** server (or that was disabled with a startup option). If **mysql** does not support a storage engine, it instead creates the table as a **MyISAM** table, which is nontransactional.

You can check the storage engine for a table by using either of these statements:

```
SHOW TABLE STATUS LIKE 'tbl_name';
SHOW CREATE TABLE tbl_name;
```

See Section 13.7.5.37, “SHOW TABLE STATUS Statement”, and Section 13.7.5.12, “SHOW CREATE TABLE Statement”.

You can check which storage engines your **mysql** server supports by using this statement:

```
SHOW ENGINES;
```

You can also use the following statement, and check the value of the variable that is associated with the storage engine in which you are interested:

```
SHOW VARIABLES LIKE 'have_%';
```

For example, to determine whether the **InnoDB** storage engine is available, check the value of the `have_innodb` variable.

See Section 13.7.5.17, “SHOW ENGINES Statement”, and Section 13.7.5.40, “SHOW VARIABLES Statement”.

**B.4.4.6 Deleting Rows from Related Tables**

If the total length of the **DELETE** statement for `related_table` is more than 1MB (the default value of the `max_allowed_packet` system variable), you should split it into smaller parts and execute multiple **DELETE** statements. You probably get the fastest **DELETE** by specifying only 100 to 1,000
related_column values per statement if the related_column is indexed. If the related_column isn't indexed, the speed is independent of the number of arguments in the IN clause.

**B.4.4.7 Solving Problems with No Matching Rows**

If you have a complicated query that uses many tables but that returns no rows, you should use the following procedure to find out what is wrong:

1. Test the query with EXPLAIN to check whether you can find something that is obviously wrong. See Section 13.8.2, “EXPLAIN Statement”.
2. Select only those columns that are used in the WHERE clause.
3. Remove one table at a time from the query until it returns some rows. If the tables are large, it is a good idea to use LIMIT 10 with the query.
4. Issue a SELECT for the column that should have matched a row against the table that was last removed from the query.
5. If you are comparing FLOAT or DOUBLE columns with numbers that have decimals, you cannot use equality (=) comparisons. This problem is common in most computer languages because not all floating-point values can be stored with exact precision. In some cases, changing the FLOAT to a DOUBLE fixes this. See Section B.4.4.8, “Problems with Floating-Point Values”.
6. If you still cannot figure out what is wrong, create a minimal test that can be run with mysql test < query.sql that shows your problems. You can create a test file by dumping the tables with mysqldump --quick db_name tbl_name_1 ... tbl_name_n > query.sql. Open the file in an editor, remove some insert lines (if there are more than needed to demonstrate the problem), and add your SELECT statement at the end of the file.

Verify that the test file demonstrates the problem by executing these commands:

```shell
shell> mysqladmin create test2
shell> mysql test2 < query.sql
```

Attach the test file to a bug report, which you can file using the instructions in Section 1.6, “How to Report Bugs or Problems”.

**B.4.4.8 Problems with Floating-Point Values**

Floating-point numbers sometimes cause confusion because they are approximate and not stored as exact values. A floating-point value as written in an SQL statement may not be the same as the value represented internally. Attempts to treat floating-point values as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. The FLOAT and DOUBLE data types are subject to these issues. For DECIMAL columns, MySQL performs operations with a precision of 65 decimal digits, which should solve most common inaccuracy problems.

The following example uses DOUBLE to demonstrate how calculations that are done using floating-point operations are subject to floating-point error.

```sql
mysql> CREATE TABLE t1 (i INT, d1 DOUBLE, d2 DOUBLE);
mysql> INSERT INTO t1 VALUES (1, 101.40, 21.40), (1, -80.00, 0.00),
-> (2, 0.00, 0.00), (2, -13.20, 0.00), (2, 59.60, 46.40),
-> (2, 30.40, 30.40), (3, 37.00, 7.40), (3, -29.60, 0.00),
-> (4, 0.00, 0.00), (4, -10.60, 0.00), (4, -34.00, 0.00),
-> (5, 33.00, 0.00), (5, -25.80, 0.00), (5, 0.00, 7.20),
-> (6, 0.00, 0.00), (6, -51.40, 0.00);
```
The result is correct. Although the first five records look like they should not satisfy the comparison (the values of \(a\) and \(b\) do not appear to be different), they may do so because the difference between the numbers shows up around the tenth decimal or so, depending on factors such as computer architecture or the compiler version or optimization level. For example, different CPUs may evaluate floating-point numbers differently.

If columns \(d1\) and \(d2\) had been defined as \texttt{DECIMAL} rather than \texttt{DOUBLE}, the result of the \texttt{SELECT} query would have contained only one row—the last one shown above.

The correct way to do floating-point number comparison is to first decide on an acceptable tolerance for differences between the numbers and then do the comparison against the tolerance value. For example, if we agree that floating-point numbers should be regarded the same if they are same within a precision of one in ten thousand (0.0001), the comparison should be written to find differences larger than the tolerance value:

```sql
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) > 0.0001;
```

```plaintext
+------+-------+------+
| i    | a     | b    |
| 6    | -51.4 | 0    |
+------+-------+------+
1 row in set (0.00 sec)
```

Conversely, to get rows where the numbers are the same, the test should find differences within the tolerance value:

```sql
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) <= 0.0001;
```

```plaintext
+------+-------+------+
| i    | a     | b    |
| 1    | 21.4  | 21.4 |
| 2    | 76.8  | 76.8 |
| 3    | 7.4   | 7.4  |
| 4    | 15.4  | 15.4 |
| 5    | 7.2   | 7.2  |
+------+-------+------+
5 rows in set (0.03 sec)
```

Floating-point values are subject to platform or implementation dependencies. Suppose that you execute the following statements:

```sql
CREATE TABLE t1(c1 FLOAT(53,0), c2 FLOAT(53,0));
INSERT INTO t1 VALUES('1e+52','-1e+52');
SELECT * FROM t1;
```

On some platforms, the \texttt{SELECT} statement returns \texttt{inf} and \texttt{-inf}. On others, it returns 0 and \texttt{-0}. 

3172
Optimizer-Related Issues

An implication of the preceding issues is that if you attempt to create a replication slave by dumping table contents with `mysqldump` on the master and reloading the dump file into the slave, tables containing floating-point columns might differ between the two hosts.

B.4.5 Optimizer-Related Issues

MySQL uses a cost-based optimizer to determine the best way to resolve a query. In many cases, MySQL can calculate the best possible query plan, but sometimes MySQL does not have enough information about the data at hand and has to make “educated” guesses about the data.

For the cases when MySQL does not do the "right" thing, tools that you have available to help MySQL are:

- Use the `EXPLAIN` statement to get information about how MySQL processes a query. To use it, just add the keyword `EXPLAIN` to the front of your `SELECT` statement:

  ```sql
  mysql> EXPLAIN SELECT * FROM t1, t2 WHERE t1.i = t2.i;
  ```

  `EXPLAIN` is discussed in more detail in Section 13.8.2, “EXPLAIN Statement”.

- Use `ANALYZE TABLE tbl_name` to update the key distributions for the scanned table. See Section 13.7.2.1, “ANALYZE TABLE Statement”.

- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

  ```sql
  SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
  WHERE t1.col_name=t2.col_name;
  ```

  `USE INDEX` and `IGNORE INDEX` may also be useful. See Section 8.9.3, “Index Hints”.

- Global and table-level `STRAIGHT_JOIN`. See Section 13.2.9, “SELECT Statement”.

- You can tune global or thread-specific system variables. For example, start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.7, “Server System Variables”.

B.4.6 Table Definition-Related Issues

B.4.6.1 Problems with ALTER TABLE

If you get a duplicate-key error when using `ALTER TABLE` to change the character set or collation of a character column, the cause is either that the new column collation maps two keys to the same value or that the table is corrupted. In the latter case, you should run `REPAIR TABLE` on the table. `REPAIR TABLE` works for `MyISAM`, `ARCHIVE`, and `CSV` tables.

If `ALTER TABLE` dies with the following error, the problem may be that MySQL crashed during an earlier `ALTER TABLE` operation and there is an old table named `A-xxx` or `B-xxx` lying around:

```sql
Error on rename of './database/name.frm'
to './database/B-xxx.frm' (Errcode: 17)
```

In this case, go to the MySQL data directory and delete all files that have names starting with `A-` or `B-`.

(You may want to move them elsewhere instead of deleting them.)

`ALTER TABLE` works in the following way:

- Create a new table named `A-xxx` with the requested structural changes.
known issues in MySQL

- Copy all rows from the original table to A-xxx.
- Rename the original table to B-xxx.
- Rename A-xxx to your original table name.
- Delete B-xxx.

If something goes wrong with the renaming operation, MySQL tries to undo the changes. If something goes seriously wrong (although this shouldn't happen), MySQL may leave the old table as B-xxx. A simple rename of the table files at the system level should get your data back.

If you use ALTER TABLE on a transactional table or if you are using Windows, ALTER TABLE unlocks the table if you had done a LOCK TABLE on it. This is done because InnoDB and these operating systems cannot drop a table that is in use.

B.4.6.2 TEMPORARY Table Problems

Temporary tables created with CREATE TEMPORARY TABLE have the following limitations:

- TEMPORARY tables are supported only by the InnoDB, MEMORY, MyISAM, and MERGE storage engines.
- Temporary tables are not supported for NDB Cluster.
- The SHOW TABLES statement does not list TEMPORARY tables.
- To rename TEMPORARY tables, RENAME TABLE does not work. Use ALTER TABLE instead:

```sql
ALTER TABLE old_name RENAME new_name;
```

- You cannot refer to a TEMPORARY table more than once in the same query. For example, the following does not work:

```sql
SELECT * FROM temp_table JOIN temp_table AS t2;
```

The statement produces this error:

```sql
ERROR 1137: Can't reopen table: 'temp_table'
```

- The Can't reopen table error also occurs if you refer to a temporary table multiple times in a stored function under different aliases, even if the references occur in different statements within the function.

- If a TEMPORARY is created with the same name as an existing non-TEMPORARY table, the non-TEMPORARY table is hidden until the TEMPORARY table is dropped, even if the tables use different storage engines.

- There are known issues in using temporary tables with replication. See Section 17.4.1.30, “Replication and Temporary Tables”, for more information.

B.4.7 Known Issues in MySQL

This section lists known issues in recent versions of MySQL.

For information about platform-specific issues, see the installation and porting instructions in Section 2.1, “General Installation Guidance”, and Section 24.5, “Debugging and Porting MySQL”.

The following problems are known:

- Subquery optimization for IN is not as effective as for =.
Known Issues in MySQL

- Even if you use `lower_case_table_names=2` (which enables MySQL to remember the case used for databases and table names), MySQL does not remember the case used for database names for the function `DATABASE()` or within the various logs (on case-insensitive systems).

- Dropping a `FOREIGN KEY` constraint does not work in replication because the constraint may have another name on the slave.

- `REPLACE` (and `LOAD DATA` with the `REPLACE` option) does not trigger `ON DELETE CASCADE`.

- `DISTINCT` with `ORDER BY` does not work inside `GROUP_CONCAT()` if you do not use all and only those columns that are in the `DISTINCT` list.

- When inserting a big integer value (between $2^{63}$ and $2^{64} - 1$) into a decimal or string column, it is inserted as a negative value because the number is evaluated in signed integer context.

- `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` may cause problems on tables for which you are using `INSERT DELAYED`.

- With statement-based binary logging, the master writes the executed queries to the binary log. This is a very fast, compact, and efficient logging method that works perfectly in most cases. However, it is possible for the data on the master and slave to become different if a query is designed in such a way that the data modification is nondeterministic (generally not a recommended practice, even outside of replication).

For example:

- `CREATE TABLE ... SELECT` or `INSERT ... SELECT` statements that insert zero or null values into an `AUTO_INCREMENT` column.

- `DELETE` if you are deleting rows from a table that has foreign keys with `ON DELETE CASCADE` properties.

- `REPLACE ... SELECT`, `INSERT IGNORE ... SELECT` if you have duplicate key values in the inserted data.

If and only if the preceding queries have no `ORDER BY` clause guaranteeing a deterministic order.

For example, for `INSERT ... SELECT` with no `ORDER BY`, the `SELECT` may return rows in a different order (which results in a row having different ranks, hence getting a different number in the `AUTO_INCREMENT` column), depending on the choices made by the optimizers on the master and slave.

A query is optimized differently on the master and slave only if:

- The table is stored using a different storage engine on the master than on the slave. (It is possible to use different storage engines on the master and slave. For example, you can use `InnoDB` on the master, but `MyISAM` on the slave if the slave has less available disk space.)

- MySQL buffer sizes (`key_buffer_size`, and so on) are different on the master and slave.

- The master and slave run different MySQL versions, and the optimizer code differs between these versions.

This problem may also affect database restoration using `mysqlbinlog|mysql`.

The easiest way to avoid this problem is to add an `ORDER BY` clause to the aforementioned nondeterministic queries to ensure that the rows are always stored or modified in the same order. Using row-based or mixed logging format also avoids the problem.
Known Issues in MySQL

• Log file names are based on the server host name if you do not specify a file name with the startup option. To retain the same log file names if you change your host name to something else, you must explicitly use options such as `--log-bin=old_host_name-bin`. See Section 5.1.6, "Server Command Options". Alternatively, rename the old files to reflect your host name change. If these are binary logs, you must edit the binary log index file and fix the binary log file names there as well. (The same is true for the relay logs on a slave server.)

• `mysqlbinlog` does not delete temporary files left after a `LOAD DATA` statement. See Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files".

• `RENAME` does not work with `TEMPORARY` tables or tables used in a `MERGE` table.

• When using `SET CHARACTER SET`, you cannot use translated characters in database, table, and column names.

• You cannot use `_` or `%` with `ESCAPE` in `LIKE ... ESCAPE`.

• The server uses only the first `max_sort_length` bytes when comparing data values. This means that values cannot reliably be used in `GROUP BY`, `ORDER BY`, or `DISTINCT` if they differ only after the first `max_sort_length` bytes. To work around this, increase the variable value. The default value of `max_sort_length` is 1024 and can be changed at server startup time or at runtime.

• Numeric calculations are done with `BIGINT` or `DOUBLE` (both are normally 64 bits long). Which precision you get depends on the function. The general rule is that bit functions are performed with `BIGINT` precision, `IF()` and `ELT()` with `BIGINT` or `DOUBLE` precision, and the rest with `DOUBLE` precision. You should try to avoid using unsigned long long values if they resolve to be larger than 63 bits (9223372036854775807) for anything other than bit fields.

• You can have up to 255 `ENUM` and `SET` columns in one table.

• In `MIN()`, `MAX()`, and other aggregate functions, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set.

• In an `UPDATE` statement, columns are updated from left to right. If you refer to an updated column, you get the updated value instead of the original value. For example, the following statement increments `KEY` by 2, not 1:

```sql
mysql> UPDATE tbl_name SET KEY=KEY+1,KEY=KEY+1;
```

• You can refer to multiple temporary tables in the same query, but you cannot refer to any given temporary table more than once. For example, the following does not work:

```sql
mysql> SELECT * FROM temp_table, temp_table AS t2;
ERROR 1137: Can't reopen table: 'temp_table'
```

• The optimizer may handle `DISTINCT` differently when you are using “hidden” columns in a join than when you are not. In a join, hidden columns are counted as part of the result (even if they are not shown), whereas in normal queries, hidden columns do not participate in the `DISTINCT` comparison.

An example of this is:

```sql
SELECT DISTINCT mp3id FROM band_downloads
WHERE userid = 9 ORDER BY id DESC;
```

and

```sql
SELECT DISTINCT band_downloads.mp3id
FROM band_downloads,band_mp3
WHERE band_downloads.userid = 9
```
AND band_mp3.id = band_downloads.mp3id
ORDER BY band_downloads.id DESC;

In the second case, you may get two identical rows in the result set (because the values in the hidden id column may differ).

Note that this happens only for queries that do not have the ORDER BY columns in the result.

• If you execute a PROCEDURE on a query that returns an empty set, in some cases the PROCEDURE does not transform the columns.

• Creation of a table of type MERGE does not check whether the underlying tables are compatible types.

• If you use ALTER TABLE to add a UNIQUE index to a table used in a MERGE table and then add a normal index on the MERGE table, the key order is different for the tables if there was an old, non-UNIQUE key in the table. This is because ALTER TABLE puts UNIQUE indexes before normal indexes to be able to detect duplicate keys as early as possible.
Appendix C Indexes

Table of Contents

General Index ................................................................. 3179
C Function Index .......................................................... 3389
Command Index .................................................................. 3404
Function Index .................................................................. 3447
INFORMATION_SCHEMA Index .............................................. 3478
Join Types Index ................................................................ 3486
Operator Index .................................................................... 3488
Option Index ...................................................................... 3496
Privileges Index .................................................................. 3583
SQL Modes Index .................................................................. 3592
Statement/Syntax Index ..................................................... 3596
Status Variable Index ....................................................... 3669
System Variable Index ...................................................... 3689
Transaction Isolation Level Index ...................................... 3734

General Index

Symbols

! (logical NOT), 1237
!= (not equal), 1232
" , 1038
#mysql50 identifier prefix, 1039, 1046
% , 1244
% (modulo), 1249
% (wildcard character), 1031
& (bitwise AND), 1328
&& (logical AND), 1237
() (parentheses), 1230
(Control+Z \Z , 1031, 1500
* (multiplication), 1243
+ (addition), 1243
- (subtraction), 1243
- (unary minus), 1243
--all
  removed features, 16
--base64-output
  deprecated features, 14
--config-file
  deprecated features, 14
  removed features, 16
--default-character-set
  removed features, 15
--default-collation
  removed features, 15
--default-table-type
  removed features, 15
--delay-key-write-for-all-tables
  removed features, 15
--enable-locking
  removed features, 15
--enable-pstack
  removed features, 16
--first-slave
  removed features, 16
--language
  deprecated features, 14
--log-long-format
  removed features, 15
--log-update
  removed features, 15
--master-xxx
  removed features, 15
--no-named-commands
  removed features, 15
--no-pager
  removed features, 15
--no-tee
  removed features, 15
--password option, 736
--position
  removed features, 16
--safe-show-database
  removed features, 15
--set-variable
  removed features, 16
--skip-locking
  removed features, 15
--skip-symlink
  removed features, 15
--sql-bin-update-same
  removed features, 15
--use-symbolic-links
  removed features, 15
--warnings
  removed features, 15
--with-pstack
  removed features, 16
-? option (NDB Cluster programs), 2439
-c option (NDB Cluster programs), 2440
-c option (ndb_mgmd) (OBSOLETE), 2362
-d option (ndb_index_stat), 2392
-d option (ndb_mgmd), 2361
-e option (ndb_mgm), 2369
-f option (ndb_mgmd), 2362
-l option (ndbinfo_select_all), 2358
-n option (ndbd), 2354
-n option (ndbmt), 2354
-p option, 736
>P option (ndb_mgmd), 2367
-V option (NDB Cluster programs), 2441
-v option (ndb_mgmd), 2368
.frm file, 1452
.ibd file, 1452
.my.cnf option file, 270, 271, 287, 713, 736, 790
.MYD file, 1452
.MYI file, 1452
.mysql_history file, 331, 737
.pid (process ID) file, 876
/ (division), 1244
/etc/passwd, 744, 1521
:= (assignment operator), 1238
:= (assignment), 1072
< (less than), 1232
<< (left shift), 256, 1329
<= (less than or equal), 1232
=> (equal to), 1231
<> (not equal), 1232
= (assignment operator), 1239
= (assignment), 1072
= (equal), 1231
> (greater than), 1232
>= (greater than or equal), 1232
>> (right shift), 1329
[api] (NDB Cluster), 2183
[computer] (NDB Cluster), 2184
[ndbd (NDB Cluster), 2176
[nbd] (NDB Cluster), 2176
[ndbd (NDB Cluster), 2182
[sci] (NDB Cluster), 2184
[shm] (NDB Cluster), 2184
[std] (NDB Cluster), 2184
" (double quote), 1030
' (single quote), 1030
\ (mysql client command), 251, 334
\0 (ASCII NUL), 1030, 1500
\b (backspace), 1030, 1500
\n (linefeed), 1030, 1500
\n (newline), 1030, 1500
\N (NULL), 1500
\r (carriage return), 1030, 1500
\t (tab), 1030, 1500
\Z (Control+Z ASCII 26, 1031, 1500
\ (escape), 1031
^ (bitwise XOR), 1328
_ (wildcard character), 1031
.ai collation suffix, 1090
.as collation suffix, 1090
.bin collation suffix, 1090, 1112
.cl collation suffix, 1090
.cs collation suffix, 1090
.rowid
SELECT statements, 1418, 1436, 1436
`\, 1038
| (bitwise OR), 1328
|| (logical OR), 1237
~ (invert bits), 1329

A
abort-on-error option
    ndb_move_data, 2397
abort-slave-event-count option
    mysql, 2019
aborted clients, 3153
aborted connection, 3153
ABS(), 1245
access control, 749, 766
access denied errors, 3143
access privileges, 749
account management, 749
account names, 764
accounts
    adding privileges, 772
    anonymous user, 199
    creating, 772
    default, 199
    deleting, 775
    root, 199
ACID, 1698, 1707, 3737
ACLs, 749
ACOS(), 1245
activating plugins, 694
ActiveState Perl, 224
adaptive flushing, 3737
adaptive hash index, 1718, 3737
add-drop-database option
    mysql, 359
add-drop-table option
    mysql, 359
add-drop-trigger option
    mysql, 359
add-locks option
    mysql, 359
ADDDATE(), 1255
adding
    character sets, 1139
    functions, 2996
    native functions, 3007
    new account privileges, 772
    new user privileges, 772
    new users, 194
    user-defined functions, 2997
addition (+), 1243
ADDTIME(), 1256
adthodest option
    mysqlhotcopy, 437
administration
  server, 337
administration of NDB Cluster, 2368
administrative programs, 264
AES_DECRYPT(), 1331
AES_ENCRYPT(), 1331
After create
  thread state, 1015
age
  calculating, 240
AIO, 3738
alias names
  case sensitivity, 1042
aliases
  for expressions, 1371
  for tables, 1516
  in GROUP BY clauses, 1371
  names, 1038
  on expressions, 1516
ALL, 1532
  SELECT modifier, 1519
ALL join type
  optimizer, 965
ALL privilege, 754
ALL PRIVILEGES privilege, 754
all-databases option
  mysqlcheck, 348
  mysqldump, 359
all-in-1 option
  mysqlcheck, 348
all-tablespaces option
  mysqldump, 359
allocating local table
  thread state, 1022
allow-keywords option
  mysqldump, 359
allow-suspicious-udfs option
  mysqld, 505
allowold option
  mysqlhotcopy, 437
ALLOW_INVALID_DATES SQL mode, 652
ALTER COLUMN, 1397
ALTER DATABASE, 1386
ALTER EVENT, 1387
  and replication, 2096
ALTER FUNCTION, 1389
ALTER LOGFILE GROUP, 1389
  (see also NDB Cluster Disk Data)
ALTER privilege, 754
ALTER PROCEDURE, 1390
ALTER ROUTINE privilege, 754
ALTER SCHEMA, 1386
ALTER SERVER, 1391
ALTER TABLE, 1391, 1398, 3173
ROW_FORMAT, 1796
ALTER TABLESPACE, 1410
(see also NDB Cluster Disk Data)
ALTER VIEW, 1411
altering
database, 1386
schema, 1386
ANALYZE()
PROCEDURE, 939
analyze option
myisamchk, 402
mysqlcheck, 348
ANALYZE TABLE
and partitioning, 2634
ANALYZE TABLE statement, 1618
Analyzing
thread state, 1015
AND
bitwise, 1328
logical, 1237
anonymous user, 199, 199, 767, 770
ANSI mode
running, 24
ansi option
mysqld, 505
ANSI SQL mode, 651, 657
ANSI_QUOTES SQL mode, 652
Antelope, 3738
Antelope file format, 1788, 1817
ANY, 1532
Apache, 259
API node (NDB Cluster)
defined, 2118
API nodes (see SQL nodes)
APIs, 2813
list of, 39
Perl, 2945
append option
ndb_restore, 2408
application programming interface (API), 3738
apply, 3738
apply-slave-statements option
mysqldump, 360
apply_status table (OBSOLETE), 2564
(see also NDB Cluster replication)
approximate-value literals, 1375
approximate-value numeric literals, 1032, 1376
Arbitration, 2252
ArbitrationDelay, 2206, 2286
ArbitrationRank, 2205, 2286
ArbitrationTimeout, 2252
arbitrator_validity_detail
ndbinfo table, 2490
arbitrator_validity_summary
ndbinfo table, 2491
ARCHIVE storage engine, 1887, 1909
Area(), 1357
argument processing, 3002
arithmetic expressions, 1243
arithmetic functions, 1328
arithmetic operators, 1328
.ARM file, 3737
.ARZ file, 3737
AS, 1516, 1522
AsBinary(), 1353
ASCIIf(), 1275
ASIN(), 1245
ASINH(), 1245
assignment operator
  :=, 1238
  =, 1239
assignment operators, 1238
AsText(), 1353
asynchronous I/O, 1772, 3738
asynchronous replication (see NDB Cluster replication)
ATAN(), 1246
ATAN2(), 1246
atomic, 3738
atomic DDL, 3738
atomic instruction, 3739
attackers
  security against, 743
attribute demotion
  replication, 2089
attribute promotion
  replication, 2089
audit plugins, 2952
audit-log option
  --mysqld, 846
audit_log plugin, 829
  installing, 831
  startup failure, 844
audit_log_buffer_size system variable, 847
audit_log_file system variable, 847
audit_log_flush system variable, 848
audit_log_format system variable, 848
audit_log_policy system variable, 849
audit_log_rotate_on_size system variable, 849
audit_log_strategy system variable, 850
authentication plugin
  --authentication_pam, 810
  --authentication_windows, 821
  --authentication_windows_client, 821
  --auth_socket, 826
  --auth_test_plugin, 828
  --mysql_clear_password, 809
  --mysql_native_password, 807
  --mysql_old_password, 808
  --test_plugin_server, 828
authentication plugins, 2952
authentication_pam authentication plugin, 810
AUTHENTICATION_PAM_LOG environment variable, 449, 820
authentication_windows authentication plugin, 821
authentication_windows_client authentication plugin, 821
authentication_windows_log_level system variable, 529
authentication_windows_use_principal_name system variable, 530
auth_socket authentication plugin, 826
auth_test_plugin authentication plugin, 828
auto-generate-sql option
  mysqlslap, 386
auto-generate-sql-add-autoincrement option
  mysqlslap, 386
auto-generate-sql-execute-number option
  mysqlslap, 386
auto-generate-sql-guid-primary option
  mysqlslap, 386
auto-generate-sql-load-type option
  mysqlslap, 386
auto-generate-sql-secondary-indexes option
  mysqlslap, 386
auto-generate-sql-unique-query-number option
  mysqlslap, 386
auto-generate-sql-unique-write-number option
  mysqlslap, 386
auto-generate-sql-write-number option
  mysqlslap, 386
auto-inc lock, 1742
auto-increment, 1726, 1726, 1732, 1733, 3739
auto-increment locking, 3739
auto-rehash option
  mysql, 318
auto-repair option
  mysqlcheck, 348
auto-vertical-output option
  mysql, 318
autocommit, 3739
autocommit mode, 1749
autocommit system variable, 530
automatic_sp_privileges system variable, 531
AutoReconnect
  API and SQL nodes, 2289
AUTO_INCREMENT, 257, 1163
  and NULL values, 3169
  and replication, 2083
auto_increment_increment system variable, 2016
auto_increment_offset system variable, 2019
availability, 3739
AVG(), 1363
AVG(DISTINCT), 1363

B

B-tree, 3740
B-tree indexes, 932, 1733
background threads, 1772
  read, 1771
  write, 1771
backslash
  escape character, 1029
backspace (\b), 1030, 1500
backticks, 3740
backup, 3740
BACKUP Events (NDB Cluster), 2464
backup identifiers
  native backup and restore, 2451
backup option
  myisamchk, 400
  myisampack, 412
BACKUP TABLE
  removed features, 15
backup-path option
  ndb_restore, 2408
BackupDataBufferSize, 2260, 2452
BackupDataDir, 2214
backupid option
  ndb_restore, 2408
BackupLogBufferSize, 2260, 2452
BackupMaxWriteSize, 2262, 2452
BackupMemory, 2261, 2452
BackupReportFrequency, 2261
backups, 853, 3022
  databases and tables, 353, 436
    in NDB Cluster, 2404, 2448, 2449, 2449, 2452
    in NDB Cluster replication, 2572
    InnoDB, 1874
    with mysqldump, 863
backups, troubleshooting
  in NDB Cluster, 2453
BackupWriteSize, 2262, 2452
back_log system variable, 532
Barracuda, 3740
Barracuda file format, 1777, 1788, 1817
base64-output option
  mysqlbinlog, 423
basedir option
  mysql.server, 297
  mysqld, 506
  mysqld_safe, 291
  mysql_install_db, 304
  mysql_plugin, 306
  mysql_upgrade, 311
basedir system variable, 532
batch mode, 250
batch option
  mysql, 318
batch SQL files, 314
BatchByteSize, 2287
batched updates (NDB Cluster Replication), 2568
BatchSize, 2287
BatchSizePerLocalScan, 2225
BEGIN, 1545, 1574
  labels, 1575
  XA transactions, 1558
BENCHMARK(), 1338
benchmarks, 1011, 1012
beta, 3741
BETWEEN ... AND, 1233
big5, 3052
BIGINT data type, 1160
big_tables system variable, 532
BIN(), 1275
BINARY, 1314
binary collation, 1112
BINARY data type, 1180, 1183
binary distributions
  installing, 59
binary log, 679, 3741
  event groups, 1568
binary logging
  and NDB Cluster, 2141
binary-as-hex option
  mysql, 318
bind-address option
  mysql, 318
  mysqladmin, 342
  mysqlbinlog, 423
  mysqlcheck, 349
  mysqld, 506
  mysqldump, 360
  mysqlimport, 374
  mysqlshow, 380
bind-address option (ndb_mgmd), 2361
binlog, 3741
Binlog Dump
  thread command, 1013
BINLOG statement, 1682
  mysqlbinlog output, 431
binlog-do-db option
  mysqld, 2040
binlog-ignore-db option
  mysqld, 2042
binlog-row-event-max-size option
  mysqld, 2039
binlog_cache_size system variable, 2043
binlog_direct_non_transactional_updates system variable, 2044
binlog_format
  BLACKHOLE, 2084
binlog_format system variable, 2045
  NDB Cluster, 2045, 2046
binlog_index table (OBSOLETE) (see NDB Cluster replication)
binlog_stmt_cache_size system variable, 2046
BIT data type, 1159
bit functions, 1328
    example, 256
bit operators, 1328
bit-value literal introducer, 1037
bit-value literals, 1036
BIT_AND(), 1363
BIT_COUNT, 256
BIT_COUNT(), 1329
BIT_LENGTH(), 1275
BIT_OR, 256
BIT_OR(), 1363
BIT_XOR(), 1363
BLACKHOLE
    binlog_format, 2084
    replication, 2084
BLACKHOLE storage engine, 1887, 1910
blind query expansion, 3741
BLOB
    size, 1212
BLOB columns
    default values, 1185
    indexing, 928, 1433
    inserting binary data, 1031
BLOB data type, 1180, 1184
/blob-info option
    ndb_desc, 2386
Block Nested-Loop join algorithm, 891
block-search option
    myisamchk, 402
blocks
    ndbinfo table, 2491
BOOL data type, 1159
BOOLEAN data type, 1159
boolean literals, 1038
boolean options, 275
bootstrap option
    mysqld, 507
bottleneck, 3741
bounce, 3741
brackets
    square, 1158
brief option
    mysqlaccess, 418
buddy allocator, 1845, 3741
buffer, 3742
buffer pool, 978, 1766, 1767, 1768, 3742
    and compressed tables, 1785
    monitoring, 1712
buffer pool instance, 3742
buffer sizes, 978
    client, 2813
bugs
    known, 3174
NDB Cluster
   reporting, 2388
   reporting, 2, 19
bugs database, 19
bugs.mysql.com, 19
build configuration
   new features, 13
builddir option
   mysql_install_db, 304
BuildIndexThreads, 2265
building
   client programs, 2824
BUILD_CONFIG option
   CMake, 179
built-in, 3742
bulk loading
   for InnoDB tables, 949
   for MyISAM tables, 956
bulk_insert_buffer_size system variable, 533, 1897
business rules, 3742

C
C API, 2813
   data structures, 2829
   data types, 2822
   example programs, 2824
   FAQ, 3065
   functions, 2834
   linking problems, 2826
C++, 2816
C:\my.cnf option file, 713
cache, 3743
CACHE INDEX
   and partitioning, 2644
CACHE INDEX statement, 1682
caches
   clearing, 1684
calculating
   aggregate value for a set of rows, 1362
   cardinality, 1656
   dates, 240
calendar, 1296
CALL, 1478
calling sequences for aggregate functions
   UDF, 3001
calling sequences for simple functions
   UDF, 2999
can't create/write to file, 3154
Can't reopen table
   error message, 3174
cardinality, 913, 3743
carriage return (\r), 1030, 1500
CASE, 1239, 1578
case sensitivity
  access checking, 764
  account names, 765
  in identifiers, 1042
  in names, 1042
  in searches, 3165
  in string comparisons, 1286
  of database names, 25
  of replication filtering options, 2061
  of table names, 25
CAST, 1315
  cast functions, 1310
  cast operators, 1310
  casts, 1225, 1231, 1310
CC environment variable, 188, 449
CEIL(), 1246
CEILING(), 1246
Centroid(), 1358
.cfg file, 3743
cflags option
  mysql_config, 444
change buffer, 1715, 3743
  monitoring, 1717
change buffering, 3744
  disabling, 1716
CHANGE MASTER TO, 1563
  in NDB Cluster, 2566
Change user
  thread command, 1013
changes to privileges, 775
changing
  column, 1396
  field, 1396
  socket location, 296, 3165
  table, 1391, 1398, 3173
Changing master
  thread state, 1025
CHAR data type, 1178, 1179
CHAR VARYING data type, 1180
CHAR(), 1275
CHARACTER data type, 1179
character set introducer, 1097
character set repertoire, 1120
character sets, 1084
  adding, 1139
  and replication, 2084
  Asian, 1133
  Baltic, 1132
  binary, 1136
  Central European, 1130
  Cyrillic, 1132
  Middle East, 1131
  repertoire, 1086
  restrictions, 1137
CHARACTER VARYING data type, 1180
character-set-client-handshake option
  mysql, 507
character-sets-dir option
  myisamchk, 400
  myisampack, 412
  mysql, 318
  msqladmin, 342
  mysqlbinlog, 423
  mysqlcheck, 349
  mysqldump, 360
  mysqlimport, 374
  mysqlshow, 380
  mysql_upgrade, 311
  ndb_move_data, 2397
character-sets-dir option (NDB Cluster programs), 2438, 2438
characters
  multibyte, 1142
CHARACTER_LENGTH(), 1276
CHARACTER_SETS
  INFORMATION_SCHEMA table, 2695
character_sets_dir system variable, 536
character_set_client system variable, 533
character_set_connection system variable, 534
character_set_database system variable, 534
character_set_filesystem system variable, 534
character_set_results system variable, 535
character_set_server system variable, 535
character_set_system system variable, 535
charset command
  mysql, 327
charset option
  comp_err, 302
CHARSET(), 1339
CHAR_LENGTH(), 1276
check option
  myisamchk, 399
  mysqlcheck, 349
check options
  myisamchk, 399
CHECK TABLE
  and partitioning, 2634
CHECK TABLE statement, 1619
check-only-changed option
  myisamchk, 399
  mysqlcheck, 349
check-orphans option
  ndb_blob_tool, 2370
check-upgrade option
  mysqlcheck, 349
checking
tables for errors, 872
Checking master version
  thread state, 1024
checking permissions
  thread state, 1015
checking privileges on cached query
  thread state, 1023
checking query cache for query
  thread state, 1023
Checking table
  thread state, 1015
checkpoint, 3744
CHECKPOINT Events (NDB Cluster), 2460
checkpoint option
  mysqlhotcopy, 437
Checksum, 2335, 2347
checksum, 3744
Checksum (NDB Cluster), 2338
checksum errors, 163
CHECKSUM TABLE
  and replication, 2085
CHECKSUM TABLE statement, 1622
child table, 3744
Chinese, Japanese, Korean character sets
  frequently asked questions, 3052
choosing
  a MySQL version, 44
data types, 1213
chroot option
  mysqld, 507
  mysqlhotcopy, 437
circular replication
  in NDB Cluster, 2557, 2578, 2582
CJK (Chinese, Japanese, Korean)
  Access, PHP, etc., 3052
  availability of specific characters, 3052
  big5, 3052
  character sets available, 3052
  characters displayed as question marks, 3052
  CJKV, 3052
  collations, 3052, 3052
  conversion problems with Japanese character sets, 3052
data truncation, 3052
Database and table names, 3052
documentation in Chinese, 3052
documentation in Japanese, 3052
documentation in Korean, 3052
FAQ, 3052
gb2312, gbk, 3052
Japanese character sets, 3052
Korean character set, 3052
LIKE and FULLTEXT, 3052
MySQL 4.0 behavior, 3052
ORDER BY treatment, 3052, 3052
problems with Access, PHP, etc., 3052
problems with Big5 character sets (Chinese), 3052
problems with data truncation, 3052
problems with euckr character set (Korean), 3052
problems with GB character sets (Chinese), 3052
problems with LIKE and FULLTEXT, 3052
problems with Yen sign (Japanese), 3052
rejected characters, 3052
sort order problems, 3052, 3052
sorting problems, 3052, 3052
testing availability of characters, 3052
Unicode collations, 3052
Vietnamese, 3052
Yen sign, 3052
clean page, 3744
clean shutdown, 668, 3744
clearing up
  thread state, 1016
clear command
  mysql, 327
Clearing
  thread state, 1026
clearing
  caches, 1684
client, 3744
  signal handling, 451
client connections, 1007
client programs, 263
  building, 2824
client tools, 2813
clients
  debugging, 3016
  threaded, 2827
cloning tables, 1453
CLOSE, 1583
Close stmt
  thread command, 1013
closing
  tables, 940
closing tables
  thread state, 1016
cluster database (OBSOLETE) (see NDB Cluster replication)
cluster logs, 2456, 2458
cluster.binlog_index table (OBSOLETE) (see NDB Cluster replication)
clustered index, 3744
  InnoDB, 1733
Clustering (see NDB Cluster)
CLUSTERLOG commands (NDB Cluster), 2458
CLUSTERLOG STATISTICS command (NDB Cluster), 2464
cluster_operations
  ndbinfo table, 2491
cluster_replication database (OBSOLETE) (see NDB Cluster replication)
cluster_transactions
  ndbinfo table, 2493
CMake
BUILD_CONFIG option, 179
CMAKE_BUILD_TYPE option, 179
CMAKE_CXX_FLAGS option, 186
CMAKE_C_FLAGS option, 186
CMAKE_INSTALL_PREFIX option, 180
COMPILATION_COMMENT option, 182
CPACK_MONOLITHIC_INSTALL option, 179
DEFAULT_CHARSET option, 182
DEFAULT_COLLATION option, 183
ENABLED_LOCAL_INFILE option, 183
ENABLED_PROFILING option, 184
ENABLE_DEBUG_SYNC option, 183
ENABLE_DOWNLOADS option, 183
ENABLE_DTRACE option, 183
ENABLE_GCOV option, 183
IGNORE_AIO_CHECK option, 184
INSTALL_BINDIR option, 180
INSTALL_DOCDIR option, 180
INSTALL_DOCREADMEDIR option, 180
INSTALL_INCLUDEDIR option, 180
INSTALL_INFODIR option, 180
INSTALL_LAYOUT option, 180
INSTALL_LIBDIR option, 180
INSTALL_MANDIR option, 180
INSTALL_MYSQLSHAREDIR option, 180
INSTALL_MYSQLTESTDIR option, 180
INSTALL_PLUGINDIR option, 181
INSTALL_SBINDIR option, 181
INSTALL_SCRIPTDIR option, 181
INSTALL_SECURE_FILE_PRIVDIR option, 181
INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR option, 181
INSTALL_SHAREDIR option, 181
INSTALL_SQLBENCHDIR option, 181
INSTALL_SUPPORTFILESDIR option, 181
MEMCACHED_HOME option, 187
MYSQL_DATADIR option, 181
MYSQL_MAINTAINER_MODE option, 184
MYSQL_PROJECT_NAME option, 184
MYSQL_TCP_PORT option, 184
MYSQL_UNIX_ADDR option, 184
ODBC_INCLUDES option, 181
ODBC_LIB_DIR option, 181
options, 175
REPRODUCIBLE_BUILD option, 184
running after prior invocation, 171, 188
SYSCONFDIR option, 182
TMPDIR option, 182
VERSION file, 189
WITH_ASAN option, 184
WITH_BUNDLED_LIBEVENT option, 187
WITH_BUNDLED_MEMCACHED option, 187
WITH_CLASSPATH option, 187
WITH_DEBUG option, 184
WITH_EMBEDDED_SERVER option, 185
WITH_EMBEDDED_SHARED_LIBRARY option, 185
WITH_ERROR_INSERT option, 187
WITH_EXTRA_CHARSET option, 185
WITH_LIBEDIT option, 185
WITH_LIBWRAP option, 185
WITH_NDBCLUSTER option, 187
WITH_NDBCLUSTER_STORAGE_ENGINE option, 187
WITH_NDBMTD option, 187
WITH_NDB_BINLOG option, 188
WITH_NDB_DEBUG option, 188
WITH_NDB_JAVA option, 188
WITH_NDB_PORT option, 188
WITH_NDB_TEST option, 188
WITH_REALLINE option, 185
WITH_SSL option, 185
WITH_UNIT_TESTS option, 185
WITH_UNIXODBC option, 186
WITH_VALGRIND option, 186
WITH_ZLIB option, 186
CMakeCache.txt file, 188
CMAKE_BUILD_TYPE option
  CMake, 179
CMAKE_CXX_FLAGS option
  CMake, 186
CMAKE_C_FLAGS option
  CMake, 186
CMAKE_INSTALL_PREFIX option
  CMake, 180
COALESCE(), 1233
coeercibility
collation, 1111
COERCIBILITY(), 1339
cold backup, 3745
collating
  strings, 1141
collation
  adding, 1142
coeercibility, 1111
  INFORMATION_SCHEMA, 1116
  modifying, 1143
COLLATION(), 1340
collations, 1084
  Asian, 1133
  Baltic, 1132
  binary, 1112, 1137
  Central European, 1131
  Cyrillic, 1132
  Middle East, 1131
  naming conventions, 1090
  PAD SPACE, 1114, 1183
  South European, 1131
  Unicode, 1125
  West European, 1129
_ai suffix, 1090
_as suffix, 1090
_bin suffix, 1090, 1112
_ci suffix, 1090
_ss suffix, 1090

COLLATIONS
  INFORMATION_SCHEMA table, 2695

COLLATION_CHARACTER_SET_APPLICABILITY
  INFORMATION_SCHEMA table, 2696

  collation_connection system variable, 536
  collation_database system variable, 536
  collation_server system variable, 536

  column, 3745
    changing, 1396
    types, 1157
  column alias
    problems, 3169
    quoting, 1039, 3169
  column comments, 1435
  column format, 1435
  column index, 3745
  column names
    case sensitivity, 1042
  column prefix, 3745
  column storage, 1435
  column-names option
    mysql, 318
  column-type-info option
    mysql, 318

  columns
    displaying, 378
    indexes, 928
    names, 1038
    other types, 1213
    selecting, 238
    storage requirements, 1209

COLUMNS
  INFORMATION_SCHEMA table, 2696

  columns option
    mysqlimport, 374
  columns partitioning, 2606
  columns per table
    maximum, 944
  columns_priv table
    system table, 671, 759

COLUMN_PRIVILEGES
  INFORMATION_SCHEMA table, 2699

command-separated values data, reading, 1499, 1522
command option precedence, 268
command options
  mysql, 315
  mysqladmin, 340
  mysqld, 504
command options (NDB Cluster)
mysql, 2293
ndbd, 2349
ndbinfo_select_all, 2357
ndb_mgm, 2369
ndb_mgmd, 2359
command syntax, 4
command-line history
  mysql, 331
command-line options (NDB Cluster), 2437
command-line tool, 90, 314
commands
  for binary distribution, 60
commands out of sync, 3155
comment syntax, 1080
comments
  adding, 1080
  starting, 29
comments option
  mysql, 318
  mysqldump, 360
COMMIT, 1545
  XA transactions, 1558
commit, 3745
commit option
  mysqlaccess, 418
  mysqlslap, 387
Committing events to binlog
  thread state, 1026
compact option
  mysqldump, 360
compact row format, 1794, 3745
comparison operators, 1230
comparisons
  access checking, 764
  account names, 765
compatibility
  between MySQL versions, 205
  with mSQL, 1289
  with ODBC, 602, 1041, 1161, 1226, 1235, 1434, 1524
  with Oracle, 26, 1366, 1396, 1692
  with PostgreSQL, 27
  with standard SQL, 23
compatible option
  mysqldump, 360
COMPILATION_COMMENT option
  CMake, 182
compiling
  optimizing, 998
  problems, 188
  user-defined functions, 3005
compiling clients
  on Unix, 2824
  on Windows, 2825
complete-insert option
mysql, 319
mysqladmin, 342
mysqlcheck, 349
mysqldump, 360
mysqlimport, 374
mysqlshow, 380
mysqslap, 387
mysql_upgrade, 311
COMPRESS(), 1331
compressed backup, 3746
compressed row format, 1796, 3746
compressed table, 3746
compressed tables, 411, 1900
CompressedBackup, 2239
CompressedLCP, 2239
compression, 1776, 3746
  algorithms, 1782
  application and schema design, 1780
  BLOBs, VARCHAR and TEXT, 1784
  buffer pool considerations, 1785
  compressed page size, 1781
  configuration characteristics, 1781
  connection, 288
  data and indexes, 1783
  data characteristics, 1779
  enabling for a table, 1777
  implementation, 1782
  information schema, 1844, 1844
  KEY_BLOCK_SIZE, 1781
  log file format, 1785
  modification log, 1783
  monitoring, 1781
  overflow pages, 1784
  overview, 1777
  tuning, 1778
  workload characteristics, 1781
compression failure, 3747
comp_err, 263, 301
charset option, 302
debug option, 302
debug-info option, 302
header-file option, 302
help option, 302
in-file option, 302
name-file option, 302
out-dir option, 302
out-file option, 302
state-file option, 302
version option, 302
CONCAT(), 1276
concatenation
  string, 1029, 1276
CONCAT_WS(), 1277
concurrency, 1698, 3747
  of commits, 1814
  of threads, 1840
  tickets, 1814
concurrency option
  mysqlslap, 387
concurrent inserts, 991, 993
concurrent_insert system variable, 538
condition handling
  INOUT parameters, 1600
  OUT parameters, 1600
Conditions, 1585
conditions, 1651, 1680
cond_instances table
  performance_schema, 2790
config-cache option (ndb_mgmd), 2361
config-file option
  mysqlld_multi, 299
  my_print_defaults, 445
  ndb_config, 2375
config-file option (ndb_mgmd), 2362
config.ini (NDB Cluster), 2163, 2192, 2193, 2368
configdir option (ndb_mgmd), 2363
configinfo option
  ndb_config, 2374
configuration
  NDB Cluster, 2176
    server, 454
configuration file, 3747
configuration files, 790
configure option
  MySQLInstallerConsole, 91
configuring backups
  in NDB Cluster, 2452
configuring NDB Cluster, 2146, 2173, 2368, 2453
Configuring NDB Cluster (concepts), 2118
config_from_node option
  ndb_config, 2375
config_params
  ndbinfo table, 2494
conflict detection status variables
  NDB Cluster Replication, 2588
conflict resolution
  and ndb_replication system table, 2584
  enabling, 2584
  in NDB Cluster Replication, 2582
  mysqld startup options, 2583
Connect
  thread command, 1013
connect command
mysql, 327
CONNECT command (NDB Cluster), 2444
connect option
ndb_restore, 2409
Connect Out
thread command, 1013
connect-delay option (ndbd), 2351
connect-delay option (ndbmttd), 2351
connect-retries option (ndbd), 2351
connect-retries option (ndbmttd), 2351
connect-string option (NDB Cluster programs), 2440
connect-timeout option
mysql, 319
ConnectBackoffMaxTime, 2291
ConnectCheckIntervalDelay, 2245
connecting
remotely with SSH, 806
to the server, 227, 285
verification, 767
Connecting to master
thread state, 1024
connection
aborted, 3153
connection compression, 288
CONNECTION Events (NDB Cluster), 2459
connection string (see NDB Cluster)
connection-timeout option (ndb_error_reporter), 2389
ConnectionMap, 2284
connections option
ndb_config, 2375
CONNECTION_ID(), 1340
Connector/C++, 2813, 2816
Connector/J, 2813, 2816
Connector/NET, 2813, 2816
Connector/ODBC, 2813, 2816
Connector/Python, 2813, 2816
Connectors, 2813
connect_timeout system variable, 538
connect_timeout variable, 345
consistent read, 3747
consistent reads, 1750
console option
mysql, 507
const table
optimizer, 963, 1520
constant table, 882
constraint, 3748
constraints, 29
foreign keys, 1457
Contains(), 1361
contributing companies
list of, 40
contributors
list of, 33
control flow functions, 1239
Control+C
    statement termination, 315, 324
CONV(), 1246
conventions
    syntax, 2
    typographical, 2
CONVERT, 1315
CONVERT TO, 1399
converting HEAP to MyISAM
    thread state, 1016
CONVERT_TZ(), 1256
copy option
    mysqlaccess, 418
copy to tmp table
    thread state, 1016
copying databases, 217
copying tables, 1454
Copying to group table
    thread state, 1016
Copying to tmp table
    thread state, 1016
Copying to tmp table on disk
    thread state, 1016
core-file option
    mysql, 508
core-file option (NDB Cluster programs), 2438
core-file-size option
    mysql_safe, 291
correct-checksum option
    myisamchk, 400
correlated subqueries, 1535
corruption, 1880
    InnoDB, 1875
COS(), 1247
COT(), 1247
count option
    myisam_ftdump, 392
    mysqladmin, 342
    mysqlshow, 380
COUNT(), 1363
COUNT(DISTINCT), 1364
counter, 3748
counters
    ndbinfo table, 2494
counting
    table rows, 245
covering index, 3748
CPACK_MONOLITHIC_INSTALL option
    CMake, 179
CPU-bound, 3748
crash, 3009, 3748
    recovery, 871
repeated, 3161
replication, 2100
crash recovery, 3748
InnoDB, 1875
crash-me, 1011
crash-me program, 1011
CrashOnCorruptedTuple, 2237
CRC32(), 1247
CREATE ... IF NOT EXISTS
and replication, 2085
CREATE DATABASE, 1411
Create DB
thread command, 1013
CREATE EVENT, 1412
and replication, 2096
CREATE FUNCTION, 1423
CREATE FUNCTION statement, 1627
CREATE INDEX, 1417, 1801
CREATE LOGFILE GROUP, 1422
(see also NDB Cluster Disk Data)
CREATE NODEGROUP command (NDB Cluster), 2447
create option
mysqlslap, 387
CREATE privilege, 754
CREATE PROCEDURE, 1423
CREATE ROUTINE privilege, 754
CREATE SCHEMA, 1411
CREATE SERVER, 1429
CREATE TABLE, 1430
DIRECTORY options
and replication, 2092
KEY_BLOCK_SIZE, 1781
options for table compression, 1777
ROW_FORMAT, 1796
statement retention, 1451
table definition, 1451
CREATE TABLE ... SELECT
and replication, 2085
CREATE TABLESPACE, 1464
(see also NDB Cluster Disk Data)
CREATE TABLESPACE privilege, 754
CREATE TEMPORARY TABLES privilege, 754
CREATE TRIGGER, 1465
CREATE USER privilege, 754
CREATE USER statement, 772, 775, 1600
CREATE VIEW, 1467
CREATE VIEW privilege, 754
create-options option
mysqlslap, 387
create-schema option
mysqldump, 360
creating
bug reports, 19
database, 1411
databases, 231
default startup options, 270
function, 1627
schema, 1411
tables, 233
Creating delayed handler
  thread state, 1022
Creating index
  thread state, 1016
Creating sort index
  thread state, 1016
creating table
  thread state, 1016
Creating tmp table
  thread state, 1016
creating user accounts, 1600
CROSS JOIN, 1522
cross-bootstrap option
  mysql_install_db, 304
Crosses(), 1360
CRUD, 3748
CR_ALREADY_CONNECTED error code, 3139
CR_AUTH PLUGIN_CANNOT_LOAD error code, 3139
CR_CANT_READ CHARSET error code, 3136
CR_COMMANDS_OUT_OF_SYNC error code, 3135
CR_CONNECTION_ERROR error code, 3135
CR_CONN_HOST_ERROR error code, 3135
CR_CONN_UNKNOWN_PROTOCOL error code, 3138
CR_DATA_TRUNCATED error code, 3137
CR_EMBEDDED_CONNECTION error code, 3136
CR_FETCH_CANCELED error code, 3138
CR_INVALID_BUFFER_USE error code, 3137
CR_INVALID_CONN_HANDLE error code, 3138
CR_INVALID_PARAMETER_NO error code, 3137
CR_IPSOCK_ERROR error code, 3135
CR_LOCALHOST_CONNECTION error code, 3135
CR_MALFORMED_PACKET error code, 3136
CR_NAMEDPIPEOPEN_ERROR error code, 3136
CR_NAMEDPIPESETSTATE_ERROR error code, 3136
CR_NAMEDPIPE_WAIT_ERROR error code, 3136
CR_NAMEDPIPE_CONNECTION error code, 3136
CR_NET_PACKET_TOO_LARGE error code, 3136
CR_NEW_STMT_METADATA error code, 3139
CR_NOT_IMPLEMENTED error code, 3138
CR_NO_DATA error code, 3138
CR_NO_PARAMETERS_EXISTS error code, 3137
CR_NO_PREPARE_STMT error code, 3137
CR_NO_RESULT_SET error code, 3138
CR_NO_STMT_METADATA error code, 3138
CR_NULL_POINTER error code, 3137
CR_OUT_OF_MEMORY error code, 3135
CR_PARAMS_NOT_BOUND error code, 3137
CR_PROBE_MASTER_CONNECT error code, 3136
CR_PROBE_SLAVE_CONNECT error code, 3136
CR_PROBE_SLAVE_HOSTS error code, 3136
CR_PROBE_SLAVE_STATUS error code, 3136
CR_SECURE_AUTH error code, 3138
CR_SERVER_GONE_ERROR, 3150
CR_SERVER_GONE_ERROR error code, 3135
CR_SERVER_HANDSHAKE_ERR error code, 3135
CR_SERVER_LOST error code, 3135
CR_SERVER_LOST_ERROR, 3150
CR_SERVER_LOST_EXTENDED error code, 3138
CR_SHARED_MEMORY_CONNECTION error code, 3137
CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR error code, 3138
CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR error code, 3137
CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR error code, 3137
CR_SHARED_MEMORY_CONNECT_MAP_ERROR error code, 3137
CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR error code, 3137
CR_SHARED_MEMORY_CONNECT_SET_ERROR error code, 3138
CR_SHARED_MEMORY_EVENT_ERROR error code, 3138
CR_SHARED_MEMORY_FILE_MAP_ERROR error code, 3138
CR_SHARED_MEMORY_MAP_ERROR error code, 3138
CR_SOCKET_CREATE_ERROR error code, 3135
CR_SSL_CONNECTION_ERROR error code, 3136
CR_STMT_CLOSED error code, 3138
CR_TCP_CONNECTION error code, 3135
CR_UNKNOWN_ERROR error code, 3135
CR_UNKNOWN_HOST error code, 3135
CR_UNSUPPORTED_PARAM_TYPE error code, 3137
CR_VERSION_ERROR error code, 3135
CR_WRONG_HOST_INFO error code, 3135
CR_WRONG_LICENSE error code, 3137
CSV data, reading, 1499, 1522
csv option
mysqlslap, 387
CSV storage engine, 1887, 1907
CURDATE(), 1256
CURRENT_DATE, 1256
CURRENT_TIME, 1256
CURRENT_TIMESTAMP, 1257
CURRENT_USER(), 1340
cursor, 3749
Cursors, 1582
CURTIME(), 1257
CXX environment variable, 188, 449

D
Daemon
thread command, 1013
daemon option (ndb_mgmd), 2361
daemon plugins, 2951
data
importing, 334, 372
loading into tables, 235
retrieving, 236
size, 936
data dictionary, 3749
    data directory, 3749
        mysql_upgrade_info file, 310
DATA DIRECTORY
    and replication, 2092
    data files, 3749
    data node (NDB Cluster)
        defined, 2118
    data nodes
        memory allocation, 2266
    data nodes (NDB Cluster), 2349, 2358
    Data on disk (NDB Cluster)
        and INFORMATION_SCHEMA.FILES table, 2749
    data structures
        C API, 2829
        prepared statement C API, 2892
    Data truncation with CJK characters, 3052
    data type
        BIGINT, 1160
        BINARY, 1180, 1183
        BIT, 1159
        BLOB, 1180, 1184
        BOOL, 1159, 1213
        BOOLEAN, 1159, 1213
        CHAR, 1178, 1179
        CHAR VARYING, 1180
        CHARACTER, 1179
        CHARACTER VARYING, 1180
        DATE, 1167, 1169
        DATETIME, 1168, 1169
        DEC, 1161
        DECIMAL, 1160, 1375
        DOUBLE, 1161
        DOUBLE PRECISION, 1162
        ENUM, 1181, 1186
        FIXED, 1161
        FLOAT, 1161, 1161, 1161
        GEOMETRY, 1193
        GEOMETRYCOLLECTION, 1193
        INT, 1160
        INTEGER, 1160
        LINESTRING, 1193
        LONG, 1184
        LONGBLOB, 1181
        LONGTEXT, 1181
        MEDIUMBLOB, 1181
        MEDIUMINT, 1160
        MEDIUMTEXT, 1181
        MULTILINESTRING, 1193
        MULTINOPOINT, 1193
        MULTIPOLYGON, 1193
        NATIONAL CHAR, 1179
        NATIONAL VARCHAR, 1180
        NCHAR, 1179
NUMERIC, 1161
NVARCHAR, 1180
POINT, 1193
POLYGON, 1193
REAL, 1162
SET, 1181, 1189
SMALLINT, 1160
TEXT, 1180, 1184
TIME, 1168, 1170
TIMESTAMP, 1168, 1169
TINYBLOB, 1180
TINYINT, 1159
TINYTEXT, 1180
VARBINARY, 1180, 1183
VARCHAR, 1178, 1180
VARCHARACTER, 1180
YEAR, 1168, 1171
data types, 1157
C API, 2822
date and time, 1166
numeric, 1158
string, 1178
data warehouse, 3749
data-file-length option
myisamchk, 400
database, 3749
altering, 1386
creating, 1411
deleting, 1471
renaming, 1477
Database information
obtaining, 1635
database metadata, 2691
database names
case sensitivity, 25, 1042
database objects
metadata, 1088
database option
mysql, 319
mysqlbinlog, 423
ndb_blob_tool, 2371
ndb_desc, 2386
ndb_move_data, 2397
ndb_show_tables, 2431
database option (ndb_index_stat), 2392
DATABASE(), 1341
databases
backups, 853
copying, 217
creating, 231, 1411
defined, 4
displaying, 378
dumping, 353, 436
information about, 249
names, 1038
replicating, 1991
selecting, 232
symbolic links, 1000
using, 231
databases option
mysqlcheck, 349
mysqldump, 360
DataDir, 2206, 2214
datadir option
mysql.server, 297
mysqld, 508
mysqld_safe, 291
mysql_install_db, 304
mysql_plugin, 306
mysql_upgrade, 311
datadir system variable, 539
DataMemory, 2215
DATE, 3167
date and time data types, 1166
date and time functions, 1253
date calculations, 240
DATE columns
problems, 3167
DATE data type, 1167, 1169
date data types
storage requirements, 1211
date literals, 1032
date values
problems, 1169
DATE(), 1257
DATEDIFF(), 1257
dates
used with partitioning, 2598
used with partitioning (examples), 2601, 2614, 2619, 2638
DATETIME data type, 1168, 1169
datetime_format system variable, 539
DATE_ADD(), 1257
date_format system variable, 539
DATE_FORMAT(), 1258
DATE_SUB(), 1257, 1259
DAY(), 1260
Daylight Saving Time, 666, 934, 1271
DAYNAME(), 1260
DAYOFMONTH(), 1260
DAYOFWEEK(), 1260
DAYOFYEAR(), 1260
db option
mysqlaccess, 418
db table
sorting, 770
system table, 199, 671, 759
DB2 SQL mode, 657
DBI interface, 2945
DBI->quote, 1031
DBI->trace, 3013
DBI/DBD interface, 2945
DBI_TRACE environment variable, 449, 3013
DBI_USER environment variable, 449
DBG package, 3017
DCL, 1603, 1615, 3750
DDL, 1386, 3750
DDL log, 692
deadlock, 990, 1553, 1754, 1758, 1759, 1760, 1832, 3750
deadlock detection, 3750
DEALLOCATE PREPARE, 1570, 1574
Debug
  thread command, 1014
debug option
    comp_err, 302
    myisamchk, 397
    myisampack, 412
    mysql, 319
    mysqldaccess, 419
    mysqldadmin, 342
    mysqldbina, 361
    mysqlcheck, 349
    mysqld, 508
    mysqldump, 361
    mysqldumpslow, 435
    mysqlhotcopy, 437
    mysqlimport, 374
    mysqlshow, 380
    mysqlslap, 387
    mysql_upgrade, 312
    my_print_defaults, 445
debug option (NDB Cluster programs), 2439
debug system variable, 539
debug-check option
    mysql, 319
    mysqldadmin, 342
    mysqlbinlog, 424
    mysqlcheck, 349
    mysqldump, 361
    mysqlimport, 374
    mysqlshow, 380
    mysqlslap, 387
    mysql_upgrade, 312
debug-info option
    comp_err, 302
    mysql, 319
    mysqldadmin, 342
    mysqlbinlog, 425
    mysqlcheck, 349
    mysqldump, 361
    mysqlimport, 374
    mysqlshow, 380
    mysqlslap, 387
mysql_upgrade, 312
deploy-sync-timeout option
  mysql, 509
deploying
  client, 3016
  server, 3009
deploying support, 175
deploy_sync system variable, 540
DEC data type, 1161
decimal arithmetic, 1375
DECIMAL data type, 1160, 1375
decimal point, 1158
DECLARE, 1576
DECODE(), 1332
decode_bits myisamchk variable, 398
DEFAULT
  constraint, 31
default
    privileges, 199
default accounts, 199
default host name, 285
default installation location, 59
default options, 270
default proxy user, 784
default storage engine
    new features, 10
DEFAULT value clause, 1207, 1434
default values, 1207, 1434, 1486
    BLOB and TEXT columns, 1185
    explicit, 1207
    implicit, 1207
    suppression, 31
DEFAULT(), 1371
default-auth option, 281
  mysql, 319
  mysqladmin, 342
  mysqlbinlog, 425
  mysqlcheck, 350
  mysqldump, 361
  mysqlimport, 374
  mysqlshow, 381
  mysqlslap, 387
  mysql_upgrade, 312
default-character-set option
  mysql, 319
  mysqladmin, 343
  mysqlcheck, 349
  mysqldump, 361
  mysqlimport, 374
  mysqlshow, 380
  mysqlslap, 387
  mysql_upgrade, 312
default-time-zone option
  mysql, 509
DefaultHashMapSize, 2226, 2290
DefaultOperationRedoProblemAction
  API and SQL nodes, 2289
defaults
  embedded, 2818
defaults-extra-file option, 275, 304
  myisamchk, 397
  mysql, 319
  mysqladmin, 343
  mysqlbinlog, 425
  mysqlcheck, 350
  mysqld, 509
  mysqldump, 361
  mysqld_multi, 298
  mysqld_safe, 291
  mysqlimport, 375
  mysqlshow, 381
  mysqlslap, 387
  mysql_upgrade, 312
  my_print_defaults, 445
  NDB client programs, 2439
defaults-file option, 275, 304
  myisamchk, 397
  mysql, 319
  mysqladmin, 343
  mysqlbinlog, 425
  mysqlcheck, 350
  mysqld, 510
  mysqldump, 361
  mysqld_multi, 298
  mysqld_safe, 291
  mysqlimport, 375
  mysqlshow, 381
  mysqlslap, 388
  mysql_upgrade, 312
  my_print_defaults, 445
  NDB client programs, 2439
defaults-group-suffix option, 275
  myisamchk, 397
  mysql, 320
  mysqladmin, 343
  mysqlbinlog, 425
  mysqlcheck, 350
  mysqld, 510
  mysqldump, 361
  mysqlimport, 375
  mysqlshow, 381
  mysqlslap, 388
  mysql_upgrade, 312
  my_print_defaults, 445
  NDB client programs, 2439
  DEFAULT_CHARSET option
  CMake, 182
  DEFAULT_COLLATION option
  CMake, 183
default_storage_engine system variable, 541
default_week_format system variable, 541
DEFINER privileges, 1655, 2676
DEGREES(), 1247
delay option (ndbinfo_select_all), 2358
DELAYED, 1492
  INSERT modifier, 1488
  when ignored, 1488
Delayed insert
  thread command, 1014
delayed inserts
  thread states, 1021
delayed-insert option
    mysqldump, 361
delayed_insert_limit, 1494
delayed_insert_limit system variable, 542
delayed_insert_timeout system variable, 543
delayed_queue_size system variable, 543
delay_key_write system variable, 541, 1897
DELETE, 1480
  and NDB Cluster, 2136
delete, 3750
delete buffering, 3751
delete option
  mysqlimport, 375
delete option (ndb_index_stat), 2392
DELETE privilege, 754
delete-master-logs option
  mysqldump, 361
delete-orphans option
  ndb_blob_tool, 2371
deleting
  accounts, 775
database, 1471
  foreign key, 1399, 1460
  function, 1628
  index, 1398, 1473
  primary key, 1398
  rows, 3170
  schema, 1471
  table, 1474
  user, 1603
  users, 1603
deleting from main table
  thread state, 1016
deleting from reference tables
  thread state, 1016
deletion
  mysql.sock, 3164
delimiter command
    mysql, 327
delimiter option
    mysql, 320
    mysqlslap, 388
    ndb_select_all, 2428
denormalized, 3751
deprecated features, 13
   --base64-output, 14
   --config-file, 14
   --language, 14
engine_condition_pushdown, 14
GROUP BY sorting, 14
ignore_builtin_innodb, 14
option files, 14
option prefixes, 14
SHOW AUTHORS, 14
SHOW CONTRIBUTORS, 14
storage_engine, 14
timed_mutexes, 14
YEAR(2), 14
derived tables, 1535
des-key-file option
   mysql, 510
DESC, 1691
descending index, 3751
descending option
   ndb_select_all, 2427
DESCRIBE, 249, 1691
description option
   myisamchk, 402
design
   issues, 3174
DES_DECRYPT(), 1332
DES_ENCRYPT(), 1332
detach option
   mysqlslap, 388
development of NDB Cluster, 2125
development source tree, 173
diagnostics
   new features, 12
dictionary collation, German, 1086, 1130, 1130
digits, 1158
Dimension(), 1354
directory structure
   default, 59
dirty page, 1809, 3751
dirty read, 3751
disable named command
   mysql, 320
   --disable option prefix, 275
disable-indexes option
   ndb_restore, 2409
disable-keys option
   mysqldump, 362
disable-log-bin option
   mysqlbinlog, 425
DISCARD TABLESPACE, 1400
discard_or_import_tablespace
   thread state, 1017
disconnect-slave-event-count option
  mysqld, 2020
disconnecting
  from the server, 227
Disjoint(), 1361
Disk Data tables (NDB Cluster) (see NDB Cluster Disk Data)
disk failure
  InnoDB, 1875
disk full, 3163
disk I/O, 951
disk option
  ndb_select_all, 2428
disk performance, 999
disk-based, 3751
disk-bound, 3751
DiskCheckpointSpeed, 2250
DiskCheckpointSpeedInRestart, 2251
DiskIOThreadPool, 2273, 2278
Diskless, 2238
diskpagebuffer
  ndbinfotable, 2495
DiskPageBufferEntries, 2272
DiskPageBufferMemory, 2272, 2278
disks
  splitting data across, 1002
DiskSyncSize, 2250
display size, 1158
display triggers, 1677
display width, 1158
displaying
  database information, 378
  information
    Cardinality, 1656
    Collation, 1656
    SHOW, 1635, 1639, 1676
    SHOW statement, 1655, 1657
table status, 1673
DISTINCT, 238, 908
  AVG(), 1363
  COUNT(), 1364
  MAX(), 1365
  MIN(), 1365
  SELECT modifier, 1519
  SUM(), 1366
DISTINCTROW
  SELECT modifier, 1519
distributed privileges (NDB Cluster), 2539
  and NDB API applications, 2542
DIV, 1244
division (/), 1244
div_precision_increment system variable, 544
DML, 3751
  DELETE statement, 1480
  INSERT statement, 1485
UPDATE statement, 1543
DNS, 1009
DO, 1483
DocBook XML
documentation source format, 2
document id, 3752
Documentation
in Chinese, 3052
in Japanese, 3052
in Korean, 3052
Documenters
list of, 37
don't-ignore-systab-0 option
ndb_restore, 2409
DOUBLE data type, 1161
DOUBLE PRECISION data type, 1162
double quote ("), 1030
doublewrite buffer, 1798, 3752
downgrades
NDB Cluster, 2171, 2454
downgrading, 218, 1707
downloading, 45
drop, 3752
DROP ... IF EXISTS
and replication, 2093
DROP DATABASE, 1471
Drop DB
thread command, 1014
DROP EVENT, 1473
DROP FOREIGN KEY, 1399, 1460
DROP FUNCTION, 1474
DROP FUNCTION statement, 1628
DROP INDEX, 1398, 1473, 1801
DROP LOGFILE GROUP, 1473
(see also NDB Cluster Disk Data)
DROP NODEGROUP command (NDB Cluster), 2448
DROP PREPARE, 1574
DROP PRIMARY KEY, 1398
DROP privilege, 754
DROP PROCEDURE, 1474
DROP SCHEMA, 1471
DROP SERVER, 1474
DROP TABLE, 1474
and NDB Cluster, 2136
DROP TABLESPACE, 1475
(see also NDB Cluster Disk Data)
DROP TRIGGER, 1476
DROP USER statement, 772, 1603
DROP VIEW, 1476
drop-source option
ndb_move_data, 2397
dropping
accounts, 775
user, 1603
dry-scp option (ndb_error_reporter), 2389

dryrun option
   mysqlhotcopy, 437
DTrace, 714
   and memcached, 1941
DUAL, 1515
dump option
   myisam_ftdump, 393
   ndb_redo_log_reader, 2401
dump option (ndb_index_stat), 2393
dump-date option
   mysqldump, 362
dump-file option
   ndb_blob_tool, 2371
dump-slave option
   mysqldump, 362
DUMPFILE, 1522
dumping
   databases and tables, 353, 436
duplicate-key error, 1733
DYLD_LIBRARY_PATH environment variable, 2828
dynamic row format, 1795, 3752
dynamic table characteristics, 1899

E

eyearly adopter, 3752
edit command
   mysql, 327
EE_BADCLOSE error code, 3139
EE_CANTCREATEFILE error code, 3139
EE_CANTLOCK error code, 3139
EE_CANTUNLOCK error code, 3140
EE_CANT_CHSIZE error code, 3140
EE_CANT_MKDIR error code, 3140
EE_CANT_OPEN_STREAM error code, 3140
EE_CANT_READLINK error code, 3140
EE_CANT_SEEK error code, 3141
EE_CANT_SYMLINK error code, 3141
EE_CHANGE_OWNERSHIP error code, 3141
EE_CHANGE_PERMISSIONS error code, 3141
EE_DELETE error code, 3139
EE_DIR error code, 3140
EE_DISK_FULL error code, 3140
EE_EOFERR error code, 3139
EE_FILENOTFOUND error code, 3141
EE_FILE_NOT_CLOSED error code, 3141
EE_GETWD error code, 3140
EE_LINK error code, 3139
EE_LINK_WARNING error code, 3140
EE_OPEN_WARNING error code, 3140
EE_OUTOFMEMORY error code, 3139
EE_OUT_OF_FILERESOURCES error code, 3140
EE_READ error code, 3139

3216
EE_REALPATH error code, 3141
EE_SETWD error code, 3140
EE_STAT error code, 3140
EE_SYNC error code, 3141
EEUNKNOWN_CHARSET error code, 3140
EEUNKNOWN_COLLATION error code, 3141
EE_WRITE error code, 3139
ego command
  mysql, 327
Eiffel Wrapper, 2946
ELT(), 1277
embedded MySQL server library, 2817
embedded option
  mysql_config, 444
embedded-libs option
  mysql_config, 444
--enable option prefix, 275
enable-cleartext-plugin option
  mysql, 320
  mysqladmin, 343
  mysqlcheck, 350
  mysqldump, 363
  mysqlimport, 375
  mysqlshow, 381
  mysqlslap, 388
ENABLED_LOCAL_INFILE option
  CMake, 183
ENABLED_PROFILING option
  CMake, 184
ENABLE_DEBUG_SYNC option
  CMake, 183
ENABLE_DOWNLOADS option
  CMake, 183
ENABLE_DTRACE option
  CMake, 183
ENABLE_GCOV option
  CMake, 183
ENCODE(), 1333
ENCRYPT(), 1333
encrypted connections, 795
  command options, 282
encryption, 795
encryption functions, 1329
end
  thread state, 1017
END, 1574
EndPoint(), 1355
engine condition pushdown, 889
engine option
  mysqlslap, 388
ENGINES
  INFORMATION_SCHEMA table, 2699
engine_condition_pushdown
  deprecated features, 14
engine_condition_pushdown system variable, 544
ENTER SINGLE USER MODE command (NDB Cluster), 2447
entering queries, 228
enterprise components
MySQL Enterprise Audit, 829, 3024
MySQL Enterprise Backup, 3022
MySQL Enterprise Data Masking and De-Identification, 3024
MySQL Enterprise Encryption, 3023
MySQL Enterprise Firewall, 3024
MySQL Enterprise Monitor, 3021
MySQL Enterprise Security, 810, 821, 3023
MySQL Enterprise Thread Pool, 699, 3024
ENUM
size, 1212
ENUM data type, 1181, 1186
Envelope(), 1354
environment variable
AUTHENTICATION_PAM_LOG, 449, 820
CC, 188, 449
CXX, 188, 449
DBI_TRACE, 449, 3013
DBI_USER, 449
DYLD_LIBRARY_PATH, 2828
HOME, 331, 449
LD_LIBRARY_PATH, 225, 2828
LD_RUN_PATH, 225, 449
LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN, 449
LIBMYSQL_PLUGINS, 2931
MYSQL_DEBUG, 266, 449, 3016
MYSQL_GROUP_SUFFIX, 449
MYSQL_HISTFILE, 331, 449
MYSQL_HOME, 449
MYSQL_HOST, 288, 449
MYSQL_PS1, 449
MYSQL_PWD, 266, 288, 449
MYSQL_TCP_PORT, 266, 449, 713, 713
MYSQL_UNIX_PORT, 193, 266, 449, 713, 713
PATH, 123, 129, 197, 267, 449
TMPDIR, 193, 266, 449, 3163
TZ, 449, 663, 3165
UMASK, 449, 3158
UMASK_DIR, 449, 3158
USER, 288, 449
environment variables, 266, 288, 790
list of, 448
equal (=), 1231
Equals(), 1361
eq_ref join type
optimizer, 963
Errcode, 446
errno, 446
Error
thread command, 1014
error code
CR_ALREADY_CONNECTED, 3139
CR_AUTH_PLUGIN_CANNOT_LOAD, 3139
CR_CANT_READ_CHARSET, 3136
CR_COMMANDS_OUT_OF_SYNC, 3135
CR_CONN_HOST_ERROR, 3135
CR_CONN_UNKNOWN_PROTOCOL, 3138
CR_DATA_TRUNCATED, 3137
CR_EMBEDDED_CONNECTION, 3136
CR_FETCH_CANCELED, 3138
CR_INVALID_BUFFER_USE, 3137
CR_INVALID_CONN_HANDLE, 3138
CR_INVALID_PARAMETER_NO, 3137
CR_IPSOCK_ERROR, 3135
CR_LOCALHOST_CONNECTION, 3135
CR_MALFORMED_PACKET, 3136
CR_NAMEDPIPEOPEN_ERROR, 3136
CR_NAMEDPIPESETSTATE_ERROR, 3136
CR_NAMEDPIPEWAIT_ERROR, 3136
CR_NAMEDPIPE_CONNECTION, 3136
CR_NET_PACKET_TOO_LARGE, 3136
CR_NEW_STMT_METADATA, 3139
CR_NOT_IMPLEMENTED, 3138
CR_NO_DATA, 3138
CR_NO_PARAMETERS_EXISTS, 3137
CR_NO_PREPARE_STMT, 3137
CR_NO_RESULT_SET, 3138
CR_NO_STMT_METADATA, 3138
CR_NULL_POINTER, 3137
CR_OUT_OF_MEMORY, 3135
CR_PARAMS_NOT_BOUND, 3137
CR_PROBE_MASTER_CONNECT, 3136
CR_PROBE_SLAVE_CONNECT, 3136
CR_PROBE_SLAVE_HOSTS, 3136
CR_PROBE_SLAVE_STATUS, 3136
CR_SECURE_AUTH, 3138
CR_SERVER_GONE_ERROR, 3135
CR_SERVER_HANDSHAKE_ERR, 3135
CR_SERVER_LOST, 3135
CR_SERVER_LOST_EXTENDED, 3138
CR_SHARED_MEMORY_CONNECTION, 3137
CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR, 3138
CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR, 3137
CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR, 3137
CR_SHARED_MEMORY_CONNECT_MAP_ERROR, 3137
CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR, 3137
CR_SHARED_MEMORY_CONNECT_SET_ERROR, 3138
CR_SHARED_MEMORY_EVENT_ERROR, 3138
CR_SHARED_MEMORY_FILE_MAP_ERROR, 3138
CR_SSL_CONNECTION_ERROR, 3135
CR_STMT_CLOSED, 3138
CR_TCP_CONNECTION, 3135
CR_UNKNOWN_ERROR, 3135
CR_UNKNOWN_HOST, 3135
CR_UNSUPPORTED_PARAM_TYPE, 3137
CR_VERSION_ERROR, 3135
CR_WRONG_HOST_INFO, 3135
CR_WRONG_LICENSE, 3137
EE_BADCLOSE, 3139
EE_CANTCREATEFILE, 3139
EE_CANTLOCK, 3139
EE_CANTUNLOCK, 3140
EE_CANT_CHSIZE, 3140
EE_CANT_MKDIR, 3140
EE_CANT_OPEN_STREAM, 3140
EE_CANT_READLINK, 3140
EE_CANTSEEK, 3141
EE_CANT_SYMLINK, 3141
EE_CHANGE_OWNERSHIP, 3141
EE_CHANGE_PERMISSIONS, 3141
EE_DELETE, 3139
EE_DIR, 3140
EE_DISK_FULL, 3140
EE_EOFERR, 3139
EE_FILENOTFOUND, 3141
EE_FILE_NOT_CLOSED, 3141
EE_GETWD, 3140
EE_LINK, 3139
EE_LINK_WARNING, 3140
EE_OPEN_WARNING, 3140
EE_OUTOFMEMORY, 3139
EE_OUT_OF_FILERESOURCES, 3140
EE_READ, 3139
EE_REALPATH, 3141
EE_SETWD, 3140
EE_STAT, 3140
EE_SYNC, 3141
EE_UNKNOWN_CHARSET, 3140
EE_UNKNOWN_COLLATION, 3141
EE_WRITE, 3139
ER_ABORTING_CONNECTION, 3090
ER_ACCESS_DENIED_ERROR, 3083
ER_ACCESS_DENIED_NO_PASSWORD_ERROR, 3131
ER_ADD_PARTITION_NO_NEW_PARTITION, 3116
ER_ADD_PARTITION_SUBPART_ERROR, 3116
ER_ADMIN_WRONG_MRG_TABLE, 3113
ER_ALTER_FILEGROUP_FAILED, 3117
ER_ALTER_INFO, 3086
ER_AMBIGUOUS_FIELD_TERM, 3113
ER_AUTOINC_READ_FAILED, 3113
ER_AUTO_CONVERT, 3097
ER_BAD_DB_ERROR, 3083
ER_BAD_FT_COLUMN, 3084
ER_BAD_FILE_ERROR, 3100
ER_BAD_HOST_ERROR, 3082
ER_BAD_LOG_STATEMENT, 3121
ER_BAD_NULL_ERROR, 3083
ER_BAD_SLAVE, 3094
ER_BAD_SLAVE_UNTIL_COND, 3100
ER_BAD_TABLE_ERROR, 3083
ER_BASE64_DECODE_ERROR, 3121
ER_BINLOG_CREATE_ROUTINE_NEED_SUPER, 3109
ER_BINLOG_LOGGING_IMPOSSIBLE, 3122
ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE, 3127
ER_BINLOG_PURGE_EMFILE, 3121
ER_BINLOG_PURGE_FATAL_ERR, 3106
ER_BINLOG_PURGE_PROHIBITED, 3106
ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE, 3127
ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE, 3127
ER_BINLOG_ROW_LOGGING_FAILED, 3117
ER_BINLOG_ROW_MODE_AND_STMT_ENGINE, 3127
ER_BINLOG_ROW_RBR_TO_SBR, 3118
ER_BINLOG_ROW_WRONG_TABLE_DEF, 3118
ER_BINLOG_STMT_MODE_AND_ROW_ENGINE, 3127
ER_BINLOG_STMT_MODE_AND_STMT_ENGINE, 3127
ER_BINLOG_UNSAFE_AND_STMT_ENGINE, 3122
ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT, 3133
ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT, 3133
ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC, 3134
ER_BINLOG_UNSAFE_INSERT_DELAYED, 3128
ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT, 3132
ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE, 3133
ER_BINLOG_UNSAFE_INSERT_TWO_KEYS, 3134
ER_BINLOG_UNSAFE_LIMIT, 3128
ER_BINLOG_UNSAFE_Mixed_STATEMENT, 3130
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE, 3130
ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS, 3128
ER_BINLOG_UNSAFE_REPLACE_SELECT, 3133
ER_BINLOG_UNSAFE_ROUTINE, 3109
ER_BINLOG_UNSAFE_STATEMENT, 3122
ER_BINLOG_UNSAFE_SYSTEM_FUNCTION, 3128
ER_BINLOG_UNSAFE_SYSTEM_TABLE, 3128
ER_BINLOG_UNSAFE_SYSTEM_VARIABLE, 3128
ER_BINLOG_UNSAFE_UDF, 3128
ER_BINLOG_UNSAFE_UPDATE_IGNORE, 3133
ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT, 3134
ER_BLOBS_AND_NO_TERMINATED, 3086
ER_BLOB_CANT_HAVE_DEFAULT, 3087
ER_BLOB_FIELD_IN_PART_FUNC_ERROR, 3115
ER_BLOB_KEY_WITHOUT_LENGTH, 3092
ER_BLOB_USED_AS_KEY, 3085
ER_CANNOT_ADD_FOREIGN, 3095
ER_CANNOT_LOAD_FROM_TABLE, 3118
ER_CANNOT_USER, 3108
ER_CANT_ACTIVATE_LOG, 3120
ER_CANT_AGGREGATE_2COLLATIONS, 3099
ER_CANT_AGGREGATE_3COLLATIONS, 3099

3221
ER_CANT_AGGREGATE_NCOLLATIONS, 3099
ER_CANT_CHANGE_TX_ISOLATION, 3120
ER_CANT_CREATE_DB, 3080
ER_CANT_CREATE_FEDERATED_TABLE, 3110
ER_CANT_CREATE_FILE, 3079
ER_CANT_CREATE_GEOMETRY_OBJECT, 3109
ER_CANT_CREATE_HANDLER_FILE, 3115
ER_CANT_CREATE_SROUTINE, 3123
ER_CANT_CREATE_TABLE, 3080
ER_CANT_CREATE_THREAD, 3089
ER_CANT_CREATE_USER_WITH_GRANT, 3108
ER_CANT_DELETE_FILE, 3080
ER_CANT_DO_THIS_DURING_AN_TRANSACTION, 3092
ER_CANT_DROP_FIELD_OR_KEY, 3086
ER_CANT_FIND_DL_ENTRY, 3089
ER_CANT_FIND_SYSTEM_REC, 3080
ER_CANT_FIND_UDF, 3088
ER_CANT_GET_STAT, 3080
ER_CANT_GET_WD, 3081
ER_CANT_INITIALIZE_UDF, 3088
ER_CANT_LOCK, 3080
ER_CANT_LOCK_LOG_TABLE, 3119
ER_CANT_OPEN_FILE, 3080
ER_CANT_OPEN_LIBRARY, 3089
ER_CANT_READ_DIR, 3081
ER_CANT_REMOVE_ALL_FIELDS, 3086
ER_CANT_RENAME_LOG_TABLE, 3121
ER_CANT_REOPEN_TABLE, 3089
ER_CANT_SET_WD, 3081
ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG, 3111
ER_CANT_UPDATE_WITH_READLOCK, 3096
ER_CANT_USE_OPTION_HERE, 3097
ER_CANT_WRITE_LOCK_LOG_TABLE, 3119
ER_CHECKREAD, 3081
ER_CHECK_NOT_IMPLEMENTED, 3092
ER_CHECK_NO_SUCH_TABLE, 3092
ER_COALESCE_ONLY_ON_HASH_PARTITION, 3116
ER_COALESCE_PARTITION_NO_PARTITION, 3116
ER_COLLATION_CHARSET_MISMATCH, 3098
ER_COLUMNACCESS_DENIED_ERROR, 3090
ER_COL_COUNT_DOESNT_MATCH_CORRUPTED, 3118
ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE, 3119
ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG, 3109
ER_COND_ITEM_TOO_LONG, 3126
ER_CONFLICTING_DECLARATIONS, 3101
ER_CONFLICT_FN_PARSE_ERROR, 3124
ER_CONNECT_TO_FOREIGN_DATA_SOURCE, 3110
ER_CONNECT_TO_MASTER, 3096
ER_CONSECUTIVE_REORG_PARTITIONS, 3116
ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR, 3114
ER_CON_COUNT_ERROR, 3082
ER_CORRUPT_HELP_DB, 3097
ER_CRASHED_ON_REPAIR, 3093
ER_CRASHED_ON_USAGE, 3093
ER_CREATE_DB_WITH_READ_LOCK, 3095
ER_CREATE_FILEGROUP_FAILED, 3117
ER_CUT_VALUE_GROUP_CONCAT, 3098
ER_CYCLIC_REFERENCE, 3097
ER_DATABASE_NAME, 3125
ER_DATA_OUT_OF_RANGE, 3130
ER_DATA_TOO_LONG, 3108
ER_DATETIME_FUNCTION_OVERFLOW, 3111
ER_DBACCESS_DENIED_ERROR, 3083
ER_DB_CREATE_EXISTS, 3080
ER_DB_DROP_DELETE, 3080
ER_DB_DROP_EXISTS, 3080
ER_DB_DROP_RMDIR, 3080
ER_DDL_LOG_ERROR, 3120
ER_DEBUG_SYNC_HIT_LIMIT, 3125
ER_DEBUG_SYNC_TIMEOUT, 3125
ER_DELAYED_CANT_CHANGE_LOCK, 3090
ER_DELAYED_INSERT_TABLE_LOCKED, 3091
ER_DELAYED_NOT_SUPPORTED, 3124
ER_DERIVED_MUST_HAVE_ALIAS, 3098
ER_DIFF_GROUPS_PROC, 3107
ER_DISK_FULL, 3081
ER_DIVISION_BY_ZERO, 3105
ER_DROP_DB_WITH_READ_LOCK, 3095
ER_DROP_FILEGROUP_FAILED, 3117
ER_DROP_INDEX_FK, 3119
ER_DROP_LAST_PARTITION, 3116
ER_DROP_PARTITION_NON_EXISTENT, 3116
ER_DROP_USER, 3099
ER_DUMP_NOT_IMPLEMENTED, 3093
ER_DUPLICATED_VALUE_IN_TYPE, 3100
ER_DUP_ARGUMENT, 3096
ER_DUP_ENTRY, 3084
ER_DUP_ENTRY_AUTOINCREMENT_CASE, 3120
ER_DUP_ENTRY_WITH_KEY_NAME, 3121
ER_DUP_FIELDNAME, 3084
ER_DUP_KEY, 3081
ER_DUP_KEYNAME, 3084
ER_DUP_SIGNAL_SET, 3125
ER_DUP_UNIQUE, 3091
ER_EMPTY_QUERY, 3084
ER_ERROR_DURING_CHECKPOINT, 3093
ER_ERROR_DURING_COMMIT, 3092
ER_ERROR_DURING_FLUSH_LOGS, 3093
ER_ERROR_DURING_ROLLBACK, 3093
ER_ERROR_IN_TRIGGER_BODY, 3132
ER_ERROR_IN_UNKNOWN_TRIGGER_BODY, 3132
ER_ERROR_ON_CLOSE, 3081
ER_ERROR_ON_READ, 3081
ER_ERROR_ON_RENAME, 3081
ER_ERROR_ON_WRITE, 3081
ER_ERROR_WHEN_EXECUTING_COMMAND, 3096
ER_EVENTS_DB_ERROR, 3121
ER_EVENT_ALREADY_EXISTS, 3118
ER_EVENT_CANNOT_ALTER_IN_THE_PAST, 3122
ER_EVENT_CANNOT_CREATE_IN_THE_PAST, 3122
ER_EVENT_CANNOT_DELETE, 3118
ER_EVENT_CANT_ALTER, 3118
ER_EVENT_COMPILE_ERROR, 3119
ER_EVENT_DATA_TOO_LONG, 3119
ER_EVENT_DOES_NOT_EXIST, 3118
ER_EVENT_DROP_FAILED, 3118
ER_EVENT_ENDS_BEFORE_STARTS, 3118
ER_EVENT_EXEC_TIME_IN_THE_PAST, 3118
ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG, 3118
ER_EVENT_INVALID_CREATION_CTX, 3123
ER_EVENT_MODIFY_QUEUE_ERROR, 3120
ER_EVENT_NEITHER_M_EXPR_NOR_M_AT, 3118
ER_EVENT_OPEN_TABLE_FAILED, 3118
ER_EVENT_RECURSION_FORBIDDEN, 3121
ER_EVENTSAME_NAME, 3119
ER_EVENT_SET_VAR_ERROR, 3120
ER_EVENT_STORE_FAILED, 3118
ER_EXCEPTIONS_WRITE_ERROR, 3124
ER_EXEC_STMT_WITH_OPEN_CURSOR, 3109
ER_FAILED_READ_FROM_PAR_FILE, 3131
ER_FAILED_ROUTINE_BREAK_BINLOG, 3109
ER_FEATURE_DISABLED, 3100
ER_FIELD_NOT_FOUND_PART_ERROR, 3114
ER_FIELD_SPECIFIED_TWICE, 3087
ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD, 3127
ER_FILEGROUP_OPTION_ONLY_ONCE, 3117
ER_FILE_EXISTS_ERROR, 3086
ER_FILE_NOT_FOUND, 3081
ER_FILE_USED, 3081
ER_FILSORT_ABORT, 3081
ER_FLUSH_MASTER_BINLOG_CLOSED, 3093
ER_FORBID_SCHEMA_CHANGE, 3111
ER_FORCING_CLOSE, 3085
ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST, 3110
ER_FOREIGN_DATA_STRING_INVALID, 3110
ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE, 3110
ER_FOREIGN_DUPLICATE_KEY, 3119
ER_FOREIGN_KEY_ON_PARTITIONED, 3116
ER_FOREIGN_SERVER_DOESNT_EXIST, 3113
ER_FOREIGN_SERVER_EXISTS, 3113
ER_FORM_NOT_FOUND, 3081
ER_FPARSER_BAD_HEADER, 3104
ER_FPARSER_EOF_IN_COMMENT, 3104
ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER, 3104
ER_FPARSER_ERROR_IN_PARAMETER, 3104
ER_FPARSER_TOO_BIG_FILE, 3104
ER_FRM_UNKNOWN_TYPE, 3104
ER_FSEEK_FAIL, 3106
ER_FT_MATCHING_KEY_NOT_FOUND, 3093
ER_FUNCTION_NOT_DEFINED, 3089
ER_FUNC_INEXISTENT_NAME_COLLISION, 3125
ER_GET_ERRMSG, 3101
ER_GET_ERRNO, 3082
ER_GET_TEMPORARY_ERRMSG, 3101
ER_GLOBAL_VARIABLE, 3096
ER_GOT_SIGNAL, 3085
ER_GRANT_PLUGIN_USER_EXISTS, 3131
ER_GRANT WRONG_HOST_OR_USER, 3090
ER_HANDSHAKE_ERROR, 3082
ER_HASHCHK, 3079
ER_HOSTNAME, 3113
ER_HOST IS_BLOCKED, 3089
ER_HOST NOT_PRIVILEGED, 3089
ER_ILLEGAL_GRANT FOR TABLE, 3090
ER_ILLEGAL HA, 3082
ER_ILLEGAL HA CREATE OPTION, 3113
ER_ILLEGAL REFERENCE, 3097
ER_ILLEGAL_VALUE FOR TYPE, 3106
ER_INCONSISTENT_PARTITION_INFO_ERROR, 3114
ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR, 3115
ER_INCORRECT_GLOBAL_LOCAL_VAR, 3097
ER_INDEX_COLUMN_TOO_LONG, 3132
ER_INDEX_CORRUPT, 3132
ER_INDEX REBUILD, 3093
ER_INSERT INFO, 3086
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG DIRECT, 3129
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT, 3129
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN, 3130
ER_INVALID_CHARACTER_STRING, 3101
ER_INVALID_DEFAULT, 3084
ER_INVALID_GROUP_FUNC_USE, 3087
ER_INVALID_ON_UPDATE, 3101
ER_INVALID USE OF NULL, 3089
ER_IO_ERR_LOG_INDEX_READ, 3106
ER_IPSOCK_ERROR, 3085
ER_KEY_COLUMN DOES NOT EXITS, 3085
ER_KEY DOES NOT EXITS, 3092
ER_KEY NOT FOUND, 3082
ER_KEY PART 0, 3107
ER_KEY REF DO NOT MATCH TABLE REF, 3097
ER_KILL_DENIED_ERROR, 3086
ER_LIMITED PART RANGE, 3117
ER_LIST OF FIELDS ONLY IN HASH ERROR, 3114
ER_LOAD DATA INVALID COLUMN, 3123
ER_LOAD FROM FIXED_SIZE ROWS TO_VAR, 3108
ER_LOAD INFO, 3086
ER_LOCAL_VARIABLE, 3096
ER_LOCK ABORTED, 3130
ER_LOCK DEADLOCK, 3095
ER_LOCK OR ACTIVE TRANSACTION, 3093
ER_LOCK TABLE FULL, 3094
ER_LOCK WAIT TIMEOUT, 3094
ER_LOGGING_PROHIBIT changing OF, 3107
ER_LOG IN USE, 3106
ER_LOG_PURGE NO_FILE, 3123
ER_LOG_PURGE UNKNOWN ERR, 3086
ER_MALFORMED_DEFINER, 3111
ER_MASTER, 3093
ER_MASTER_FATAL_ERROR_READING_BINLOG, 3097
ER_MASTER_INFO, 3094
ER_MASTER_NET_READ, 3093
ER_MASTER_NET_WRITE, 3093
ER_MAXVALUE_IN_VALUES_IN, 3126
ER_MAX_PREPARED_STMT_COUNT_REACHED, 3112
ER_MESSAGE_AND_STATEMENT, 3128
ER_MISSING_SKIP_SLAVE, 3100
ER_MIXING_NOT_ALLOWED, 3096
ER_MIX_HANDLER_ERROR, 3115
ER_MIX_OF_GROUP_FUNC_AND_FIELDS, 3090
ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR, 3115
ER_MULTI_UPDATE_KEY_CONFLICT, 3132
ER_M BIGGER_THAN_D, 3110
ER_NAME_BECOMES_EMPTY, 3113
ER_NATIVE_FCT_NAME_COLLISION, 3121
ER_NDB_CANT_SWITCH_BINLOG_FORMAT, 3120
ER_NDB_REPLICATION_SCHEMA_ERROR, 3124
ER_NEED_REPREPARE, 3124
ER_NET_ERROR_ON_WRITE, 3091
ER_NET_FCNTL_ERROR, 3091
ER_NET_PACKETS_OUT_OF_ORDER, 3091
ER_NET_PACKET_TOO_LARGE, 3090
ER_NET_READ_ERROR, 3091
ER_NET_READ_ERROR_FROM_PIPE, 3090
ER_NET_READ_INTERRUPTED, 3091
ER_NET_UNCOMPRESS_ERROR, 3091
ER_NET_WRITE_INTERRUPTED, 3091
ER_NEVER_USED, 3123
ER_NEW_ABORTING_CONNECTION, 3093
ER_NISAMCHK, 3079
ER_NO, 3079
ER_NONEXISTING_GRANT, 3090
ER_NONEXISTING_PROC_GRANT, 3108
ER_NONEXISTING_TABLE_GRANT, 3090
ER_NONUNIQ_TABLE, 3084
ER_NONUPDATEABLE_COLUMN, 3104
ER_NON_GROUPING_FIELD_USED, 3112
ER_NON_INSERTABLE_TABLE, 3113
ER_NON_UNIQ_ERROR, 3083
ER_NON_UPDATABLE_TABLE, 3100
ER_NORMAL_SHUTDOWN, 3085
ER_NOT_ALLOWED_COMMAND, 3090
ER_NOT_FORM_FILE, 3082
ER_NOT_KEYFILE, 3082
ER_NOT_SUPPORTED_AUTH_MODE, 3098
ER_NOT_SUPPORTED_YET, 3097
ER_NO_BINARY_LOGGING, 3107
ER_NO_BINLOG_ERROR, 3116
ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR, 3114
ER_NO_DB_ERROR, 3083
ER_SLAVE_AMBIGOUS_EXEC_MODE, 3123
ER_SLAVE_CANT_CREATE_CONVERSION, 3129
ER_SLAVE_CONVERSION_FAILED, 3129
ER_SLAVE_CORRUPT_EVENT, 3123
ER_SLAVE_CREATE_EVENT_FAILURE, 3122
ER_SLAVE_FATAL_ERROR, 3122
ER_SLAVE_HEARTBEAT_FAILURE, 3124
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE, 3124
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX, 3131
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN, 3131
ER_SLAVE_IGNORED_SSL_PARAMS, 3099
ER_SLAVE_IGNORED_TABLE, 3097
ER_SLAVE_IGNORE_SERVER_IDS, 3126
ER_SLAVE_INCIDENT, 3122
ER_SLAVE_MASTER_COM_FAILURE, 3122
ER_SLAVE_MUST_STOP, 3094
ER_SLAVE_NOT_RUNNING, 3094
ER_SLAVE_RELAY_LOG_READ_FAILURE, 3122
ER_SLAVE_RELAY_LOG_WRITE_FAILURE, 3122
ER_SLAVE_THREAD, 3094
ER_SLAVE_WAS_NOT_RUNNING, 3098
ER_SLAVE_WAS_RUNNING, 3098
ER_SPATIAL_CANT_HAVE_NULL, 3098
ER_SPATIAL_MUST_HAVE_GEOM_COL, 3130
ER_SPECIFIC_ACCESS_DENIED_ERROR, 3096
ER_SP_ALREADY_EXISTS, 3101
ER_SP_BADRETURN, 3102
ER_SP_BADSELECT, 3102
ER_SP_BADSTATEMENT, 3102
ER_SP_BAD_CURSOR_QUERY, 3103
ER_SP_BAD_CURSOR_SELECT, 3103
ER_SP_BAD_SQLSTATE, 3108
ER_SP_BAD_VAR_SHADOW, 3112
ER_SP_CANT_ALTER, 3103
ER_SP_CANT_SET_AUTOCOMMIT, 3111
ER_SP_CASE_NOT_FOUND, 3104
ER_SP_COND_MISMATCH, 3102
ER_SP_CURSOR_AFTER_HANDLER, 3104
ER_SP_CURSOR_ALREADY_OPEN, 3103
ER_SP_CURSOR_MISMATCH, 3103
ER_SP_CURSOR_NOT_OPEN, 3103
ER_SP DOES NOT_EXIST, 3101
ER_SP_DROP_FAILED, 3101
ER_SP_DUP_COND, 3103
ER_SP_DUP_CURS, 3103
ER_SP_DUP_HANDLER, 3109
ER_SP_DUP_PARAM, 3103
ER_SP_DUP_VAR, 3103
ER_SP_FETCH_NO_DATA, 3103
ER_SP_GOTO_IN_HNDLR, 3105
ER_SP_LABEL_MISMATCH, 3102
ER_SP_LABEL_REDEFINE, 3102
ER_SP_LILABEL_MISMATCH, 3102
ER_SP_NORETURN, 3102
ER_WARN_TOO_MANY_RECORDS, 3098
ER_WARN_USING_OTHER_HANDLER, 3099
ER_WARN_VIEW_MERGE, 3105
ER_WARN_VIEW_WITHOUT_KEY, 3105
ER_WRONG_ARGUMENTS, 3095
ER_WRONG_AUTO_KEY, 3085
ER_WRONG_COLUMN_NAME, 3091
ER_WRONG_DB_NAME, 3087
ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR, 3114
ER_WRONG_FIELD_SPEC, 3084
ER_WRONG_FIELD_TERMINATORS, 3085
ER_WRONG_FIELD_WITHOUT_GROUP, 3084
ER_WRONG_FK_DEF, 3097
ER_WRONG_GROUP_FIELD, 3084
ER_WRONG_KEY_COLUMN, 3091
ER_WRONG_LOCK_OF_SYSTEM_TABLE, 3110
ER_WRONG_MAGIC, 3107
ER_WRONG_MRG_TABLE, 3091
ER_WRONG_NAME_FOR_CATALOG, 3100
ER_WRONG_NAME_FOR_INDEX, 3100
ER_WRONG_NATIVE_TABLE_STRUCTURE, 3129
ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT, 3096
ER_WRONG_OBJECT, 3104
ER_WRONG_OUTER_JOIN, 3088
ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT, 3121
ER_WRONG_PARAMCOUNT_TO_PROCEDURE, 3087
ER_WRONG_PARAMETERS_TO_NATIVE_FCT, 3121
ER_WRONG_PARAMETERS_TO_PROCEDURE, 3087
ER_WRONG_PARAMETERS_TO_STORED_FCT, 3121
ER_WRONG_PARTITION_NAME, 3120
ER_WRONG_PERFSCHEMA_USAGE, 3129
ER_WRONG_SIZE_NUMBER, 3117
ER_WRONG_SPVAR_TYPE_IN_LIMIT, 3130
ER_WRONG_STRING_LENGTH, 3113
ER_WRONG_SUB_KEY, 3086
ER_WRONG_SUM_SELECT, 3084
ER_WRONG_TABLE_NAME, 3087
ER_WRONG_TYPE_COLUMN_VALUE_ERROR, 3126
ER_WRONG_TYPE_FOR_VAR, 3096
ER_WRONG_USAGE, 3096
ER_WRONG_VALUE, 3117
ER_WRONG_VALUE_COUNT, 3084
ER_WRONG_VALUE_COUNT_ON_ROW, 3089
ER_WRONG_VALUE_FOR_TYPE, 3109
ER_WRONG_VALUE_FOR_VAR, 3096
ER_XSAS_FAILED, 3107
ER_XAER_DUPID, 3111
ER_XAER_INVAL, 3108
ER_XAER_NOTA, 3108
ER_XAER_OUTSIDE, 3108
ER_XAER_RMERR, 3108
ER_XAER_RMFAIL, 3108
ER_XA_RBDEADLOCK, 3124
ER_XA_RBROLLBACK, 3108
ER_XA_RBTIMEOUT, 3123
ER_YES, 3079
ER_ZLIB_Z_BUF_ERROR, 3098
ER_ZLIB_Z_DATA_ERROR, 3098
ER_ZLIB_Z_MEM_ERROR, 3098
WARN_COND_ITEM_TRUNCATED, 3126
WARN_DATA_TRUNCATED, 3099
WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED, 3125
WARN_NO_MASTER_INFO, 3124
WARN_OPTION_BELOW_LIMIT, 3132
WARN_OPTION_IGNORED, 3124
WARN_PLUGIN_BUSY, 3124
WARN_PLUGIN_DELETE_BUILTIN, 3124
ERROR Events (NDB Cluster), 2463
error log, 3753
error logs (NDB Cluster), 2355
error messages
can't find file, 3158
Can't reopen table, 3174
displaying, 446
languages, 1138, 1138
The used command is not allowed with this MySQL version, 748
error-insert option
ndb_move_data, 2397
errors
access denied, 3143
and replication, 2101
checking tables for, 872
common, 3141
directory checksum, 163
handling for UDFs, 3004
in subqueries, 1538
known, 3174
linking, 2826
list of, 3143
lost connection, 3148
reporting, 19, 19
sources of information, 3077
error_count system variable, 545
ERROR FOR DIVISION BY ZERO SQL mode, 652
ER_ABORTING_CONNECTION error code, 3089
ER_ACCESS_DENIED_ERROR error code, 3083
ER_ACCESS_DENIED_NO_PASSWORD_ERROR error code, 3131
ER_ADD_PARTITION_NO_NEW_PARTITION error code, 3116
ER_ADD_PARTITION_SUBPART_ERROR error code, 3116
ER_ADMIN_WRONG_MRG_TABLE error code, 3113
ER_AMBIGUOUS_FIELD_TERM error code, 3113
ER_AUTOINC_READ_FAILED error code, 3113
ER_AUTO_CONVERT error code, 3097
ER_BAD_DB_ERROR error code, 3083
ER_BAD_FIELD_ERROR error code, 3084
ER_BAD_FT_COLUMN error code, 3084
ER_BAD_FT_COLUMN error code, 3100
ER_BAD_HOST_ERROR error code, 3082
ER_BAD_LOG_STATEMENT error code, 3121
ER_BAD_NULL_ERROR error code, 3083
ER_BAD_SLAVE error code, 3094
ER_BAD_SLAVE_UNTIL_COND error code, 3100
ER_BAD_TABLE_ERROR error code, 3083
ER_BASE64_DECODE_ERROR error code, 3121
ER_BINLOG_CREATE_ROUTINE_NEED_SUPER error code, 3109
ER_BINLOG_LOGGING_IMPOSSIBLE error code, 3122
ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE error code, 3127
ER_BINLOG_PURGE_EMFILE error code, 3121
ER_BINLOG_PURGE_FATAL_ERR error code, 3106
ER_BINLOG_PURGE_PROHIBITED error code, 3106
ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE error code, 3127
ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE error code, 3127
ER_BINLOG_ROW_INJECTION_AND_STMT_MODE error code, 3127
ER_BINLOG_ROW_LOGGING_FAILED error code, 3117
ER_BINLOG_ROW_MODE_AND_STMT_ENGINE error code, 3127
ER_BINLOG_ROW_RBR_TO_SBR error code, 3118
ER_BINLOG_ROW_WRONG_TABLE_DEF error code, 3118
ER_BINLOG_STMT_MODE_AND_ROW_ENGINE error code, 3127
ER_BINLOG_UNSAFE_AND_STMT_ENGINE error code, 3127
ER_BINLOG_UNSAFE_AUTOINC_COLUMNS error code, 3128
ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST error code, 3134
ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT error code, 3133
ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT error code, 3133
ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC error code, 3134
ER_BINLOG_UNSAFE_INSERT_DELAYED error code, 3128
ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT error code, 3132
ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE error code, 3133
ER_BINLOG_UNSAFE_INSERT_TWO_KEYS error code, 3134
ER_BINLOG_UNSAFE_LIMIT error code, 3128
ER_BINLOG_UNSAFE_MIXED_STATEMENT error code, 3130
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE error code, 3130
ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS error code, 3128
ER_BINLOG_UNSAFE_REPLACE_SELECT error code, 3133
ER_BINLOG_UNSAFE_ROUTINE error code, 3109
ER_BINLOG_UNSAFE_STATEMENT error code, 3122
ER_BINLOG_UNSAFE_SYSTEM_FUNCTION error code, 3128
ER_BINLOG_UNSAFE_SYSTEM_TABLE error code, 3128
ER_BINLOG_UNSAFE_SYSTEM_VARIABLE error code, 3128
ER_BINLOG_UNSAFE_UDF error code, 3128
ER_BINLOG_UNSAFE_UPDATE_IGNORE error code, 3133
ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT error code, 3134
ER_BLOBS_AND_NO_TERMINATED error code, 3086
ER_BLOB_CANT_HAVE_DEFAULT error code, 3087
ER_BLOB_FIELD_IN_PART_FUNC_ERROR error code, 3115
ER_BLOB_KEYWITHOUT_LENGTH error code, 3092
ER_BLOB_USED AS_KEY error code, 3085
ER_CANNOT_ADD_FOREIGN error code, 3095
ER_CANNOT_LOAD_FROM_TABLE error code, 3118
ER_CANNOT_USER error code, 3108
ER_CANT_ACTIVATE_LOG error code, 3120
ER_CANTAgregarate_2COLLATIONS error code, 3099
ER_CANT_AGGREGATE_3COLLATIONS error code, 3099
ER_CANT_AGGREGATE_NCOLLATIONS error code, 3099
ER_CANT_CHANGE_TX_ISO error code, 3120
ER_CANT_CREATE_DB error code, 3080
ER_CANT_CREATE_FEDERATED_TABLE error code, 3110
ER_CANT_CREATE_FILE error code, 3079
ER_CANT_CREATE_GEOMETRY_OBJECT error code, 3109
ER_CANT_CREATE_HANDLER_FILE error code, 3115
ER_CANT_CREATE_SROUTINE error code, 3123
ER_CANT_CREATE_TABLE error code, 3080
ER_CANT_CREATE_THREAD error code, 3089
ER_CANT_CREATE_USER_WITH_GRANT error code, 3108
ER_CANT_DELETE_FILE error code, 3080
ER_CANT_DO_THIS_DURING_AN_TRANSACTION error code, 3092
ER_CANT_DROP_FIELD_OR_KEY error code, 3086
ER_CANT_FIND_DL_ENTRY error code, 3089
ER_CANT_FIND_SYSTEM_REC error code, 3080
ER_CANT_FIND_UDF error code, 3088
ER_CANT_GET_STAT error code, 3080
ER_CANT_GET_WD error code, 3080
ER_CANT_INITIALIZATE_UDF error code, 3088
ER_CANT_LOCK error code, 3080
ER_CANT_LOCK_LOG_TABLE error code, 3119
ER_CANT_OPEN_FILE error code, 3080
ER_CANT_OPEN_LIBRARY error code, 3089
ER_CANT_READ_DIR error code, 3081
ER_CANT_REMOVE_ALL_FIELDS error code, 3086
ER_CANT_RENAME_LOG_TABLE error code, 3121
ER_CANT_REOPEN_TABLE error code, 3089
ER_CANT_SET_WD error code, 3081
ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG error code, 3111
ER_CANT_UPDATE_WITH_READLOCK error code, 3096
ER_CANT_USE_OPTION_HERE error code, 3097
ER_CANT_WRITE_LOCK_LOG_TABLE error code, 3119
ER_CHECKREAD error code, 3081
ER_CHECK_NOT_IMPLEMENTED error code, 3092
ER_CHECK_NO_SUCH_TABLE error code, 3092
ER_COALESCE_ONLY_ON_HASH_PARTITION error code, 3116
ER_COALESCE_PARTITION_NO_PARTITION error code, 3116
ER_COLLATION_CHARSET_MISMATCH error code, 3098
ER_COLUMNACCESS_DENIED_ERROR error code, 3090
ER_COLUMN_COUNT_DOESNT_MATCH_CORRUPTED error code, 3118
ER_COLUMN_COUNT_DOESNT_MATCH_PLEASE_UPDATE error code, 3119
ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG error code, 3109
ER_COND_ITEM_TOO_LONG error code, 3126
ER_CONFLICTING_DECLARATIONS error code, 3101
ER_CONFLICT_FUNCTIONS error code, 3124
ER_CONNECT_TO_FOREIGN_DATA_SOURCE error code, 3110
ER_CONNECT_TO_MASTER error code, 3096
ER_CONSECUTIVE_REORG_PARTITION error code, 3116
ER_CONST_EXPR_IN_PARTITION_FUNC error code, 3114
ER_CON_COUNT_ERROR error code, 3082
ER_CORRUPT_HELP_DB error code, 3097
ER_CRASHED_ON_REPAIR error code, 3093
ER_EVENT_ALREADY_EXISTS error code, 3118
ER_EVENT_CANNOT_ALTER_IN_THE_PAST error code, 3122
ER_EVENT_CANNOT_CREATE_IN_THE_PAST error code, 3122
ER_EVENT_CANNOT_DELETE error code, 3118
ER_EVENT_CANT_ALTER error code, 3118
ER_EVENT_COMPILE_ERROR error code, 3119
ER_EVENT_DATA_TOO_LONG error code, 3119
ER_EVENT_DOES_NOT_EXIST error code, 3118
ER_EVENT_DROP_FAILED error code, 3118
ER_EVENT_ENDS_BEFORE_STARTS error code, 3118
ER_EVENT_EXEC_TIME_IN_THE_PAST error code, 3118
ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG error code, 3118
ER_EVENT_INVALID_CREATION_CTX error code, 3123
ER_EVENT_MODIFY_QUEUE_ERROR error code, 3120
ER_EVENT_NEITHER_M_EXPR_NOR_M_AT error code, 3118
ER_EVENT_OPEN_TABLE_FAILED error code, 3118
ER_EVENT_RECURSION_FORBIDDEN error code, 3121
ER_EVENT_SAME_NAME error code, 3119
ER_EVENT_SET_VAR_ERROR error code, 3120
ER_EVENT_STORE_FAILED error code, 3118
ER_EXCEPTIONS_WRITE_ERROR error code, 3124
ER_EXEC_STMT_WITH_OPEN_CURSOR error code, 3109
ER_FAILED_READ_FROM_PAR_FILE error code, 3131
ER_FAILED_ROUTINE_BREAK_BINLOG error code, 3109
ER_FEATURE_DISABLED error code, 3100
ER_FIELD_NOT_FOUND_PART_ERROR error code, 3114
ER_FIELD_SPECIFIED_TWICE error code, 3087
ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD error code, 3127
ER_FILEGROUP_OPTION_ONLY_ONCE error code, 3117
ER_FILE_EXISTS_ERROR error code, 3086
ER_FILE_NOT_FOUND error code, 3081
ER_FILE_USED error code, 3081
ER_FILSORT_ABORT error code, 3081
ER_FLUSH_MASTER_BINLOG_CLOSED error code, 3093
ER_FORBID_SCHEMA_CHANGE error code, 3111
ER_FORCING_CLOSE error code, 3085
ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST error code, 3110
ER_FOREIGN_DATA_STRING_INVALID error code, 3110
ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE error code, 3110
ER_FOREIGN_DUPLICATE_KEY error code, 3119
ER_FOREIGN_KEY_ON_PARTITIONED error code, 3116
ER_FOREIGN_SERVER_DOESNT_EXIST error code, 3113
ER_FOREIGN_SERVER_EXISTS error code, 3113
ER_FORM_NOT_FOUND error code, 3081
ER_FPARSER_BAD_HEADER error code, 3104
ER_FPARSER_EOF_IN_COMMENT error code, 3104
ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER error code, 3104
ER_FPARSER_ERROR_IN_PARAMETER error code, 3104
ER_FPARSER_TOO_BIG_FILE error code, 3104
ER_FRM_UNKNOWN_TYPE error code, 3104
ER_FSEEK_FAIL error code, 3106
ER_FT_MATCHING_KEY_NOT_FOUND error code, 3093
ER_FUNCTION_NOT_DEFINED error code, 3089
ER_FUNC_INEXISTENT_NAME_COLLISION error code, 3125
ER_GET_ERRMSG error code, 3101
ER_GET_ERRNO error code, 3082
ER_GET_TEMPORARY_ERRMSG error code, 3101
ER_GLOBAL_VARIABLE error code, 3096
ER_GOT_SIGNAL error code, 3085
ER_GRANT_PLUGIN_USER_EXISTS error code, 3131
ER_GRANT_WRONG_HOST_OR_USER error code, 3090
ER_HANDSHAKE_ERROR error code, 3082
ER_HASHCHK error code, 3079
ER_HOSTNAME error code, 3113
ER_HOST_IS_BLOCKED error code, 3089
ER_HOST_NOT_PRIVILEGED error code, 3089
ER_ILLEGAL_GRANT_FOR_TABLE error code, 3090
ER_ILLEGAL_HA error code, 3082
ER_ILLEGAL_HA_CREATE_OPTION error code, 3113
ER_ILLEGAL_REFERENCE error code, 3097
ER_ILLEGAL_VALUE_FOR_TYPE error code, 3106
ER_INCONSISTENT_PARTITION_INFO_ERROR error code, 3114
ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR error code, 3115
ER_INCORRECT_GLOBAL_LOCAL_VAR error code, 3097
ER_INDEX_COLUMN_TOO_LONG error code, 3132
ER_INDEX_CORRUPT error code, 3132
ER_INDEX_REBUILD error code, 3093
ER_INSERT_INFO error code, 3086
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT error code, 3129
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT error code, 3129
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN error code, 3130
ER_INVALID_CHARACTER_STRING error code, 3101
ER_INVALID_DEFAULT error code, 3084
ER_INVALID_GROUP_FUNC_USE error code, 3087
ER_INVALID_ON_UPDATE error code, 3101
ER_INVALID_USE_OF_NULL error code, 3089
ER_IO_ERR_LOG_INDEX_READ error code, 3106
ER_IPSOCK_ERROR error code, 3085
ER_KEY_COLUMN DOES NOT EXITS error code, 3085
ER_KEY_DOES NOT EXITS error code, 3092
ER_KEY_NOT_FOUND error code, 3082
ER_KEY_PART_0 error code, 3107
ER_KEY_REF_DO NOT MATCH_TABLE_REF error code, 3097
ER_KILL_DENIED_ERROR error code, 3086
ER_LIMITED_PART_RANGE error code, 3117
ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR error code, 3114
ER_LOAD_DATA_INVALID_COLUMN error code, 3123
ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR error code, 3108
ER_LOAD_INFO error code, 3086
ER_LOCAL_VARIABLE error code, 3096
ER_LOCK_ABORTED error code, 3130
ER_LOCK_DEADLOCK error code, 3095
ER_LOCK_OR_ACTIVE_TRANSACTION error code, 3093
ER_LOCK_TABLE_FULL error code, 3094
ER_LOCK_WAIT_TIMEOUT error code, 3094
ER_LOGGING_PROHIBIT_CHANGING_OF error code, 3107
ER_LOG_IN_USE error code, 3106
ER_LOG_PURGE_NO_FILE error code, 3123
ER_LOG_PURGE_UNKNOWN_ERR error code, 3106
ER_MALFORMED_DEFINER error code, 3111
ER_MASTER error code, 3093
ER_MASTER_FATAL_ERROR_READING_BINLOG error code, 3097
ER_MASTER_INFO error code, 3094
ER_MASTER_NET_READ error code, 3093
ER_MASTER_NET_WRITE error code, 3093
ER_MAXVALUE_IN_VALUES_IN error code, 3126
ER_MAX_PREPARED_STMT_COUNT_REACHED error code, 3112
ER_MESSAGE_AND_STATEMENT error code, 3128
ER_MISSNING_SKIP_SLAVE error code, 3100
ER_MIXING_NOT_ALLOWED error code, 3096
ER_MIX_HANDLER_ERROR error code, 3115
ER_MIX_OF_GROUP_FUNC_AND_FIELDS error code, 3090
ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR error code, 3115
ER_MULTIPLE_PRI_KEY error code, 3085
ER_MULTI_UPDATE_KEY_CONFLICT error code, 3132
ER_M_BIGGER_THAN_D error code, 3110
ER_NAME_BECOMES_EMPTY error code, 3113
ER_NATIVE_FCT_NAME_COLLISION error code, 3121
ER_NDB_CANT_SWITCH_BINLOG_FORMAT error code, 3120
ER_NDB_REPLICATION_SCHEMA_ERROR error code, 3124
ER_NEED_REPREPARE error code, 3124
ER_NET_ERROR_ON_WRITE error code, 3091
ER_NET_FCNTL_ERROR error code, 3091
ER_NET_PACKETS_OUT_OF_ORDER error code, 3091
ER_NET_PACKET_TOO_LARGE error code, 3090
ER_NET_READ_ERROR error code, 3091
ER_NET_READ_ERROR_FROM_PIPE error code, 3090
ER_NET_READ_INTERRUPTED error code, 3091
ER_NET_UNCOMPRESS_ERROR error code, 3091
ER_NET_WRITE_INTERRUPTED error code, 3091
ER_NEW_ABORTING_CONNECTION error code, 3091
ER_NISAMCHK error code, 3079
ER_NO error code, 3079
ER_NONEXISTING_GRANT error code, 3090
ER_NONEXISTING_PROC_GRANT error code, 3108
ER_NONEXISTING_TABLE_GRANT error code, 3090
ER_NONUNIQ_TABLE error code, 3084
ER_NONUPDATEABLE_COLUMN error code, 3104
ER_NON_GROUPING_FIELD_USED error code, 3112
ER_NON_INSERTABLE_TABLE error code, 3113
ER_NON_UNIQ_ERROR error code, 3083
ER_NON_UPDATABLE_TABLE error code, 3100
ER_NORMAL_SHUTDOWN error code, 3085
ER_NOT_ALLOWED_COMMAND error code, 3090
ER_NOT_FORM_FILE error code, 3082
ER_NOT_KEYFILE error code, 3082
ER_NOT_SUPPORTED_AUTH_MODE error code, 3098
ER_NOT_SUPPORTED_YET error code, 3097
ER_NO_BINARY_LOGGING error code, 3107
ER_NO_BINLOG_ERROR error code, 3116
ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR error code, 3114
ER_NO_DB_ERROR error code, 3083
ER_NO_DEFAULT error code, 3096
ER_NO_DEFAULT_FOR_FIELD error code, 3105
ER_NO_DEFAULT_FOR_VIEW_FIELD error code, 3109
ER_NO_FILE_MAPPING error code, 3107
ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT error code, 3123
ER_NO_GROUP_FOR_PROC error code, 3107
ER_NO_PARTITION_FOR_GIVEN_VALUE error code, 3117
ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT error code, 3122
ER_NO_PARTS_ERROR error code, 3115
ER_NO_PERMISSION_TO_CREATE_USER error code, 3095
ER_NO_RAID_COMPILED error code, 3092
ER_NO_REFERENCED_ROW error code, 3095
ER_NO_REFERENCED_ROW_2 error code, 3112
ER_NO_SUCH_INDEX error code, 3085
ER_NO_SUCH_TABLE error code, 3090
ER_ONLY_INTEGERS_ALLOWED error code, 3121
ER_OUTOFMEMORY error code, 3082
ER_PARSECOLUMN error code, 3084
ER_PARTITIONS_MUST_BE_DEFINED_ERROR error code, 3115
ER_PARTITION_COLUMN_LIST_ERROR error code, 3126
ER_PARTITION_CONST_DOMAIN_ERROR error code, 3120
ER_PARTITION_MAXVALUE_ERROR error code, 3114
ER_PARTITION_MGMT_ON_NONPARTITIONED error code, 3115
ER_PARTITION_NAME error code, 3125
ER_PARTITION_SUBPART_MIX_ERROR error code, 3114
ER_PARTITION_WRONG_NO_PART_ERROR error code, 3114
ER_PARTITION_WRONG_NO_SUBPART_ERROR error code, 3114
ER_PARTITION_WRONG_VALUES_ERROR error code, 3114
ER_PART_STATE_ERROR error code, 3117
ER_PASSWD_LENGTH error code, 3106
ER_PASSWORD_ANONYMOUS_USER error code, 3089
ER_PASSWORD_NOT_ALLOWED error code, 3089
ER_PASSWORD_NO_MATCH error code, 3089
ER_PATH_LENGTH error code, 3129
ER_PLUGIN_IS_NOT_LOADED error code, 3117
ER_PLUGIN_IS_PERMANENT error code, 3131
ER_PLUGIN_NO_INSTALL error code, 3133
ER_PLUGIN_NO_UNINSTALL error code, 3133
ER_PRIMARY_CANT_HAVE_NULL error code, 3092
ER_PROCACCESS_DENIED_ERROR error code, 3106
ER_PROC_AUTO_GRANT_FAIL error code, 3108
ER_PROC_AUTO_REVOKE_FAIL error code, 3108
ER_PS_MANY_PARAM error code, 3107
ER_PS_NO_RECURSION error code, 3111
ER_QUERY_CACHE_DISABLED error code, 3126
ER_QUERY_INTERRUPTED error code, 3102
ER_QUERY_ON_FOREIGN_DATA_SOURCE error code, 3110
ER_QUERY_ON_MASTER error code, 3096
ER_RANGE_NOT_INCREASING_ERROR error code, 3115
ER_RBR_NOT_AVAILABLE error code, 3120
ER_READY error code, 3085
ER_READ_ONLY_TRANSACTION error code, 3094
ER_RECORD_FILE_FULL error code, 3088
ER_REGEXP_ERROR error code, 3089
ER_RELAY_LOG_FAIL error code, 3106
ER_RELAY_LOG_INIT error code, 3106
ER_REMOVED_SPACES error code, 3113
ER_RENAMED_NAME error code, 3125
ER_REORG_HASH_ONLY_ON_SAME_NO error code, 3116
ER_REORG_NO_PARAM_ERROR error code, 3116
ER_REORG_OUTSIDE_RANGE error code, 3117
ER_REORG_PARTITION_NOT_EXIST error code, 3116
ER_REQUIRES_PRIMARY_KEY error code, 3092
ER_RESERVED_SYNTAX error code, 3107
ER_RESCALE WITHOUT_ACTIVE_HANDLER error code, 3126
ER_REVOKE_GRANTS error code, 3099
ER_ROW_IS_REFERENCED error code, 3095
ER_ROW_IS_REFERENCED_2 error code, 3111
ER_ROW_SINGLE_PARTITION_FIELD_ERROR error code, 3126
ERSAME_NAME_PARTITION error code, 3116
ER SAME_NAME_PARTITION error code, 3126
ER_SELECT_REduced error code, 3098
ER_SERVER_IS_IN_SECURE_AUTH_MODE error code, 3099
ER_SERVER_SHUTDOWN error code, 3083
ER_SET_CONSTANTS_ONLY error code, 3094
ER_SET_PASSWORD_AUTH_PLUGIN error code, 3131
ER_SHUTDOWN_COMPLETE error code, 3085
ER_SIGNAL_BAD_CONDITION_TYPE error code, 3126
ER_SIGNAL_EXCEPTION error code, 3126
ER_SIGNAL_NOT_FOUND error code, 3125
ER_SIGNAL_WARN error code, 3125
ER_SIZE_OVERFLOW_ERROR error code, 3117
ER_SLAVE_AMBIGOUS_EXEC_MODE error code, 3123
ER_SLAVE_CANT_CREATE_CONVERSION error code, 3129
ER_SLAVE_CONVERSION_FAILED error code, 3129
ER_SLAVE_CORRUPT_EVENT error code, 3123
ER_SLAVE_CREATE_EVENT_FAILURE error code, 3122
ER_SLAVE_FATAL_ERROR error code, 3122
ER_SLAVE_HEARTBEAT_FAILURE error code, 3124
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE error code, 3124
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX error code, 3131
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN error code, 3131
ER_SLAVE_IGNORED_SSL_PARAMS error code, 3099
ER_SLAVE_IGNORED_TABLE error code, 3097
ER_SLAVE_IGNORE_SERVER_IDS error code, 3126
ER_SLAVE_INCIDENT error code, 3122
ER_SLAVE_MASTER_COM_FAILURE error code, 3122
ER_SLAVE_MUST_STOP error code, 3094
ER_SLAVE_NOT_RUNNING error code, 3094
ER_SLAVE_RELAY_LOG_READ_FAILURE error code, 3122
ER_SLAVE_RELAY_LOG_WRITE_FAILURE error code, 3122
ER_SLAVE_THREAD error code, 3094
ER_SLAVE_WAS_NOT_RUNNING error code, 3098
ER_SLAVE_WAS_RUNNING error code, 3098
ER_SPATIAL_CANT_HAVE_NULL error code, 3098
ER_SPATIAL_MUST_HAVE_GEOM_COL error code, 3130
ER_SPECIFIC_ACCESS_DENIED_ERROR error code, 3096
ER_SP_ALREADY_EXISTS error code, 3101
ER_SP_BADRETURN error code, 3102
ER_SP_BADSELECT error code, 3102
ER_SP_BAD_CURSOR_QUERY error code, 3103
ER_SP_BAD_CURSOR_SELECT error code, 3103
ER_SP_BAD_SQLSTATE error code, 3108
ER_SP_BAD_VAR_SHADOW error code, 3112
ER_SP_CASE_NOT_FOUND error code, 3104
ER_SP_COND_MISMATCH error code, 3102
ER_SP_COND_MISMATCH error code, 3102
ER_SP_DOES_NOT_EXIST error code, 3104
ER_SP_DROP_FAILED error code, 3101
ER_SP_DUP_COND error code, 3103
ER_SP_DUP_CURS error code, 3103
ER_SP_DUP_HANDLER error code, 3109
ER_SP_DUP_CURS error code, 3103
ER_SP_DUP_HANDLER error code, 3109
ER_SP_DUP_PARAM error code, 3103
ER_SP_DUP_VAR error code, 3103
ER_SP_FETCH_NO_DATA error code, 3103
ER_SP_GOTO_IN_HNDLR error code, 3111
ER_SP_GOTO_IN_HNDLR error code, 3111
ER_SP_LABEL_MISMATCH error code, 3102
ER_SP_LABEL_REDEFINE error code, 3102
ER_SP_LILABEL_MISMATCH error code, 3102
ER_SP_LABEL_MISMATCH error code, 3102
ER_SP_LABEL_REDEFINE error code, 3102
ER_SP_LILABEL_MISMATCH error code, 3102
ER_SP_NORETURN error code, 3102
ER_SP_NORETURNEND error code, 3103
ER_SP_NOT_VAR_ARG error code, 3109
ER_SP_NO_AGGR error code, 3111
ER_SP_NO_DROP_SP error code, 3105
ER_SP_NO_RECURSION error code, 3109
ER_SP_NO_RECURSIVE_CREATE error code, 3101
ER_SP_NO_RECURSIVE_SET error code, 3109
ER_SP_PROC_TABLE_CORRUPT error code, 3112
ER_SP_REC error code, 3112
ER_SP_STORE_FAILED error code, 3102
ER_SP_SUBSELECT_NYI error code, 3103
ER_SP_UNDECLARED_VAR error code, 3103
ER_SP_UNINIT_VAR error code, 3102
ER_SP_VARCOND_AFTerror code, 3104
ER_SP_WRONG_NAME error code, 3112
ER_SP_WRONG_NO_OF_ARGS error code, 3102
ER_SP_WRONG_NO_OF_FETCH_ARGS error code, 3103
ER_SR_INVALID_CREATION_CTX error code, 3122
ER_STACK_OVERRUN error code, 3088
ER_STACK_OVERRUN_NEED_MORE error code, 3110
ER.Startup error code, 3108
ER_STMT_CACHE_FULL error code, 3132
ER_STMT_HAS_NO_OPEN_CURSOR error code, 3109
ER_STMT_NOT_ALLOWED_IN_SP error code, 3103
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT error code, 3130
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT error code, 3120
ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN error code, 3130
ER_SUBPARTITION_ERROR error code, 3115
ER_SUBPARTITION_NAME error code, 3125
ER_SUBQUERY_NO_1_ROW error code, 3097
ER_SYNTAX_ERROR error code, 3090
ER_TABLEACCESS_DENIED_ERROR error code, 3090
ER_TABLENAME_NOT_ALLOWED_HERE error code, 3098
ER_TABLESPACE_AUTO_EXTEND_ERROR error code, 3117
ER_TABLE_CANT_HANDLE_AUTO_INCREMENT error code, 3091
ER_TABLE_CANT_HANDLE_BLOB error code, 3091
ER_TABLE_CANT_HANDLE_FT error code, 3095
ER_TABLE_CANT_HANDLE_SPKEYS error code, 3112
ER_TABLE_DEF_CHANGED error code, 3109
ER_TABLE_EXISTS_ERROR error code, 3083
ER_TABLE_IN_FK_CHECK error code, 3134
ER_TABLE_MUST_HAVE_COLUMNS error code, 3088
ER_TABLE_NAME error code, 3125
ER_TABLE_NEEDS_REBUILD error code, 3132
ER_TABLE_NEEDS_UPGRADE error code, 3112
ER_TABLE_NOT_LOCKED error code, 3087
ER_TABLE_NOT_LOCKED_FOR_WRITE error code, 3087
ER_TEMPORARY_NAME error code, 3125
ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR error code, 3119
ER_TEXTFILE_NOT_READABLE error code, 3086
ER_TOO_BIG_DISPLAYWIDTH error code, 3111
ER_TOO_BIG_FIELDLENGTH error code, 3085
ER_TOO_BIG_FOR_UNCOMPRESS error code, 3098
ER_TOO_BIG_PRECISION error code, 3110
ER_TOO_BIG_ROWSIZE error code, 3088
ER_TOO_BIG_SCALE error code, 3110
ER_TOO_BIG_SELECT error code, 3087
ER_TOO_BIG_SET error code, 3086
ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT error code, 3113
ER_TOO_LONG_BODY error code, 3110
ER_TOO_LONG_FIELD_COMMENT error code, 3125
ER_TOO_LONG_IDENT error code, 3084
ER_TOO_LONG_INDEX_COMMENT error code, 3130
ER_TOO_LONG_KEY error code, 3085
ER_TOO_LONG_STRING error code, 3091
ER_TOO_LONG_TABLE_COMMENT error code, 3124
ER_TOO_MANY_CONCURRENT_TRXS error code, 3125
ER_TOO_MANY_DELAYED_THREADS error code, 3090
ER_TOO_MANY_FIELDS error code, 3088
ER_TOO_MANY_KEYS error code, 3085
ER_TOO_MANY_KEY_PARTS error code, 3085
ER_TOO_MANY_PARTITIONS_ERROR error code, 3115
ER_TOO_MANY_PARTITION_FUNC_FIELDS_ERROR error code, 3126
ER_TOO_MANY_ROWS error code, 3092
ER_TOO_MANY_TABLES error code, 3088
ER_TOO_MANY_USER_CONNECTIONS error code, 3094
ER_TOO_MANY_VALUES_ERROR error code, 3126
ER_TOO MUCH_AUTO_TIMESTAMP_COLS error code, 3101
ER_TRANS_CACHE_FULL error code, 3094
ER_TRG_ALREADY_EXISTS error code, 3105
ER_TRG_CANT_CHANGE_ROW error code, 3105
ER_TRG_CANT_OPEN_TABLE error code, 3123
ER_TRG_CORRUPTED_FILE error code, 3122
ER_TRG_DOES_NOT_EXIST error code, 3105
ER_TRG INVALID_CREATION_CTX error code, 3123
ER_TRG_IN_WRONG_SCHEMA error code, 3110
ER_TRG NO CREATION_CTX error code, 3123
ER_TRG NO DEFINER error code, 3112
ER_TRG NO SUCH_ROW_IN_TRG error code, 3105
ER_TRG ON VIEW OR TEMP_TABLE error code, 3105
ER_TRUNCATED WRONG_VALUE error code, 3101
ER_TRUNCATED WRONG_VALUE FOR FIELD error code, 3106
ER_TRUNCATE_ILLEGAL_FK error code, 3131
ER_UDF_EXISTS error code, 3088
ER_UDF NO PATHS error code, 3088
ER_UNDO_RECORD_TOO_BIG error code, 3132
ER_UNEXPECTED_EOF error code, 3082
ER UNION TABLES IN DIFFERENT_DIR error code, 3095
ER UNIQUE KEY NEED ALL_FIELDS_IN_PF error code, 3115
ER UNKNOWN CHARACTER_SET error code, 3088
ER UNKNOWN COLLATION error code, 3099
ER_UNKNOWN COM_ERROR error code, 3083
ER UNKNOWN ERROR error code, 3087
ER UNKNOWN KEY CACHE error code, 3100
ER UNKNOWN LOCALE error code, 3126
ER UNKNOWN PROCEDURE error code, 3087
ER UNKNOWN_STMT_HANDLER error code, 3097
ER_WARN_TOO_FEW_RECORDS error code, 3098
ER_WARN_TOO_MANY_RECORDS error code, 3098
ER_WARN_USING_OTHER_HANDLER error code, 3099
ER_WARN_VIEW_MERGE error code, 3105
ER_WARN_VIEW_WITHOUT_KEY error code, 3105
ER_WRONG_ARGUMENTS error code, 3095
ER_WRONG_AUTO_KEY error code, 3085
ER_WRONG_COLUMN_NAME error code, 3091
ER_WRONG_DB_NAME error code, 3087
ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR error code, 3114
ER_WRONG_FIELD_SPEC error code, 3084
ER_WRONG_FIELD_TERMINATORS error code, 3085
ER_WRONG_FIELD_WITHOUT_GROUP error code, 3084
ER_WRONG_FK_DEF error code, 3097
ER_WRONG_GROUP_FIELD error code, 3084
ER_WRONG_KEY_COLUMN error code, 3091
ER_WRONG_LOCK_OF_SYSTEM_TABLE error code, 3110
ER_WRONG_MAGIC error code, 3107
ER_WRONG_MRG_TABLE error code, 3091
ER_WRONG_NAME_FOR_CATALOG error code, 3100
ER_WRONG_NAME_FOR_INDEX error code, 3100
ER_WRONG_NATIVE_TABLE_STRUCTURE error code, 3129
ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT error code, 3096
ER_WRONG_OBJECT error code, 3104
ER_WRONG_OUTER_JOIN error code, 3088
ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT error code, 3121
ER_WRONG_PARAMCOUNT_TO_PROCEDURE error code, 3087
ER_WRONG_PARAMETERS_TO_NATIVE_FCT error code, 3121
ER_WRONG_PARAMETERS_TO_PROCEDURE error code, 3087
ER_WRONG_PARAMETERS_TO_STORED_FCT error code, 3121
ER_WRONG_PARTITION_NAME error code, 3120
ER_WRONG_PERFSHEMA_USAGE error code, 3129
ER_WRONG_SIZE_NUMBER error code, 3117
ER_WRONG_SPVAR_TYPE_IN_LIMIT error code, 3130
ER_WRONG_STRING_LENGTH error code, 3113
ER_WRONG_SUB_KEY error code, 3086
ER_WRONG_SUM_SELECT error code, 3084
ER_WRONG_TABLE_NAME error code, 3087
ER_WRONG_TYPE_COLUMN_VALUE_ERROR error code, 3126
ER_WRONG_TYPE_FOR_VAR error code, 3096
ER_WRONG_USAGE error code, 3096
ER_WRONG_VALUE error code, 3117
ER_WRONG_VALUE_COUNT error code, 3084
ER_WRONG_VALUE_COUNT_ON_ROW error code, 3089
ER_WRONG_VALUE_FOR_TYPE error code, 3109
ER_WRONG_VALUE_FOR_VAR error code, 3096
ER_WSAS_FAILED error code, 3107
ER_XAER_DUPID error code, 3111
ER_XAER_INVAL error code, 3108
ER_XAER_NOTA error code, 3108
ER_XAER_OUTSIDE error code, 3108
ER_XAER_RMERR error code, 3108
ER_XAER_RMFAIL error code, 3108
ER_XA_RBDEADLOCK error code, 3124
ER_XA_RBROLLBACK error code, 3108
ER_XA_RBTIMEOUT error code, 3123
ER_YES error code, 3079
ER_ZLIB_Z_BUF_ERROR error code, 3098
ER_ZLIB_Z_DATA_ERROR error code, 3098
ER_ZLIB_Z_MEM_ERROR error code, 3098
escape (\), 1031
escape sequences
  option files, 272
  strings, 1029
establishing encrypted connections, 796
estimating
  query performance, 972
event groups, 1568
event log format (NDB Cluster), 2459
event logs (NDB Cluster), 2456, 2458, 2458
EVENT privilege, 754
event scheduler, 2655
thread states, 1026
Event Scheduler, 2664
  altering events, 1387
  and MySQL privileges, 2669
  and mysqladmin debug, 2669
  and replication, 2095, 2096
  and SHOW PROCESSLIST, 2666
  concepts, 2665
  creating events, 1412
  dropping events, 1473
  enabling and disabling, 2666
  event metadata, 2668
  obtaining status information, 2669
  SQL statements, 2667
  starting and stopping, 2666
  time representation, 2668
event severity levels (NDB Cluster), 2459
event table
  system table, 671
event types (NDB Cluster), 2457, 2459
EventLogBufferSize, 2255
events, 2655, 2664
  altering, 1387
  creating, 1412
  dropping, 1473
  metadata, 2668
  restrictions, 2685
  status variables, 2671
EVENTS
  INFORMATION_SCHEMA table, 2670, 2700
events option
  mysql dump, 362
  events_waits_current table
    performance schema, 2794
events_waits_history table
    performance schema, 2796
events_waits_history_long table
  performance_schema, 2797
events_waits_summary_by_instance table
  performance_schema, 2797
events_waits_summary_by_thread_by_event_name table
  performance_schema, 2797
events_waits_summary_global_by_event_name table
  performance_schema, 2797
event_scheduler system variable, 545
eviction, 3753
exact-value literals, 1375
exact-value numeric literals, 1032, 1376
example option
  mysqld_multi, 299
example programs
  C API, 2824
EXAMPLE storage engine, 1887, 1923
examples
  compressed tables, 413
  myisamchk output, 402
  queries, 251
exceptions table
  NDB Cluster Replication, 2589
exclude-databases option
  ndb_restore, 2409
exclude-intermediate-sql-tables option
  ndb_restore, 2410
exclude-missing-columns option
  ndb_move_data, 2397
  ndb_restore, 2410
exclude-missing-tables option
  ndb_restore, 2410
exclude-tables option
  ndb_restore, 2410
exclusive lock, 1742, 3753
Execute
  thread command, 1014
EXECUTE, 1570, 1573
execute option
  mysql, 320
execute option (ndb_mgm), 2369
EXECUTE privilege, 755
ExecuteOnComputer, 2203, 2211, 2285
executing
  thread state, 1017
executing SQL statements from text files, 250, 334
Execution of init_command
  thread state, 1017
execution plan, 959
execution threads (NDB Cluster), 2266
EXISTS
  with subqueries, 1534
exit command
  mysql, 328
EXIT command (NDB Cluster), 2447
EXIT SINGLE USER MODE command (NDB Cluster), 2447
exit-info option
  mysqld, 510
EXP(), 1247
expire_logs_days system variable, 545
EXPLAIN, 959, 1691
EXPLAIN PARTITIONS, 2635, 2636
EXPLAIN used with partitioned tables, 2635
explicit default values, 1207
EXPORT_SET(), 1277
expression aliases, 1371, 1516
expression syntax, 1075
expressions
  extended, 243
extend-check option
  myisamchk, 399, 400
extended option
  mysqlcheck, 350
extended-insert option
  mysqldump, 362
extensions
to standard SQL, 23
extent, 3753
ExteriorRing(), 1358
external locking, 510, 599, 871, 997, 1019
external-locking option
  mysqld, 510
external_user system variable, 546
extra-file option
  my_print_defaults, 445
extra-node-info option
  ndb_desc, 2386
extra-partition-info option
  ndb_desc, 2386
EXTRACT(), 1260
extracting
dates, 240
ExtractValue(), 1319
ExtraSendBufferMemory
  API nodes, 2287
data nodes, 2278
management nodes, 2208

F
failover
  in NDB Cluster replication, 2570
  Java clients, 2119
FALSE, 1032, 1038
testing for, 1234, 1235
FAQs
  C API, 2943, 3065
  libmysql, 3065
Virtualization Support, 3073
Fast Index Creation, 3753
  concurrency, 1802
  crash recovery, 1803
  examples, 1801
  implementation, 1802
  limitations, 1803
  overview, 1801
fast option
  myisamchk, 399
  mysqlcheck, 350
fast shutdown, 3754
features of MySQL, 6
features, deprecated (see deprecated features)
features, new (see new features)
features, removed (see removed features)
FEDERATED storage engine, 1887, 1918
Fetch
  thread command, 1014
FETCH, 1583
field
  changing, 1396
Field List
  thread command, 1014
FIELD(), 1277
fields option
  ndb_config, 2375
fields-enclosed-by option
  mysqldump, 363, 375
  ndb_restore, 2412
fields-escaped-by option
  mysqldump, 363, 375
fields-optionally-enclosed-by option
  mysqldump, 363, 375
  ndb_restore, 2412
fields-terminated-by option
  mysqldump, 363, 375
  ndb_restore, 2412
FILE, 1279
file format, 1788, 3754
  Antelope, 1784
  Barracuda, 1777
  downgrading, 1792
  identifying, 1791
file format management
  downgrading, 1707
FILE privilege, 755
file-per-table, 3754
files
  binary log, 679
  created by CREATE TABLE, 1452
  DDL log, 692
  error messages, 1138
  general query log, 677
log, 692
metadata log, 692
not found message, 3158
permissions, 3157
repairing, 400
script, 250
size limits, 943
slow query log, 690
text, 334, 372
tmp, 193

FILES
  INFORMATION_SCHEMA table, 2749
filesort optimization, 904
FileSystemPath, 2214
FileSystemPathDataFiles, 2275
FileSystemPathDD, 2274
FileSystemPathUndoFiles, 2275
file_instances table
    performance_schema, 2790
file_summary_by_event_name table
    performance_schema, 2799
file_summary_by_instance table
    performance_schema, 2799
fill factor, 1733, 3754
fill_help_tables.sql, 667
FIND_IN_SET(), 1278
Finished reading one binlog; switching to next binlog
    thread state, 1023
firewalls (software)
    and NDB Cluster, 2511, 2513
fix-db-names option
    mysqlcheck, 350
fix-table-names option
    mysqlcheck, 350
FIXED data type, 1161
fixed row format, 3754
fixed-point arithmetic, 1375
FLOAT data type, 1161, 1161, 1161
floating-point number, 1161
floating-point values
    and replication, 2093
floats, 1032
FLOOR(), 1247
FLUSH
    and replication, 2093
flush, 3755
flush list, 3755
flush option
    mysql, 511
FLUSH statement, 1684
flush system variable, 546
flush tables, 340
flush-logs option
    mysqldump, 363
flush-privileges option
   mysqldump, 363
flushing, 1768
flushlog option
   mysqlhotcopy, 437
flush_time system variable, 546
FOR UPDATE, 1519
FORCE
   plugin activation option, 697
FORCE INDEX, 975, 3173
FORCE KEY, 975
force option
   myisamchk, 400, 401
   myisampack, 412
   mysql, 320
   mysqladmin, 343
   mysqlcheck, 351
   mysqldump, 363
   mysqlimport, 375
   mysql_convert_table_format, 439
   mysql_install_db, 304
   mysql_upgrade, 312
force-if-open option
   mysqldbinlog, 425
force-read option
   mysqldbinlog, 425
FORCE_PLUS_PERMANENT
   plugin activation option, 697
foreign key, 3755
   constraint, 30, 30
   deleting, 1399, 1460
FOREIGN KEY constraint, 3755
foreign key constraints, 1457
FOREIGN KEY constraints
   and fast index creation, 1803
foreign keys, 28, 254, 1399
foreign_key_checks system variable, 547
FORMAT(), 1278
forums, 18
FOUND_ROWS(), 1341
FRAC_SECOND
   removed features, 15
FragmentLogFileSize, 2228
FreeBSD troubleshooting, 189
freeing items
   thread state, 1017
frequently-asked questions about NDB Cluster, 3039
   .frm file, 3753
FROM, 1516
FROM_DAYS(), 1260
FROM_UNIXTIME(), 1260
tf option (ndb_error_reporter), 2389
FTS, 3755
ft_boolean_syntax system variable, 548
ft_max_word_len myisamchk variable, 398
ft_max_word_len system variable, 548
ft_min_word_len myisamchk variable, 398
ft_min_word_len system variable, 548
ft_query_expansion_limit system variable, 549
ft_stopword_file myisamchk variable, 398
ft_stopword_file system variable, 549
full backup, 3755
full disk, 3163
full table scan, 3756
full table scans
  avoiding, 913
full-text parser plugins, 2950
full-text queries
  optimization, 928, 950
full-text search, 1296, 3756
FULLTEXT, 1296
fulltext
  stopword list, 1307
FULLTEXT index, 3756
FULLTEXT initialization
  thread state, 1017
fulltext join type
  optimizer, 964
func table
  system table, 671
function
  creating, 1627
deleting, 1628
function names
  parsing, 1046
  resolving ambiguity, 1046
functions, 1216
  adding, 2996
  and replication, 2093
arithmetic, 1328
bit, 1328
C API, 2834
cast, 1310
case, 1310
control flow, 1239
date and time, 1253
encryption, 1329
for SELECT and WHERE clauses, 1216
GROUP BY, 1362
grouping, 1230
information, 1338
locking, 1336
mathematical, 1245
miscellaneous, 1371
native
  adding, 3007
prepared statement C API, 2898, 2899
stored, 2657
string, 1273
string comparison, 1285
user-defined, 1627, 1628, 2996
    adding, 2997
fuzzy checkpointing, 3756

G
GA, 3756
    MySQL releases, 44
gap, 3756
gap event, 2557
gap lock, 1742, 3756
    InnoDB, 1757, 1825
gb2312, gbk, 3052
gci option
    ndb_select_all, 2428
gci64 option
    ndb_select_all, 2428
GCP Stop errors (NDB Cluster), 2278
gdb
    using, 3012
gdb option
    mysql, 511
general information, 1
General Public License, 5
general query log, 677, 3757
general tablespace, 3757
general_log system variable, 550
general_log table
    system table, 671
general_log_file system variable, 550
gеographic feature, 1192
GeomCollFromText(), 1351
GeomCollFromWKB(), 1352
geometry, 1192
GEOMETRY data type, 1193
geometry values
    internal storage format, 1202
    WKB format, 1201
    WKT format, 1200
GEOMETRYCOLLECTION data type, 1193
GeometryCollection(), 1352
GeometryCollectionFromText(), 1351
GeometryCollectionFromWKB(), 1352
GeometryFromText(), 1351
GeometryFromWKB(), 1352
GeometryN(), 1359
GeometryType(), 1354
GeomFromText(), 1351
GeomFromWKB(), 1352
geospatial feature, 1192
German dictionary collation, 1086, 1130, 1130
German phone book collation, 1086, 1130, 1130
getting MySQL, 45
GET_FORMAT(), 1261
GET_LOCK(), 1336
GIS, 1191
GIS data types
  storage requirements, 1213
Git tree, 173
GLength(), 1355
GLOBAL
  SET statement, 1630
  global privileges, 1603, 1615
  global transaction, 3757
GLOBAL_STATUS
  INFORMATION_SCHEMA table, 2704
GLOBAL_VARIABLES
  INFORMATION_SCHEMA table, 2704
go command
  mysql, 328
Google Test, 183
got handler lock
  thread state, 1022
got old table
  thread state, 1022
GRANT OPTION privilege, 755
GRANT statement, 772, 1603
grant table distribution (NDB Cluster), 2539
grant tables
  columns_priv table, 671, 759
  db table, 199, 671, 759
  host table, 671, 759
  procs_priv table, 671, 759
  proxies_priv, 783
  proxies_priv table, 199, 671, 759
  re-creating, 194
  sorting, 768, 770
  structure, 758
  tables_priv table, 671, 759
  user table, 199, 671, 759
granting
  privileges, 1603
grants
  display, 1654
greater than (>), 1232
greater than or equal (>=), 1232
greatest timestamp wins (conflict resolution), 2586
greatest timestamp, delete wins (conflict resolution), 2587
GREATEST(), 1233
Group (NDB Cluster), 2343
GROUP BY
  aliases in, 1371
  extensions to standard SQL, 1370, 1517
  implicit sorting, 904
  maximum sort length, 1517
  WITH ROLLUP, 1366
GROUP BY functions, 1362
GROUP BY optimizing, 906
GROUP BY sorting
  deprecated features, 14
group commit, 1740, 3757
grouping
  expressions, 1230
GROUP_CONCAT(), 1364
group_concat_max_len system variable, 550

H
HANDLER, 1484
Handlers, 1586
handling
  errors, 3004
hash index, 3757
hash indexes, 932
hash partitioning, 2614
hash partitions
  managing, 2633
  splitting and merging, 2633
have_compress system variable, 551
have_crypt system variable, 551
have_csv system variable, 551
have_dynamic_loading system variable, 551
have_geometry system variable, 551
have_innodb system variable, 551
have_openssl system variable, 551
have_partitioning system variable, 551
have_profiling system variable, 551
have_query_cache system variable, 551
have_rtree_keys system variable, 551
have_ssl system variable, 552
have_symlink system variable, 552
HAVING, 1517
HDD, 3757
header option
  ndb_select_all, 2427
header-file option
  comp_err, 302
HEAP storage engine, 1887, 1902
heartbeat, 3758
HeartbeatIntervalDbApi, 2243
HeartbeatIntervalDbDb, 2242
HeartbeatIntervalMgmdMgmd
  management nodes, 2208
HeartbeatOrder, 2244
HeartbeatThreadPriority, 2207, 2288
help command
  mysql, 326
HELP command (NDB Cluster), 2444
help option
  comp_err, 302
  myisamchk, 396
myisampack, 412
myisam_ftdump, 392
mysql, 317
mysqlaccess, 418
mysqladmin, 342
mysqlbinlog, 422
mysqlcheck, 348
mysqld, 505
mysqldump, 359
mysqldumpslow, 435
mysqld_multi, 299
mysqld_safe, 291
mysqlhotcopy, 437
mysqlimport, 374
MySQLInstallerConsole, 91
mysqlshow, 380
mysqlslap, 386
mysql_convert_table_format, 439
mysql_find_rows, 440
mysql_install_db, 304
mysql_plugin, 306
mysql_setpermission, 441
mysql_upgrade, 311
mysql_waitpid, 442
my_print_defaults, 445
perror, 447
resolveip, 448
resolve_stack_dump, 446
HELP option
    myisamchk, 396
help option (NDB Cluster programs), 2439
HELP statement, 1693
help tables
    system tables, 671
help_category table
    system table, 672
help_keyword table
    system table, 672
help_relation table
    system table, 672
help_topic table
    system table, 672
hex option
    ndb_restore, 2412
HEX(), 1248, 1278
hex-blob option
    mysql_dump, 363
hexadecimal literal introducer, 1035
hexadecimal literals, 1034
hexdump option
    mysqlbinlog, 426
high-water mark, 3758
HIGH_NOT_PRECEDENCE SQL mode, 652
HIGH_PRIORITY
INSERT modifier, 1489
SELECT modifier, 1519
hints, 24
   index, 975, 1516
history list, 3758
history of MySQL, 8
hole punching, 3758
HOME environment variable, 331, 449
host name
   default, 285
host name caching, 1009
host name resolution, 1009
host names, 285
   in account names, 765
   in default accounts, 199
host option, 281
   mysql, 320
   mysqlaccess, 419
   mysqladmin, 343
   mysqlbinlog, 426
   mysqlcheck, 351
   mysqldump, 363
   mysqlhotcopy, 437
   mysqlimport, 375
   mysqlshow, 381
   mysqlslap, 388
   mysql_convert_table_format, 439
   mysql_setpermission, 441
   mysql_upgrade, 312
   ndb_config, 2376
host table, 771
   sorting, 770
   system table, 671, 759
Host*SciId* parameters, 2344
HostName, 2204, 2211, 2285
HostName (NDB Cluster), 2510
hostname system variable, 552
HostName1, 2333, 2339, 2345
HostName2, 2334, 2339, 2345
hot, 3758
hot backup, 3758
HOUR(), 1262
howto option
   mysqlaccess, 419
html option
   mysql, 320

i-am-a-dummy option
   mysql, 323
ib-file set, 1788, 3759
ibbackup_logfile, 3759
.ibd file, 3758
include-master-host-port option
  mysqlldump, 363
include-tables option
  ndbd_restore, 2413
increasing with replication
  speed, 1991
incremental backup, 3760
incremental recovery, 868
  using NDB Cluster replication, 2577
index, 3761
  deleting, 1398, 1473
  rebuilding, 216
index cache, 3761
index condition pushdown, 3761
INDEX DIRECTORY
  and replication, 2092
index dives (for statistics estimation), 1775
index hint, 3761
index hints, 975, 1516
index join type
  optimizer, 965
index prefix, 3761
INDEX privilege, 755
index statistics
  NDB, 2280
index-record lock
  InnoDB, 1757, 1825
indexes, 1417
  and BLOB columns, 928, 1433
  and IS NULL, 933
  and LIKE, 932
  and ndbd_restore, 2418
  and NULL values, 1434
  and TEXT columns, 928, 1433
  assigning to key cache, 1682
  BLOB columns, 1418
  block size, 555
  column prefixes, 928
  columns, 928
  creating and dropping, 1802
  leftmost prefix of, 926, 930
  multi-column, 929
  multiple-part, 1417
  names, 1038
  primary (clustered) and secondary, 1802
  TEXT columns, 1418
  TIMESTAMP lookups, 934
  use of, 926
IndexMemory, 2216
IndexStatAutoCreate
  data nodes, 2280
IndexStatAutoUpdate
  data nodes, 2281
IndexStatSaveScale
data nodes, 2282
IndexStatSaveSize
data nodes, 2281
IndexStatTriggerPct
data nodes, 2282
IndexStatTriggerScale
data nodes, 2282
IndexStatUpdateDelay
data nodes, 2283
index_merge join type
  optimizer, 964
index_subquery join type
  optimizer, 964
INET_ATON(), 1371
INET_NTOA(), 1372
infimum record, 3761
INFO Events (NDB Cluster), 2463
information functions, 1338
information option
  myisamchk, 400
INFORMATION_SCHEMA
  InnoDB tables, 1844
INFORMATION_SCHEMA, 2691, 3762
  and security issues, 2515
  collation and searching, 1116
  InnoDB tables, 2731
INNODB_CMP table, 1845
INNODB_CMPMEM table, 1845
INNODB_CMPMEM_RESET table, 1845
INNODB_CMP_RESET table, 1845
INNODB_LOCKS table, 1846
INNODB_LOCK_WAITS table, 1846
INNODB_TRX table, 1846
NDB Cluster tables, 2749
Thread pool tables, 2756
INFORMATION_SCHEMA plugins, 2951
INFORMATION_SCHEMA queries
  optimization, 918
INFORMATION_SCHEMA.ENGINES table
  and NDB Cluster, 2484
INFORMATION_SCHEMA.GLOBAL_STATUS table
  and NDB Cluster, 2486
INFORMATION_SCHEMA.GLOBAL_VARIABLES table
  and NDB Cluster, 2485
init
  thread state, 1017
Init DB
  thread command, 1014
init-command option
  mysql, 320
InitFragmentLogFiles, 2228
initial option (ndbd), 2352
initial option (ndbmtd), 2352
initial option (ndb_mgmd), 2363
initial-start option (ndbd), 2353
initial-start option (ndbmtd), 2353
Initialized
  thread state, 1027
InitialLogFileGroup, 2276
InitialNoOfFile group, 2229
InitialTablespace, 2277
init_connect system variable, 552
init_file system variable, 553
init_slave system variable, 2029
INNER JOIN, 1522
innochecksum, 264, 391
InnoDB, 1698, 3762
  .frm files, 1719
    adaptive hash index, 1718
  and application feature requirements, 2133
  application performance, 1726
  applications supported, 2133
  architecture, 1709
  asynchronous I/O, 1772
  auto-inc lock, 1742
  auto-increment columns, 1726
  autocommit mode, 1749, 1749
  availability, 2131
  backups, 1874
  change buffer, 1715
  checkpoints, 1799
  clustered index, 1733
  COMPACT row format, 1794
  compared to NDB Cluster, 2131, 2131, 2133, 2133
  configuration parameters, 1804
  consistent reads, 1750
  corruption, 1875
  crash recovery, 1875, 1876
  creating tables, 1719
  data files, 1734
  deadlock detection, 1759
  deadlock example, 1758
  deadlocks, 1723, 1758, 1760
  disk failure, 1875
  disk I/O, 1797
  disk I/O optimization, 951
  DYNAMIC row format, 1796, 1796
  exclusive lock, 1742
  file space management, 1798
  file-per-table tablespace, 1737
  files, 1726
  gap lock, 1742, 1757, 1825
  in-memory structures, 1710
  index-record lock, 1757, 1825
  insert-intention lock, 1742
  intention lock, 1742
  limitations, 1885
  limits, 1884
Linux, 1772
lock modes, 1742
locking, 1741, 1742, 1754
locking reads, 1752
log files, 1740
memory usage, 1722
migrating tables, 1721
Monitors, 1799, 1875, 1879
multi-versioning, 1708
new features, 10
next-key lock, 1742, 1757, 1825
NFS, 1762
on-disk structures, 1719
page size, 1733
physical index structure, 1733
point-in-time recovery, 1875
primary keys, 1720, 1725
raw partitions, 1736
record-level locks, 1757, 1825
recovery, 1875
redo log, 1739
REDUNDANT row format, 1793
replication, 1877
restrictions, 1885
row format, 1720, 1797
secondary index, 1733
semi-consistent read, 1825
shared lock, 1742
Solaris issues, 163
storage, 1725
storage layout, 1723
system variables, 1804
table properties, 1720
tables, 1719
converting from other storage engines, 1722
transaction model, 1741, 1746
transactions, 1722
transferring data, 1724
troubleshooting, 1879
CREATE TABLE failure, 1882
data dictionary problems, 1881
deadlocks, 1758, 1759
defragmenting tables, 1800
fast index creation, 1803
I/O problems, 1879
open file error, 1882
orphan temporary tables, 1882
performance problems, 947
recovery problems, 1880
SQL errors, 1883
tablespace does not exist, 1883
InnoDB buffer pool, 978, 1712, 1766, 1767
InnoDB I/O subsystem
new features, 10
InnoDB Monitors, 1860
  enabling, 1861
  output, 1863
innodb option
  mysqlld, 1808
InnoDB parameters, deprecated
  innodb_file_io_threads, 1771
InnoDB parameters, new
  innodb_file_format_check, 1790
  innodb_large_prefix, 1824
InnoDB storage engine, 1698, 1887
  compatibility, 1702
InnoDB tables
  storage requirements, 1209
innodb-status-file option
  mysqlld, 1808
innodb_system variable
  innodb rollback_segments, 1835
innodb_adaptive_flushing system variable, 1809
innodb_adaptive_hash_index
  and innodb_thread_concurrency, 1770
  new features, 12
innodb_adaptive_hash_index system variable, 1809
innodb_additional_mem_pool_size system variable, 1810
  and innodb_use_sys_malloc, 1769
innodb_autoextend_increment system variable, 1810
innodb_autoinc_lock_mode, 3762
innodb_autoinc_lock_mode system variable, 1811
INNODB_BUFFER_PAGE
  INFORMATION_SCHEMA table, 2731
INNODB_BUFFER_PAGE_LRU
  INFORMATION_SCHEMA table, 2734
innodb_buffer_pool_instances system variable, 1811
Innodb_buffer_pool_read_ahead_rnd
  removed features, 15
Innodb_buffer_pool_read_ahead_seq
  removed features, 15
innodb_buffer_pool_size system variable, 1812
INNODB_BUFFER_POOL_STATS
  INFORMATION_SCHEMA table, 2737
innodb_change_buffering, 1716
innodb_change_buffering system variable, 1813
innodb_change_buffering_debug, 1813
innodb_checksums system variable, 1814
INNODB_CMP
  INFORMATION_SCHEMA table, 2741
INNODB_CMPMEM
  INFORMATION_SCHEMA table, 2742
INNODB_CMPMEM_RESET
  INFORMATION_SCHEMA table, 2742
INNODB_CMP_RESET
  INFORMATION_SCHEMA table, 2741
innodb_commit_concurrency system variable, 1814
innodb_concurrency_tickets, 1770
innodb_concurrency_tickets system variable, 1814
innodb_data_file_path system variable, 1815
innodb_data_home_dir system variable, 1816
innodb_doublewrite system variable, 1816
innodb_fast_shutdown system variable, 1817
innodb_file_format, 1788, 3762
Antelope, 1784
Barracuda, 1777
downgrading, 1707
identifying, 1791
innodb_file_format system variable, 1817
innodb_file_format_check, 1790
innodb_file_format_check system variable, 1818
innodb_file_format_max system variable, 1818
innodb_file_io_threads, 1771
innodb_file_per_table, 1777, 3762
new features, 12
innodb_file_per_table system variable, 1819
innodb_flush_log_at_trx_commit system variable, 1819
innodb_flush_method system variable, 1820
innodb_force_load_corrupted system variable, 1822
innodb_force_recovery system variable, 1823
innodb_io_capacity, 1772
innodb_io_capacity system variable, 1823
innodb_large_prefix system variable, 1824
innodb_limit_optimistic_insert_debug, 1824
INNODB_LOCKS
INFORMATION_SCHEMA table, 2743
innodb_locks_unsafe_for_binlog system variable, 1825
INNODB_LOCK_WAITS
INFORMATION_SCHEMA table, 2745
innodb_lock_wait_timeout, 3763
new features, 12
innodb_lock_wait_timeout system variable, 1824
innodb_log_buffer_size system variable, 1827
innodb_log_files_in_group system variable, 1828
innodb_log_file_size system variable, 1828
innodb_log_group_home_dir system variable, 1829
innodb_max_dirty_pages_pct system variable, 1829
innodb_max_purge_lag system variable, 1830
innodb_mirrored_log_groups system variable, 1830
innodb_old_blocks_pct, 1766
innodb_old_blocks_pct system variable, 1830
innodb_old_blocks_time, 1766
innodb_old_blocks_time system variable, 1830
innodb_open_files system variable, 1831
innodb_print_all_deadlocks system variable, 1831
innodb_print_all_deadlocks, 1831
innodb_purge_batch_size system variable, 1832
innodb_purge_threads system variable, 1832
innodb_random_read_ahead system variable, 1833
innodb_read_ahead_threshold, 1767
innodb_read_ahead_threshold system variable, 1833
innodb_read_io_threads, 1771
innodb_read_io_threads system variable, 1834
innodb_replication_delay system variable, 1834
innodb_rollback_on_timeout system variable, 1835
innodb_rollback_segments system variable, 1835
innodb_spin_wait_delay, 1773
innodb_spin_wait_delay system variable, 1836
innodb_stats_method system variable, 1836
innodb_stats_on_metadata
  new features, 12
innodb_stats_on_metadata system variable, 1837
innodb_stats_sample_pages, 1775
innodb_stats_sample_pages system variable, 1837
innodb_strict_mode, 945, 3763
innodb_strict_mode system variable, 1838
innodb_support_xa system variable, 1839
innodb_sync_spin_loops system variable, 1839
innodb_table_locks system variable, 1839
innodb_thread_concurrency, 1770
innodb_thread_concurrency system variable, 1840
innodb_thread_sleep_delay, 1770
innodb_thread_sleep_delay system variable, 1841
INNODB_TRX
  INFORMATION_SCHEMA table, 2746
innodb_trx_purge_view_update_only_debug, 1842
innodb_trx_rseg_n_slots_debug, 1843
innodb_use_native_aio, 1772
  new features, 11
innodb_use_native_aio system variable, 1842
innodb_use_sys_malloc
  and innodb_thread_concurrency, 1770
innodb_use_sys_malloc system variable, 1769, 1843
innodb_version system variable, 1843
innodb_write_io_threads, 1771
innodb_write_io_threads system variable, 1843
INOUT parameter
  condition handling, 1600
INSERT, 924, 1485
insert, 3763
  thread state, 1022
INSERT ... SELECT, 1489
insert buffer, 3763
insert buffering, 3763
disabling, 1716
INSERT DELAYED, 1492, 1492
insert intention lock, 3763
INSERT privilege, 755
INSERT(), 1278
insert-ignore option
  mysqldump, 364
insert-intention lock, 1742
insertable views
  insertable, 2674
inserting
  speed of, 924
inserts
  concurrent, 991, 993
insert_id system variable, 553
install option
  mysql, 511
  MySQLInstallerConsole, 91
install option (ndbd), 2353
install option (ndbmtd), 2353
install option (ndb_mgmd), 2363
INSTALL PLUGIN statement, 1628
install-manual option
  mysql, 512
Installation, 90
installation layouts, 59
installation overview, 166
installing
  binary distribution, 59
  Linux RPM packages, 147
  OS X DMG packages, 132
  overview, 42
  Perl, 223
  Perl on Windows, 224
  Solaris PKG packages, 163
  source distribution, 166
  user-defined functions, 3005
installing NDB Cluster, 2146
  Debian Linux, 2153
  Linux, 2148
  Linux binary release, 2149
  Linux RPM, 2151
  Linux source release, 2153
  Ubuntu Linux, 2153
  Windows, 2155
  Windows binary release, 2155
  Windows source, 2158
installing plugins, 694, 1628
installing UDFs, 705
INSTALL_BINDIR option
  CMake, 180
INSTALL_DOCDIR option
  CMake, 180
INSTALL_DOCREADMEDIR option
  CMake, 180
INSTALL_INCLUDEDIR option
  CMake, 180
INSTALL_INFODIR option
  CMake, 180
INSTALL_LAYOUT option
  CMake, 180
INSTALL_LIBDIR option
  CMake, 180
INSTALL_MANDIR option
  CMake, 180
INSTALL_MYSQLSHAREDIR option
invisible index, 1417
INVOKER privileges, 1655, 2676
IOPS, 3764
IP addresses
  in account names, 765
  in default accounts, 199
IPv6 addresses
  in account names, 765
  in default accounts, 199
IPv6 connections, 199, 599
IPv6 support
  new features, 13
IS boolean_value, 1234
IS NOT boolean_value, 1235
IS NOT DISTINCT FROM operator, 1231
IS NOT NULL, 1235
IS NULL, 901, 1235
  and indexes, 933
IsClosed(), 1356
IsEmpty(), 1354
.isl file, 3759
ISNULL(), 1235
ISOLATION LEVEL, 1555
isolation level, 1746, 3764
IsSimple(), 1354
IS_FREE_LOCK(), 1337
IS_USED_LOCK(), 1337
ITERATE, 1580
iterations option
  mysqlslap, 388

J
Japanese character sets
  conversion, 3052
Japanese, Korean, Chinese character sets
  frequently asked questions, 3052
Java, 2816
JDBC, 2813
jdbc:mysql:loadbalance://, 2119
join, 3764
  nested-loop algorithm, 895
JOIN, 1522
join algorithm
  Block Nested-Loop, 891
  Nested-Loop, 891
join option
  myisampack, 412
join type
  ALL, 965
  const, 963
  eq_ref, 963
  fulltext, 964
  index, 965
index_merge, 964
index_subquery, 964
range, 965
ref, 964
ref_or_null, 964
system, 963
unique_subquery, 964
joins
USING versus ON, 1527
join_buffer_size system variable, 554

K
keepold option
mysqlhotcopy, 438
keep_files_on_create system variable, 554
Key cache
MyISAM, 978
key cache
assigning indexes to, 1682
key partitioning, 2617
key partitions
managing, 2633
splitting and merging, 2633
key space
MyISAM, 1898
key-value store, 933
keys, 928
foreign, 28, 254
multi-column, 929
searching on two, 256
keys option
mysqlshow, 381
keys-used option
myisamchk, 401
keywords, 1060
KEY_BLOCK_SIZE, 1777, 1781, 3765
key_buffer_size myisamchk variable, 398
key_buffer_size system variable, 555
key_cache_age_threshold system variable, 556
key_cache_block_size system variable, 557
key_cache_division_limit system variable, 557
KEY_COLUMN_USAGE
INFORMATION_SCHEMA table, 2705
Kill
thread command, 1014
KILL statement, 1688
Killed
thread state, 1017
Killing slave
thread state, 1025
known errors, 3174
Korean, 3052
Korean, Chinese, Japanese character sets
frequently asked questions, 3052

L
labels
  stored program block, 1575
language
  removed features, 14
language option
  mysqld, 512
language support
  error messages, 1138
language system variable, 557
lap option
  ndb_redo_log_reader, 2402
large page support, 1005
large tables
  NDB Cluster, 1442
large-pages option
  mysqld, 512
large_files_support system variable, 558
large_pages system variable, 558
large_page_size system variable, 558
last row
  unique ID, 2944
LAST_DAY(), 1262
last_insert_id system variable, 559
LAST_INSERT_ID(), 1343, 1488, 2944
  and replication, 2083
  and stored routines, 2659
  and triggers, 2659
latch, 3765
LateAlloc, 2235
layout of installation, 59
lc-messages option
  mysqld, 513
lc-messages-dir option
  mysqld, 513
LCASE(), 1279
LcpScanProgressTimeout, 2230
lc_messages system variable, 559
lc_messages_dir system variable, 559
lc_time_names system variable, 559
ldata option
  mysql_install_db, 304
LDML syntax, 1149
LD_LIBRARY_PATH environment variable, 225, 2828
LD_RUN_PATH environment variable, 225, 449
LEAST(), 1236
LEAVE, 1580
ledir option
  mysqld_safe, 292
LEFT JOIN, 898, 1522
LEFT OUTER JOIN, 1522
LEFT(), 1279
leftmost prefix of indexes, 926, 930
legal names, 1038
length option
  myisam_ftdump, 393
LENGTH(), 1279
less than (<), 1232
less than or equal (<=), 1232
libmysql
  FAQ, 3065
libmysqlclient library, 2813
libmysqld, 2817
  options, 2818
libmysqld library, 2813
libmysqld-libs option
  mysql_config, 444
LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN environment variable, 449
LIBMYSQL_PLUGINS environment variable, 2931
library
  libmysqlclient, 2813
  libmysqld, 2813
libs option
  mysql_config, 444
libs_r option
  mysql_config, 444
license system variable, 559
LIKE, 1286
  and indexes, 932
  and wildcards, 932
LIMIT, 1341, 1518
  and replication, 2097
  optimizations, 909
limitations
  InnoDB, 1885
  replication, 2083
limitations of NDB Cluster, 2134
limits
  file-size, 943
  InnoDB, 1884
    maximum columns per table, 944
    maximum number of databases, 943, 1412
    maximum number of tables, 943, 1432
    maximum row size, 945
    maximum tables per join, 1524
    maximum tables per view, 2688
    table size, 943
line-numbers option
  mysql, 320
linear hash partitioning, 2616
linear key partitioning, 2618
linefeed (\n), 1030, 1500
LineFromText(), 1351
LineFromWKB(), 1352
lines-terminated-by option
    mysql, 364, 376
    ndb_restore, 2414
LINESTRING data type, 1193
LineString(), 1352
LineStringFromText(), 1351
LineStringFromWKB(), 1352
linking, 2824
    errors, 2826
    problems, 2826
links
    symbolic, 1000
list, 3765
list option
    MySQLInstallerConsole, 92
list partitioning, 2604, 2606
list partitions
    adding and dropping, 2627
    managing, 2627
literals, 1029
    bit value, 1036
    boolean, 1038
    date, 1032
    hexadecimal, 1034
    numeric, 1032
    string, 1029
    time, 1032
LN(), 1248
LOAD DATA, 1494, 3169
    and replication, 2097
LOAD DATA FROM MASTER
    removed features, 15
load emulation, 383
LOAD INDEX INTO CACHE
    and partitioning, 2644
LOAD TABLE ... FROM MASTER
    removed features, 15
LOAD XML, 1504
    new features, 13
loading
    tables, 235
LOAD_FILE(), 1279
local option
    mysqlimport, 376
local-infile option
    mysql, 320
local-load option
    mysqlbinlog, 426
local-service option
    mysql, 514
localhost
    special treatment of, 286
LOCALTIME, 1262
LOCALTIMESTAMP, 1262
local_infile system variable, 560
LOCATE(), 1280
lock, 3765
lock escalation, 3765
LOCK IN SHARE MODE, 1519
lock mode, 3765
Lock Monitor, 1860, 1863
lock option
   ndb_select_all, 2427
LOCK TABLES, 1550
LOCK TABLES privilege, 755
lock-all-tables option
   mysqlimport, 376
lock-tables option
   mysqlimport, 376
locked_in_memory system variable, 561
LockExecuteThreadToCPu, 2263
locking, 998, 1741, 3766
   external, 510, 599, 871, 997, 1019
   information schema, 1844, 1846
   InnoDB, 1742
   internal, 990
   metadata, 994
   row-level, 990
   table-level, 990
locking functions, 1336
locking methods, 990
locking read, 3766
LockMaintThreadsToCPU, 2263
LockPagesInMainMemory, 2236
lock_wait_timeout system variable, 560
log, 3766
log buffer, 3766
log file, 3766
log files
   maintaining, 692
log files (NDB Cluster), 2355
   ndbmtld, 2359
log group, 3766
log option
   mysql, 514
   mysql_multi, 299
log system variable, 561
LOG(), 1248
log-bin option
   mysql, 2039
log-bin-index option
   mysql, 2040
log-error option
   mysql, 514
   mysqlimport, 364
   mysqld_safe, 292
log-isam option
mysqld, 515
log-long-format option
mysqld, 515
log-name option (ndb_mgmd), 2364
log-short-format option
mysqld, 515
log-slow-admin-statements option
mysqld, 515
log-slow-slave-statements option
mysqld, 2020
log-tc option
mysqld, 515
log-tc-size option
mysqld, 516
log-warnings option
mysqld, 516, 2020
LOG10(), 1249
LOG2(), 1248
logbuffers
  ndbinfo table, 2497
LogDestination, 2204
logging
  passwords, 737
logging commands (NDB Cluster), 2458
logging slow query
  thread state, 1017
logical, 3766
logical backup, 3767
logical operators, 1236
login
  thread state, 1017
LogLevelCheckpoint, 2257
LogLevelCongestion, 2258
LogLevelConnection, 2257
LogLevelError, 2258
LogLevelInfo, 2258
LogLevelNodeRestart, 2257
LogLevelShutdown, 2256
LogLevelStartup, 2256
LogLevelStatistic, 2256
logs
  and TIMESTAMP, 208
  flushing, 673
  server, 672
logs
  ndbinfo table, 2497
log_bin system variable, 2047
log_bin_trust_function_creators system variable, 2047
log_bin_trust_routine_creators
  removed features, 14
log_bin_use_v1_row_events system variable, 2048
log_error system variable, 561
log_output system variable, 562
log_queries_not_using_indexes system variable, 562
log_slave_updates system variable, 2048
log_slow_queries system variable, 563
log_warnings system variable, 563
Long Data
  thread command, 1014
LONG data type, 1184
LONGBLOB data type, 1181
LongMessageBuffer, 2225
LONGTEXT data type, 1181
long_query_time system variable, 564
LOOP, 1580
  labels, 1575
loops option
  ndb_show_tables, 2431
loops option (ndbinfo_select_all), 2358
loops option (ndb_index_stat), 2395
Loose Index Scan
  GROUP BY optimizing, 906
--loose option prefix, 275
loose_, 3767
lossy-conversions option
  ndb_move_data, 2398
  ndb_restore, 2414
lost connection errors, 3148
low-priority option
  mysqlimport, 376
low-water mark, 3767
LOWER(), 1280
lower_case_file_system system variable, 564
GRANT, 1609
lower_case_table_names system variable, 565
LOW_PRIORITY
  DELETE modifier, 1481
  INSERT modifier, 1488
  UPDATE modifier, 1544
low_priority_updates system variable, 564
LPAD(), 1280
LRU, 3767
LRU page replacement, 1766
LSN, 3767
LTRIM(), 1280

M
main features of MySQL, 6
maintaining
  log files, 692
  tables, 876
maintenance
  tables, 345
MAKEDATE(), 1262
MAKETIME(), 1262
MAKE_SET(), 1281
Making temp file
thread state, 1025
malicious SQL statements
   and NDB Cluster, 2515
manage keys
   thread state, 1018
management client (NDB Cluster), 2368
   (see also mgm)
management node (NDB Cluster)
   defined, 2118
management nodes (NDB Cluster), 2359
   (see also mgmd)
managing NDB Cluster, 2441
managing NDB Cluster processes, 2349
manual
   available formats, 2
   online location, 2
   syntax conventions, 2
   typographical conventions, 2
Master has sent all binlog to slave; waiting for binlog to be updated
   thread state, 1023
master server, 3768
master thread, 3768
master-data option
   mysqldump, 364
master-info-file option
   mysql, 2021
master-retry-count option
   mysql, 2021
MASTER_POS_WAIT(), 1372, 1567
MATCH ... AGAINST(), 1296
matching
   patterns, 243
math, 1375
mathematical functions, 1245
MAX(), 1365
MAX(DISTINCT), 1365
max-allowed-packet option
   mysql, 321
   mysqldump, 365
max-binlog-dump-events option
   mysqld, 2043
max-join-size option
   mysql, 321
max-record-length option
   myisamchk, 401
max-relay-log-size option
   mysqld, 2021
MaxAllocate, 2226
MaxBufferedEpochBytes, 2248
MaxBufferedEpochs, 2248
MAXDB SQL mode, 657
MaxDMLOperationsPerTransaction, 2222
   --maximum option prefix, 275
maximums
maximum columns per table, 944
maximum number of databases, 943, 1412
maximum number of tables, 943, 1432
maximum row size, 945
maximum tables per join, 1524
maximum tables per view, 2688
table size, 943
MaxLCPStartDelay, 2230
MaxNoOfAttributes, 2231
MaxNoOfConcurrentIndexOperations, 2222
MaxNoOfConcurrentOperations, 2220
MaxNoOfConcurrentScans, 2224
MaxNoOfConcurrentSubOperations, 2235
MaxNoOfConcurrentTransactions, 2219
MaxNoOfExecutionThreads
dbmtd, 2266
MaxNoOfFiredTriggers, 2223
MaxNoOfIndexes, 2234
MaxNoOfLocalOperations, 2222
MaxNoOfLocalScans, 2224
MaxNoOfOpenFiles, 2229
MaxNoOfOrderedIndexes, 2232
MaxNoOfSavedMessages, 2230
MaxNoOfSubscribers, 2234
MaxNoOfSubscriptions, 2234
MaxNoOfTables, 2232
MaxNoOfTriggers, 2233
MaxNoOfUniqueHashIndexes, 2233
MaxParallelScansPerFragment, 2226
MaxScanBatchSize, 2288
MaxStartFailRetries, 2280
max_allowed_packet
and replication, 2098
max_allowed_packet system variable, 565
max_binlog_cache_size system variable, 2049
max_binlog_size system variable, 2050
max_binlog_stmt_cache_size system variable, 2050
max_connections system variable, 567
MAX_CONNECTIONS_PER_HOUR, 787
max_connect_errors system variable, 566
max_delayed_threads system variable, 567
max_error_count system variable, 567
max_heap_table_size system variable, 568
max_insert_delayed_threads system variable, 568
max_join_size system variable, 335, 569
max_length_for_sort_data system variable, 569
max_long_data_size system variable, 569
max_prepared_stmt_count system variable, 570
MAX_QUERIES_PER_HOUR, 787
max_relay_log_size system variable, 570
MAX_ROWS
and DataMemory (NDB Cluster), 2216
and NDB Cluster, 2597
NDB Cluster, 1442
max_seeks_for_key system variable, 571
max_sort_length system variable, 571
max_sp_recursion_depth system variable, 572
max_tmp_tables system variable, 572
MAX_UPDATES_PER_HOUR, 787
MAX_USER_CONNECTIONS, 787
max_user_connections system variable, 572
max_write_lock_count system variable, 573
MBR, 1360
MBRContains(), 1360
MBRDisjoint(), 1360
MBREqual(), 1360
MBRIntersects(), 1361
MBROverlaps(), 1361
MBRTouches(), 1361
MBRWithin(), 1361
MD5(), 1334
MDL, 3768
tmedium-check option
  myisamchk, 400
  mysqlcheck, 351
MEDIUMBLOB data type, 1181
MEDIUMINT data type, 1160
MEDIUMTEXT data type, 1181
membership
  ndbinfo table, 2497
memcached, 3768
MEMCACHED_HOME option
  CMake, 187
memlock option
  mysqld, 517
memory allocation library, 292
memory allocator
  innodb_use_sys_malloc, 1769
MEMORY storage engine, 1887, 1902
  and replication, 2098
  optimization, 929
memory usage
  myisamchk, 409
memory use, 1003
  in NDB Cluster, 2136
    Performance Schema, 2771
memoryusage
  ndbinfo table, 2499
MemReportFrequency, 2258
merge, 3768
MERGE storage engine, 1887, 1913
MERGE tables
  defined, 1913
metadata
  database, 2691
  database object, 1088
  InnoDB, 2731
  stored routines, 2659
triggers, 2664
views, 2676
metadata lock, 3768
metadata locking, 994
new features, 13
metadata log, 692
metadata_locks_cache_size system variable, 573
method option
  mysqlhotcopy, 438
methods
  locking, 990
metrics counter, 3769
mgmd (NDB Cluster)
  defined, 2118
  (see also management node (NDB Cluster))
MICROSECOND(), 1263
MID(), 1281
midpoint insertion, 1766
midpoint insertion strategy, 3769
milestone
  MySQL releases, 44
MIN(), 1365
MIN(DISTINCT), 1365
MinFreePct, 2216, 2219
mini-transaction, 3769
minimum bounding rectangle, 1360
minus
  unary (-), 1243
MINUTE(), 1263
min_examined_row_limit system variable, 573
mirror sites, 45
miscellaneous functions, 1371
mixed statements (Replication), 2103
mixed-mode insert, 3769
MLineFromText(), 1351
MLineFromWKB(), 1352
MOD (modulo), 1249
MOD(), 1249
modes
  batch, 250
modify option
  MySQLInstallerConsole, 93
modulo (%), 1249
modulo (MOD), 1249
monitor
  terminal, 227
monitoring, 1712, 1717, 1781, 1858, 3021
  threads, 1012
Monitors, 1860
  enabling, 1861
  InnoDB, 1799, 1875, 1879
  output, 1863
MONTH(), 1263
MONTHNAME(), 1263
MPointFromText(), 1351
MPointFromWKB(), 1352
MPolyFromText(), 1351
MPolyFromWKB(), 1352
.MRG file, 3767
mSQL compatibility, 1289
msql2mysql, 443
MSSQL SQL mode, 657
multi mysql, 297
multi-column indexes, 929
multi-core, 3769
multi-core scalability
   new features, 10
multi-master replication
   in NDB Cluster, 2578, 2582
multibyte character sets, 3156
multibyte characters, 1142
MULTILINESTRING data type, 1193
MultiLineString(), 1353
MultiLineStringFromText(), 1351
MultiLineStringFromWKB(), 1352
multiple buffer pools, 1766
multiple servers, 706
multiple-part index, 1417
multiplication (*), 1243
MULTIPOINT data type, 1193
MultiPoint(), 1353
MultiPointFromText(), 1351
MultiPointFromWKB(), 1352
MULTIPOLYGON data type, 1193
MultiPolygon(), 1353
MultiPolygonFromText(), 1351
MultiPolygonFromWKB(), 1352
mutex, 3769
mutex wait
   monitoring, 1858
mutex_instances table
   performance_schema, 2791
MVCC, 3769
MVCC (multi-version concurrency control), 1708
My
   derivation, 8
my-print-defaults option
   mysql_plugin, 307
my.cnf, 3770
   and NDB Cluster, 2163, 2192, 2193
   in NDB Cluster, 2453
my.cnf option file, 2083
my.ini, 3770
mycnf option
   ndb_config, 2376
   ndb_mgmd, 2364
.MYD file, 3768
.MYI file, 3768
MyISAM
  compressed tables, 411, 1900
  converting tables to InnoDB, 1722
MyISAM key cache, 978
MyISAM storage engine, 1887, 1893
myisam-block-size option
  mysql, 517
myisamchk, 264, 393
  analyze option, 402
  backup option, 400
  block-search option, 402
  character-sets-dir option, 400
  check option, 399
  check-only-changed option, 399
  correct-checksum option, 400
  data-file-length option, 400
  debug option, 397
  defaults-extra-file option, 397
  defaults-file option, 397
  defaults-group-suffix option, 397
  description option, 402
  example output, 402
  extend-check option, 399, 400
  fast option, 399
  force option, 400, 401
  help option, 396
  HELP option, 396
  information option, 400
  keys-used option, 401
  max-record-length option, 401
  medium-check option, 400
  no-defaults option, 397
  no-symlinks option, 401
  options, 396
  parallel-recover option, 401
  print-defaults option, 397
  quick option, 401
  read-only option, 400
  recover option, 401
  safe-recover option, 401
  set-auto-increment option, 402
  set-collation option, 401
  silent option, 397
  sort-index option, 402
  sort-records option, 402
  sort-recover option, 401
  tmpdir option, 402
  unpack option, 402
  update-state option, 400
  verbose option, 397
  version option, 397
  wait option, 398
myisamlog, 264, 410
myisampack, 264, 411, 1463, 1900
backup option, 412
character-sets-dir option, 412
debug option, 412
force option, 412
help option, 412
join option, 412
silent option, 412
test option, 412
tmpdir option, 412
verbose option, 412
version option, 412
wait option, 412
myisam_block_size myisamchk variable, 398
myisam_data_pointer_size system variable, 574
myisam_fdump, 264, 392
count option, 392
dump option, 393
help option, 392
length option, 393
stats option, 393
verbose option, 393
myisam_max_extra_sort_file_size
removed features, 14
myisam_max_sort_file_size system variable, 575, 1897
myisam_mmap_size system variable, 575
myisam_recover_options system variable, 576, 1897
myisam_repair_threads system variable, 577
myisam_sort_buffer_size myisamchk variable, 398
myisam_sort_buffer_size system variable, 577, 1897
myisam_stats_method system variable, 578
myisam_use_mmap system variable, 578
MySQL
defined, 4
forums, 18
introduction, 4
pronunciation, 5
upgrading, 308
websites, 18
mysql, 263, 314, 3770
auto-rehash option, 318
auto-vertical-output option, 318
batch option, 318
binary-as-hex option, 318
bind-address option, 318
character-sets-dir option, 318
charset command, 327
clear command, 327
column-names option, 318
column-type-info option, 318
comments option, 318
compress option, 319
connect command, 327
connect-timeout option, 319
database option, 319
debug option, 319
debug-check option, 319
debug-info option, 319
default-auth option, 319
default-character-set option, 319
defaults-extra-file option, 319
defaults-file option, 319
defaults-group-suffix option, 320
delimiter command, 327
delimiter option, 320
disable named commands, 320
edit command, 327
ego command, 327
enable-cleartext-plugin option, 320
execute option, 320
exit command, 328
force option, 320
go command, 328
help command, 326
help option, 317
host option, 320
html option, 320
i-am-a-dummy option, 323
ignore-spaces option, 320
init-command option, 320
line-numbers option, 320
local-infile option, 320
max-allowed-packet option, 321
max-join-size option, 321
named-commands option, 321
net-buffer-length option, 321
no-auto-rehash option, 321
no-beep option, 321
no-defaults option, 321
nopager command, 328
notee command, 328
nowarning command, 328
one-database option, 321
pager command, 328
pager option, 322
password option, 322
pipe option, 322
plugin-dir option, 322
port option, 322
print command, 328
print-defaults option, 322
prompt command, 328
prompt option, 323
protocol option, 323
quick option, 323
quit command, 328
raw option, 323
reconnect option, 323
rehash command, 328
safe-updates option, 323
secure-auth option, 324
select-limit option, 324
shared-memory-base-name option, 324
show-warnings option, 324
sigint-ignore option, 324
silent option, 324
skip-column-names option, 324
skip-line-numbers option, 324
socket option, 324
source command, 328
SSL options, 325
status command, 329
system command, 329
table option, 325
tee command, 329
tee option, 325
unbuffered option, 325
use command, 329
user option, 325
verbose option, 325
version option, 325
vertical option, 325
wait option, 325
warnings command, 329
xml option, 325
MySQL binary distribution, 44
MYSQL C type, 2829
mysql client parser
   versus mysqld parser, 337
MySQL Cluster Manager
   and ndb_mgm, 2444
mysql command options, 315
mysql commands
   list of, 326
MySQL Dolphin name, 8
MySQL Enterprise Audit, 829, 3023
   new features, 9
MySQL Enterprise Backup, 3022, 3770
MySQL Enterprise Data Masking and De-Identification, 3024
MySQL Enterprise Encryption, 3023
MySQL Enterprise Firewall, 3024
MySQL Enterprise Monitor, 3021
MySQL Enterprise Security, 810, 821, 3023
MySQL Enterprise Thread Pool, 699, 3024
   components, 700
   installing, 700
   new features, 9
MySQL history, 8
mysql history file, 331
MySQL Installer, 67
MySQL name, 8
MySQL privileges
   and NDB Cluster, 2514
mysql prompt command, 330
MySQL server
    mysqld, 289, 454
mysql source (command for reading from text files), 251, 334
MySQL source distribution, 44
MySQL storage engines, 1887
MySQL system tables
    and NDB Cluster, 2514
    and replication, 2099
MySQL version, 45
mysql \ (command for reading from text files), 251, 334
mysql.event table, 2671
mysql.ndb_binlog_index table, 2563
    (see also NDB Cluster replication)
mysql.server, 262, 295
    basedir option, 297
    datadir option, 297
    pid-file option, 297
    service-startup-timeout option, 297
mysql.sock
    protection, 3164
MYSQL323 SQL mode, 657
MYSQL40 SQL mode, 657
mysqlaccess, 264, 417
    brief option, 418
    commit option, 418
    copy option, 418
    db option, 418
    debug option, 419
    help option, 418
    host option, 419
    howto option, 419
    old_server option, 419
    password option, 419
    plan option, 419
    preview option, 419
    relnotes option, 419
    rhost option, 419
    rollback option, 419
    spassword option, 419
    superuser option, 419
    table option, 419
    user option, 420
    version option, 420
mysqladmin, 263, 337, 1412, 1472, 1672, 1678, 1684, 1688
    bind-address option, 342
    character-sets-dir option, 342
    compress option, 342
    count option, 342
    debug option, 342
    debug-check option, 342
    debug-info option, 342
    default-auth option, 342
    default-info option, 342
    default-character-set option, 343
defaults-extra-file option, 343
defaults-file option, 343
defaults-group-suffix option, 343
enable-cleartext-plugin option, 343
force option, 343
help option, 342
host option, 343
no-beep option, 343
no-defaults option, 343
password option, 344
pipe option, 344
plugin-dir option, 344
port option, 344
print-defaults option, 344
protocol option, 344
relative option, 344
shared-memory-base-name option, 344
silent option, 344
sleep option, 345
socket option, 345
SSL options, 345
user option, 345
verbose option, 345
version option, 345
wait option, 345
mysqladmin command options, 340
mysqladmin option
mysqld_multi, 299
mysqlbackup command, 3770
mysqlbinlog, 264, 420
    base64-output option, 423
    bind-address option, 423
    character-sets-dir option, 423
    database option, 423
    debug option, 424
    debug-check option, 424
    debug-info option, 425
    default-auth option, 425
    defaults-extra-file option, 425
    defaults-file option, 425
    defaults-group-suffix option, 425
    disable-log-bin option, 425
    force-if-open option, 425
    force-read option, 425
    help option, 422
    hexdump option, 426
    host option, 426
    local-load option, 426
    no-defaults option, 426
    offset option, 426
    open-files-limit option, 426
    password option, 426
    plugin-dir option, 426
port option, 426
print-defaults option, 427
protocol option, 427
read-from-remote-server option, 427
result-file option, 427
server-id option, 427
server-id-bits option, 427
set-charset option, 427
shared-memory-base-name option, 427
short-form option, 427
socket option, 427
SSL options, 428
start-datetime option, 428
start-position option, 428
stop-datetime option, 428
stop-position option, 428
to-last-log option, 428
user option, 428
verbose option, 429
version option, 429
mysqlbug, 302
mysqlcheck, 263, 345
   all-databases option, 348
   all-in-1 option, 348
   analyze option, 348
   auto-repair option, 348
   bind-address option, 349
   character-sets-dir option, 349
   check option, 349
   check-only-changed option, 349
   check-upgrade option, 349
   compress option, 349
   databases option, 349
   debug option, 349
   debug-check option, 349
   debug-info option, 349
   default-auth option, 350
   default-character-set option, 349
   defaults-extra-file option, 350
   defaults-file option, 350
   defaults-group-suffix option, 350
   enable-cleartext-plugin option, 350
   extended option, 350
   fast option, 350
   fix-db-names option, 350
   fix-table-names option, 350
   force option, 351
   help option, 348
   host option, 351
   medium-check option, 351
   no-defaults option, 351
   optimize option, 351
   password option, 351
   pipe option, 351
plugin-dir option, 351
port option, 351
print-defaults option, 351
protocol option, 352
quick option, 352
repair option, 352
shared-memory-base-name option, 352
silent option, 352
socket option, 352
SSL options, 352
tables option, 352
use-frm option, 352
user option, 352
verbose option, 353
version option, 353
write-binlog option, 353
mysqld, 262, 3770
abort-slave-event-count option, 2019
allow-suspicious-udfs option, 505
ansi option, 505
as NDB Cluster process, 2293, 2453
audit-log option, 846
basedir option, 506
bind-address option, 506
binlog-do-db option, 2040
binlog-ignore-db option, 2042
binlog-row-event-max-size option, 2039
bootstrap option, 507
character-set-client-handshake option, 507
chroot option, 507
cmd options, 504
console option, 507
core-file option, 508
data-dir option, 508
debug option, 508
debug-sync-timeout option, 509
default-time-zone option, 509
defaults-extra-file option, 509
defaults-file option, 510
defaults-group-suffix option, 510
des-key-file option, 510
disconnect-slave-event-count option, 2020
exit-info option, 510
external-locking option, 510
flush option, 511
gdb option, 511
help option, 505
innodb option, 1808
innodb-status-file option, 1808
install option, 511
install-manual option, 512
language option, 512
large-pages option, 512
lc-messages option, 513
lc-messages-dir option, 513
local-service option, 514
log option, 514
log-bin option, 2039
log-bin-index option, 2040
log-error option, 514
log-isam option, 515
log-long-format option, 515
log-short-format option, 515
log-slow-admin-statements option, 515
log-slow-slave-statements option, 2020
log-tc option, 515
log-tc-size option, 516
log-warnings option, 516, 2020
master-info-file option, 2021
master-retry-count option, 2021
max-binlog-dump-events option, 2043
max-relay-log-size option, 2021
memlock option, 517
myisam-block-size option, 517
MySQL server, 289, 454
ndb-batch-size option, 2293
ndb-blob-read-batch-bytes option, 2295
ndb-blob-write-batch-bytes option, 2295
ndb-cluster-connection-pool option, 2294
ndb-connectstring option, 2296
ndb-log-apply-status, 2296
ndb-log-empty-epochs, 2297
ndb-log-empty-update, 2297
ndb-log-orig, 2298
ndb-log-transaction-id, 2298
ndb-nodeid, 2299
ndbcluster option, 2293
no-defaults option, 518
old-style-user-limits option, 518
one-thread option, 518
partition option, 518
plugin option prefix, 519
plugin-load option, 518
port option, 520
port-open-timeout option, 520
print-defaults option, 520
relay-log-purge option, 2022
relay-log-space-limit option, 2022
remove option, 520
replicate-do-db option, 2023
replicate-do-table option, 2025
replicate-ignore-db option, 2024
replicate-ignore-table option, 2026
replicate-rewrite-db option, 2026
replicate-same-server-id option, 2027
replicate-wild-do-table option, 2027
replicate-wild-ignore-table option, 2027
role in NDB Cluster (see SQL Node (NDB Cluster))
safe-mode option, 521
safe-user-create option, 521
server-id-bits option, 2301
show-slave-auth-info option, 2015
skip-grant-tables option, 521
skip-host-cache option, 522
skip-innodb option, 522, 1809
skip-ndbcluster option, 2302
skip-new option, 522
skip-partition option, 522
skip-show-database option, 522
skip-slave-start option, 2028
skip-stack-trace option, 523
skip-symbolic-links option, 525
skip-thread-priority option, 523
slave-skip-errors option, 2028
slave_compressed_protocol option, 2028
slow-start-timeout option, 523
socket option, 523
sporadic-binlog-dump-fail option, 2043
sql-mode option, 524
SSL options, 525
standalone option, 525
starting, 746
super-large-pages option, 525
symbolic-links option, 525
sysdate-is-now option, 526
tc-heuristic-recover option, 526
temp-pool option, 526
tmpdir option, 527
transaction-isolation option, 527
user option, 527
verbose option, 528
version option, 528
mysqld (NDB Cluster), 2349
mysqld option
malloc-lib, 292
mysqld_multi, 299
mysqld_safe, 293
mysql_plugin, 307
mysqld options, 454
mysqld options and variables
NDB Cluster, 2293
mysqld parser
versus mysql client parser, 337
mysqld system variables, 454
mysqld-version option
mysql_safe, 293
mysqldump, 218, 264, 353, 3770
add-drop-database option, 359
add-drop-table option, 359
add-drop-trigger option, 359
add-locks option, 359
all-databases option, 359
all-tablespaces option, 359
allow-keywords option, 359
apply-slave-statements option, 360
bind-address option, 360
character-sets-dir option, 360
comments option, 360
compact option, 360
compatible option, 360
complete-insert option, 360
compress option, 360
create-options option, 360
databases option, 360
debug option, 361
debug-check option, 361
debug-info option, 361
default-auth option, 361
default-character-set option, 361
defaults-extra-file option, 361
defaults-file option, 361
defaults-group-suffix option, 361
delayed-insert option, 361
delete-master-logs option, 361
disable-keys option, 362
dump-date option, 362
dump-slave option, 362
enable-cleartext-plugin option, 363
events option, 362
extended-insert option, 362
fields-enclosed-by option, 363, 375
fields-escaped-by option, 363, 375
fields-optionally-enclosed-by option, 363, 375
fields-terminated-by option, 363, 375
flush-logs option, 363
flush-privileges option, 363
force option, 363
help option, 359
hex-blob option, 363
host option, 363
ignore-table option, 364
include-master-host-port option, 363
insert-ignore option, 364
lines-terminated-by option, 364, 376
lock-all-tables option, 364
lock-tables option, 364
log-error option, 364
master-data option, 364
max-allowed-packet option, 365
net-buffer-length option, 365
no-autocommit option, 365
no-create-db option, 365
no-create-info option, 365
no-data option, 365
no-defaults option, 365
no-set-names option, 365
no-tablespaces option, 366
opt option, 366
order-by-primary option, 366
password option, 366
pipe option, 366
plugin-dir option, 366
port option, 366
print-defaults option, 366
problems, 372, 2689
protocol option, 367
quick option, 367
quote-names option, 367
replace option, 367
result-file option, 367
routines option, 367
set-charset option, 367
shared-memory-base-name option, 368
single-transaction option, 368
skip-comments option, 368
skip-opt option, 368
socket option, 368
SSL options, 368
tab option, 369
tables option, 369
triggers option, 369
tz-utc option, 369
user option, 369
using for backups, 863
verbose option, 369
version option, 369
views, 372, 2689
where option, 370
workarounds, 372, 2689
xml option, 370
mysqldumpslow, 265, 434
debug option, 435
help option, 435
verbose option, 436
mysqld_multi, 262, 297
config-file option, 299
defaults-extra-file option, 298
defaults-file option, 298
example option, 299
help option, 299
log option, 299
mysqladmin option, 299
mysqld option, 299
no-defaults option, 298
no-log option, 299
password option, 299
silent option, 299
tcp-ip option, 299
user option, 299
verbose option, 300
version option, 300
mysqld_safe, 262, 290
  basedir option, 291
  core-file-size option, 291
  datadir option, 291
  defaults-extra-file option, 291
  defaults-file option, 291
  help option, 291
  ledir option, 292
  log-error option, 292
  malloc-lib option, 292
  mysqld option, 293
  mysqld-version option, 293
  nice option, 293
  no-defaults option, 293
  open-files-limit option, 293
  pid-file option, 293
  plugin-dir option, 293
  port option, 293
  skip-kill-mysqld option, 294
  skip-syslog option, 294
  socket option, 294
  syslog option, 294
  syslog-tag option, 294
  timezone option, 294
  user option, 294
mysqlhotcopy, 265, 436
  addtodest option, 437
  allowold option, 437
  checkpoint option, 437
  chroot option, 437
  debug option, 437
  dryrun option, 437
  flushlog option, 437
  help option, 437
  host option, 437
  keepold option, 438
  method option, 438
  noindices option, 438
  old_server option, 438
  password option, 438
  port option, 438
  quiet option, 438
  record_log_pos option, 438
  regexp option, 438
  resetmaster option, 438
  resetslave option, 438
  socket option, 438
  suffix option, 439
  tmpdir option, 439
  user option, 439
mysqlimport, 218, 264, 372, 1495
  bind-address option, 374
  character-sets-dir option, 374
columns option, 374
compress option, 374
debug option, 374
debug-check option, 374
debug-info option, 374
default-auth option, 374
default-character-set option, 374
defaults-extra-file option, 375
defaults-file option, 375
defaults-group-suffix option, 375
delete option, 375
enable-cleartext-plugin option, 375
force option, 375
help option, 374
host option, 375
ignore option, 375
ignore-lines option, 375
local option, 376
lock-tables option, 376
low-priority option, 376
no-defaults option, 376
password option, 376
pipe option, 376
plugin-dir option, 377
port option, 377
print-defaults option, 377
protocol option, 377
replace option, 377
shared-memory-base-name option, 377
silent option, 377
socket option, 377
SSL options, 377
use-threads option, 378
user option, 377
verbose option, 378
version option, 378
MySQLInstallerConsole, 90
configure option, 91
help option, 91
install option, 91
list option, 92
modify option, 93
remove option, 93
status option, 93
update option, 93
upgrade option, 93
mysqlshow, 264, 378
bind-address option, 380
character-sets-dir option, 380
compress option, 380
count option, 380
debug option, 380
debug-check option, 380
debug-info option, 380
default-auth option, 381
default-character-set option, 380
defaults-extra-file option, 381
defaults-file option, 381
defaults-group-suffix option, 381
enable-cleartext-plugin option, 381
help option, 380
host option, 381
keys option, 381
no-defaults option, 381
password option, 381
pipe option, 382
plugin-dir option, 382
port option, 382
print-defaults option, 382
protocol option, 382
shared-memory-base-name option, 382
show-table-type option, 382
socket option, 382
SSL options, 382
status option, 383
user option, 383
verbose option, 383
version option, 383

mysqsl, 264, 383
  auto-generate-sql option, 386
  auto-generate-sql-add-autoincrement option, 386
  auto-generate-sql-execute-number option, 386
  auto-generate-sql-guid-primary option, 386
  auto-generate-sql-load-type option, 386
  auto-generate-sql-secondary-indexes option, 386
  auto-generate-sql-unique-query-number option, 386
  auto-generate-sql-unique-write-number option, 386
  auto-generate-sql-write-number option, 386
  commit option, 387
  compress option, 387
  concurrency option, 387
  create option, 387
  create-schema option, 387
  csv option, 387
debug option, 387
debug-check option, 387
debug-info option, 387
default-auth option, 387
defaults-extra-file option, 387
defaults-file option, 388
defaults-group-suffix option, 388
delimiter option, 388
detach option, 388
enable-cleartext-plugin option, 388
gine option, 388
help option, 386
host option, 388
iterations option, 388
no-defaults option, 388
no-drop option, 388
number-char-cols option, 388
number-int-cols option, 389
number-of-queries option, 389
only-print option, 389
password option, 389
pipe option, 389
plugin-dir option, 389
port option, 389
post-query option, 389
post-system option, 389
pre-query option, 390
pre-system option, 390
print-defaults option, 390
protocol option, 390
query option, 390
shared-memory-base-name option, 390
silent option, 390
socket option, 390
SSL options, 390
user option, 390
verbose option, 391
version option, 391
mysqltest
  MySQL Test Suite, 2948
mysql_affected_rows(), 2839, 2943
mysql_autocommit(), 2840
MYSQL_BIND C type, 2893
mysql_change_user(), 2840
mysql_character_set_name(), 2842
mysql_clear_password authentication plugin, 809
mysql_client_find_plugin(), 2929
mysql_client_register_plugin(), 2930
mysql_close(), 2842
mysql_cluster_backup_privileges, 2540
mysql_cluster_move_grant_tables, 2540
mysql_cluster_move_privileges, 2540
mysql_cluster_privileges_are_distributed, 2540
mysql_cluster_restore_local_privileges, 2542
mysql_cluster_restore_privileges, 2542
mysql_cluster_restore_privileges_from_local, 2542
mysql_commit(), 2842
mysql_config, 443
cflags option, 444
embedded option, 444
embedded-libs option, 444
include option, 444
libmysqld-libs option, 444
libs option, 444
libs_r option, 444
plugindir option, 444
port option, 444
socket option, 444
variable option, 444
version option, 444
mysql_connect(), 2843
mysql_convert_table_format, 265, 439
  force option, 439
  help option, 439
  host option, 439
  password option, 439
  port option, 439
  socket option, 439
  type option, 440
  user option, 440
  verbose option, 440
  version option, 440
mysql_create_db(), 2843
MYSQL_DATADIR option
  CMake, 181
mysql_data_seek(), 2844
MYSQL_DEBUG environment variable, 266, 449, 3016
mysql_debug(), 2844
mysql_drop_db(), 2845
mysql_dump_debug_info(), 2845
mysql_eof(), 2846
mysql_errno(), 2847
mysql_error(), 2848
mysql_escape_string(), 2848
mysql_fetch_field(), 2848
mysql_fetch_fields(), 2850
mysql_fetch_field_direct(), 2849
mysql_fetch_lengths(), 2850
mysql_fetch_row(), 2851
MYSQL_FIELD C type, 2829
mysql_field_count(), 2852, 2867
MYSQL_FIELD_OFFSET C type, 2829
mysql_field_seek(), 2853
mysql_field_tell(), 2853
mysql_find_rows, 265, 440
  help option, 440
  regexp option, 440
  rows option, 440
  skip-use-db option, 440
  start_row option, 440
mysql_fix_extensions, 265, 441
mysql_free_result(), 2853
mysql_get_character_set_info(), 2854
mysql_get_client_info(), 2854
mysql_get_character_set_info(), 2855
mysql_get_host_info(), 2855
mysql_get_proto_info(), 2855
mysql_get_server_info(), 2856
mysql_get_server_version(), 2856
mysql_get_ssl_cipher(), 2856
MYSQL_GROUP_SUFFIX environment variable, 449
mysql_hex_string(), 2857
MYSQL_PS1 environment variable, 449
MYSQL_PWD environment variable, 266, 288, 449
mysql_query(), 2874, 2943
mysql_real_connect(), 2875
mysql_real_escape_string(), 1031, 1281, 2878
mysql_real_query(), 2880
mysql_refresh(), 2880
mysql_reload(), 2881
MYSQL_RES C type, 2829
mysql_rollback(), 2882
MYSQL_ROW C type, 2829
mysql_row_seek(), 2882
mysql_row_tell(), 2883
mysql_secure_installation, 263, 307
mysql_select_db(), 2883
MYSQL_SERVER_AUTH_INFO plugin structure, 2989
mysql_server_end(), 2928
mysql_server_init(), 2929
mysql_setpermission, 265, 441
  help option, 441
  host option, 441
  password option, 441
  port option, 441
  socket option, 441
  user option, 442
mysql_set_character_set(), 2884
mysql_set_local_infile_default(), 2884, 2884
mysql_set_server_option(), 2886
mysql_shutdown(), 2886
mysql_sqlstate(), 2887
mysql_ssl_set(), 2888
mysql_stat(), 2888
MYSQL_STMT C type, 2893
mysql_stmt_affected_rows(), 2902
mysql_stmt_attr_get(), 2902
mysql_stmt_attr_set(), 2903
mysql_stmt_bind_param(), 2904
mysql_stmt_bind_result(), 2905
mysql_stmt_close(), 2906
mysql_stmt_data_seek(), 2906
mysql_stmt_errno(), 2906
mysql_stmt_error(), 2907
mysql_stmt_execute(), 2907
mysql_stmt_fetch(), 2911
mysql_stmt_fetch_column(), 2916
mysql_stmt_field_count(), 2917
mysql_stmt_free_result(), 2917
mysql_stmt_init(), 2917
mysql_stmt_insert_id(), 2918
mysql_stmt_next_result(), 2918
mysql_stmt_num_rows(), 2919
mysql_stmt_param_count(), 2920
mysql_stmt_param_metadata(), 2920
mysql_stmt_prepare(), 2920
mysql_stmt_reset(), 2921
mysql_stmt_result_metadata, 2922
mysql_stmt_row_seek(), 2923
mysql_stmt_row_tell(), 2923
mysql_stmt_send_long_data(), 2923
mysql_stmt_sqlstate(), 2925
mysql_stmt_store_result(), 2926
mysql_store_result(), 2889, 2943
MYSQL_TCP_PORT environment variable, 266, 449, 713, 713
MYSQL_TCP_PORT option
  CMake, 184
mysql_thread_end(), 2927
mysql_thread_id(), 2890
mysql_thread_init(), 2928
mysql_thread_safe(), 2928
MYSQL_TIME C type, 2896
mysql_tzinfo_to_sql, 263, 308
MYSQL_UNIX_ADDR option
  CMake, 184
MYSQL_UNIX_PORT environment variable, 193, 266, 449, 713, 713
mysql_upgrade, 263, 308
  basedir option, 311
  character-sets-dir option, 311
  compress option, 311
  datadir option, 311
  debug option, 312
  debug-check option, 312
  debug-info option, 312
  default-auth option, 312
  default-character-set option, 312
  defaults-extra-file option, 312
  defaults-file option, 312
  defaults-group-suffix option, 312
  force option, 312
  help option, 311
  host option, 312
  mysql_upgrade_info file, 310
  no-defaults option, 313
  password option, 313
  pipe option, 313
  plugin-dir option, 313
  port option, 313
  print-defaults option, 313
  protocol option, 313
  shared-memory-base-name option, 313
  socket option, 314
  SSL options, 314
  tmpdir option, 314
  upgrade-system-tables option, 314
  user option, 314
  verbose option, 314
  version-check option, 314
  write-binlog option, 314
mysql_upgrade_info file
mysql_upgrade, 310
mysql_use_result(), 2891
mysql_waitpid, 265, 442
  help option, 442
  verbose option, 442
  version option, 442
mysql_warning_count(), 2892
mysql_zap, 265, 442
my_bool C type, 2829
my_bool values
  printing, 2829
my_init(), 2927
my_print_defaults, 265, 445
  config-file option, 445
  debug option, 445
  defaults-extra-file option, 445
  defaults-file option, 445
  defaults-group-suffix option, 445
  extra-file option, 445
  help option, 445
  no-defaults option, 445
  verbose option, 446
  version option, 446
my_snprintf service, 2996
my_thd_scheduler service, 2996
my_ulonglong C type, 2829
my_ulonglong values
  printing, 2829

N
name-file option
  comp_err, 302
named pipes, 120, 126
named-commands option
  mysql, 321
named_pipe system variable, 579
names, 1038
  case sensitivity, 1042
  variables, 1072
NAME_CONST(), 1372, 2683
naming
  releases of MySQL, 44
NATIONAL CHAR data type, 1179
NATIONAL VARCHAR data type, 1180
native backup and restore
  backup identifiers, 2451
native functions
  adding, 3007
NATURAL JOIN, 1522
natural key, 3770
NATURAL LEFT JOIN, 1522
NATURAL LEFT OUTER JOIN, 1522
NATURAL RIGHT JOIN, 1522
NATURAL RIGHT OUTER JOIN, 1522
NCHAR data type, 1179
NDB API
   and distributed grant tables, 2542
   and distributed privileges, 2542
NDB API counters (NDB Cluster), 2542
   scope, 2546
   status variables associated with, 2548
   types, 2546
NDB API database objects
   and NDB Cluster replication, 2556
NDB API_slave status variables
   and NDB Cluster Replication, 2554
NDB client programs
   defaults-extra-file option, 2439
   defaults-file option, 2439
   no-defaults option, 2440
   print-defaults option, 2441
NDB Cluster, 2114
   "quick" configuration, 2173
   administration, 2293, 2349, 2359, 2368, 2369, 2437, 2444, 2464
   and application feature requirements, 2133
   and DNS, 2147
   and INFORMATION_SCHEMA, 2515
   and IP addressing, 2147
   and MySQL privileges, 2514
   and MySQL root user, 2514, 2516
   and networking, 2123
   and transactions, 2216
   API node, 2118, 2283
   applications supported, 2133
   availability, 2131
   available platforms, 2115
   BACKUP Events, 2464
   backups, 2404, 2448, 2449, 2452, 2453
   binlog_format system variable, 2045, 2046
   CHECKPOINT Events, 2460
   cluster logs, 2456, 2458
   CLUSTERLOG commands, 2458
   CLUSTERLOG STATISTICS command, 2464
   commands, 2293, 2349, 2359, 2369, 2444
   compared to InnoDB, 2131, 2131, 2133, 2133
   compared to standalone MySQL Server, 2131, 2131, 2133, 2133
   compiling with icc, 3009
   concepts, 2118
   configuration, 2146, 2173, 2173, 2201, 2202, 2209, 2283, 2368, 2453
   configuration (example), 2193
   configuration changes, 2455
   configuration files, 2163, 2192
   configuration parameters, 2176, 2176, 2182, 2183, 2184
   configuring, 2452
   CONNECT command, 2444
   CONNECTION Events, 2459
   connection string, 2199
CREATE NODEGROUP command, 2447
data node, 2118, 2209
data nodes, 2349, 2358
defining node hosts, 2201
direct connections between nodes, 2337
Disk Data tables (see NDB Cluster Disk Data)
DROP NODEGROUP command, 2448
ENTER SINGLE USER MODE command, 2447
ERROR Events, 2463
error logs, 2355
event log format, 2459
event logging thresholds, 2458
event logs, 2456, 2458
event severity levels, 2459
event types, 2457, 2459
execution threads, 2266
EXIT command, 2447
EXIT SINGLE USER MODE command, 2447
FAQ, 3039
GCP Stop errors, 2278
general description, 2116
HELP command, 2444
HostName parameter
and security, 2510
INFO Events, 2463
information sources, 2116
insecurity of communication protocols, 2510
installation, 2146
installation (Linux), 2148
installation (Windows), 2155
installing .deb file (Linux), 2153
installing binary (Windows), 2155
installing binary release (Linux), 2149
installing from source (Linux), 2153
installing from source (Windows), 2158
installing RPM (Linux), 2151
interconnects, 2348
Java clients, 2119
large tables, 1442
log files, 2355, 2359
logging commands, 2458
management client (ndb_mgm), 2368
management commands, 2464
management node, 2118, 2202
management nodes, 2359
managing, 2441
MAX_ROWS, 1442
memory usage and recovery, 2136, 2455
mgm, 2437
mgm client, 2444
mgm management client, 2464
mgm process, 2369
mgmd, 2437
mgmd process, 2359
monitoring, 2542
multiple management servers, 2456
mysqld options and variables for, 2293
mysqld process, 2293, 2453
ndbd, 2349, 2437
ndbd process, 2349, 2466
ndbinfo_select_all, 2357
ndbmtd, 2358
ndb_mgm, 2166, 2368
ndb_mgmd process, 2359
network configuration
  and security, 2510
network transporters, 2348
networking, 2337, 2338, 2342
new features, 12
node failure (single user mode), 2483
node identifiers, 2340, 2340, 2343, 2343
node logs, 2456
NODERESTART Events, 2461
nodes and node groups, 2121
nodes and types, 2118
partitioning support, 2135
partitions, 2121
performing queries, 2166
preparing for replication, 2565
process management, 2349
QUIT command, 2447
replicas, 2121
replication, 2553
  (see also NDB Cluster replication)
REPORT command, 2446
requirements, 2123
resetting, 2455
RESTART command, 2446
restarting, 2170
restoring backups, 2404
rolling restarts (multiple management servers), 2456
runtime statistics, 2464
SCHEMA Events, 2463
SCI (Scalable Coherent Interface), 2342
security, 2509
  and firewalls, 2511, 2513
  and HostName parameter, 2510
  and network configuration, 2510
  and network ports, 2513
  and remote administration, 2514
  networking, 2510
security procedures, 2516
shared memory transport, 2338
SHOW command, 2445
SHUTDOWN command, 2447
shutting down, 2170
single user mode, 2447, 2482
SINGLEUSER Events, 2464
SQL node, 2118, 2283
SQL nodes, 2453
SQL statements for monitoring, 2483
START BACKUP command, 2572
START command, 2445
start phases (summary), 2442
starting, 2173
starting nodes, 2159, 2165
starting or restarting, 2442
STARTUP Events, 2460
STATISTICS Events, 2462
STATUS command, 2446
status variables, 2318
STOP command, 2445
storage requirements, 1209
thread states, 1026
trace files, 2356
transaction handling, 2139
transaction isolation level, 2137
transporters
  Scalable Coherent Interface (SCI), 2342
  shared memory (SHM), 2338
  TCP/IP, 2337
troubleshooting backups, 2453
upgrades and downgrades, 2171, 2454
USING HASH, 1420
using tables and data, 2166
NDB Cluster 7.2, 2125
NDB Cluster Disk Data, 2517
  creating log file groups, 2518
  creating tables, 2518, 2520
  creating tablespaces, 2519
  dropping Disk Data objects, 2522
  storage requirements, 2524
NDB Cluster How-To, 2146
NDB Cluster limitations, 2134
  and differences from standard MySQL limits, 2136
  binary logging, 2141
  CREATE TABLE statements, 2144
  database objects, 2140
  Disk Data storage, 2142
  error handling and reporting, 2139
  geometry data types, 2135
  implementation, 2141
  imposed by configuration, 2136
  INSERT IGNORE, UPDATE IGNORE, and REPLACE statements, 2144
  memory usage and transaction handling, 2139
  multiple data nodes, 2144
  multiple management servers, 2143
  multiple MySQL servers, 2143
  partitioning, 2135
  performance, 2141
  replication, 2136, 2144
  resolved in current version from previous versions, 2143
syntax, 2134
transactions, 2137
unsupported features, 2140
NDB Cluster processes, 2349
NDB Cluster programs, 2349
NDB Cluster replication, 2553
and --initial option, 2560
and circular replication, 2557
and NDB API database objects, 2556
and primary key, 2559
and single point of failure, 2569
and unique keys, 2559
backups, 2572
circular replication, 2578
concepts, 2555, 2555
conflict resolution, 2582
failover, 2569, 2570
gap event, 2557
known issues, 2556
loss of connection, 2557
multi-master replication, 2578
point-in-time recovery, 2577
preparing, 2565
requirements, 2555
reset-slave.pl backup automation script, 2574
restoring from backup, 2572
starting, 2567
storage engines other than NDB on slave, 2561
synchronization of master and slave, 2574
system tables used, 2563
NDB Cluster Replication
and NDB API _slave status variables, 2554
NDB Cluster replication conflict resolution
exceptions table, 2589
ndb option
perror, 447
NDB statistics variables
and NDB API counters, 2548
NDB statistics variables (NDB Cluster), 2542
scope, 2546
types, 2546
NDB storage engine (see NDB Cluster)
FAQ, 3039
NDB tables
and MySQL root user, 2514
NDB utilities
security issues, 2517
NDB$EPOCH(), 2587
limitations, 2588
NDB$EPOCH_TRANS(), 2587, 2589
NDB$MAX(), 2586
NDB$MAX_DELETE_WIN(), 2586
NDB$OLD, 2586
ndb-batch-size option
mysqld, 2293
ndb-blob-read-batch-bytes option
  mysqld, 2295
ndb-blob-write-batch-bytes option
  mysqld, 2295
ndb-cluster-connection-pool option
  mysqld, 2294
ndb-connectstring option
  mysqld, 2296
    ndb_config, 2376
ndb-connectstring option (NDB Cluster programs), 2440
ndb-deferred-constraints option (NDB Cluster), 2296
ndb-distribution option (NDB Cluster), 2296
ndb-log-apply-status option
  mysqld, 2296
ndb-log-empty-epochs option
  mysqld, 2297
ndb-log-empty-update option
  mysqld, 2297
ndb-log-orig option
  mysqld, 2298
ndb-log-transaction-id option
  mysqld, 2298
ndb-log-update-as-write (mysqld option), 2583
ndb-mgmd-host option (NDB Cluster programs), 2440
ndb-mgmd-host option (NDB Cluster), 2299
ndb-nodegroup-map option
  ndb_restore, 2415
ndb-nodeid option
  mysqld, 2299
ndb-nodeid option (NDB Cluster programs), 2440
ndb-optimized-node-selection option (NDB Cluster), 2441
ndbcluster option
  mysqld, 2293
NDBCLUSTER storage engine (see NDB Cluster)
ndbd, 2349, 2349
ndbd (NDB Cluster)
  defined, 2118
    (see also data node (NDB Cluster))
ndbinfo database, 2486
  and query cache, 2488
  basic usage, 2489
  determining support for, 2486
ndbinfo_select_all, 2349, 2357
ndbmtd, 2349, 2358
  configuration, 2269, 2269
  MaxNoOfExecutionThreads, 2266
  trace files, 2359, 2359
ndb_apply_status table (NDB Cluster replication), 2564, 2565, 2570
  (see also NDB Cluster replication)
ndb_binlog_index table
  system table, 672, 2563
ndb_binlog_index table (NDB Cluster replication), 2563, 2570
  (see also NDB Cluster replication)
ndb_blob_tool, 2349, 2370
  check-orphans option, 2370
  database option, 2371
  delete-orphans option, 2371
  dump-file option, 2371
  verbose option, 2371
ndb_config, 2349, 2372
  config-file option, 2375
  configinfo option, 2374
  config_from_node option, 2375
  connections option, 2375
  fields option, 2375
  host option, 2376
  mycnf option, 2376
  ndb-connectstring option, 2376
  nodeid option, 2377
  nodes option, 2377
  query option, 2377, 2378
  rows option, 2377
  system option, 2378
  type option, 2378
  usage option, 2379
  version option, 2379
  xml option, 2379
ndb_cpcd, 2349, 2381
ndb_delete_all, 2349, 2381
  transactional option, 2382
ndb_desc, 2349, 2382
  blob-info option, 2386
  database option, 2386
  extra-node-info option, 2386
  extra-partition-info option, 2386
  retries option, 2386
  table option, 2386
  unqualified option, 2387
ndb_dist_priv.sql, 2539
ndb_drop_index, 2349, 2387
ndb_drop_table, 2349, 2388
ndb_error_reporter, 2349, 2388
  options, 2389
ndb_index_stat, 2349, 2390
  example, 2390
  interpreting output, 2390
ndb_join_pushdown, 2308
ndb_log_apply_status variable (NDB Cluster replication), 2570
ndb_log_empty_epochs system variable, 2309
ndb_log_empty_update system variable, 2309
ndb_log_orig system variable, 2310
ndb_log_transaction_id system variable, 2310
ndb_mgm, 2349, 2368 (see mgm)
  using with MySQL Cluster Manager, 2444
ndb_mgm (NDB Cluster management node client), 2166
ndb_mgmd, 2349 (see mgmd)
  mycnf option, 2364

3310
ndb_mgmt (NDB Cluster process), 2359
ndb_mgmt (NDB Cluster)
defined, 2118
(see also management node (NDB Cluster))
ndb_move_data, 2349, 2396
abort-on-error option, 2397
calendar-sets-dir option, 2397
database option, 2397
drop-source option, 2397
error-insert option, 2397
exclude-missing-columns option, 2397
lossy-conversions option, 2398
promote-attributes option, 2398
staging-tries option, 2398
verbose option, 2398
ndb_print_backup_file, 2349, 2398
ndb_print_file, 2349, 2399
ndb_print_frag_file, 2349
ndb_print_schema_file, 2349, 2399
ndb_print_sys_file, 2349, 2400
ndb_redo_log_reader, 2400
dump option, 2401
lap option, 2402
twiddle option, 2403
ndb_replication system table, 2584
ndb_restore, 2404
and circular replication, 2580
and distributed privileges, 2542
append option, 2408
backup-path option, 2408
backupid option, 2408
connect option, 2409
disable-indexes option, 2409
dont-ignore-systab-0 option, 2409
errors, 2422
exclude-databases option, 2409
exclude-intermediate-sql-tables option, 2410
exclude-missing-columns option, 2410
exclude-missing-tables option, 2410
exclude-tables option, 2410
fields-enclosed-by option, 2412
fields-optionally-enclosed-by option, 2412
fields-terminated-by option, 2412
hex option, 2412
include-databases option, 2412
include-tables option, 2413
lines-terminated-by option, 2414
lossy-conversions option, 2414
ndb-nodegroup-map option, 2415
no-binlog option, 2414
no-restore-disk-objects option, 2415
no-upgrade option, 2415
nodeid option, 2415
parallelism option, 2415
preserve-trailing-spaces option, 2416
print option, 2416
print-data option, 2416
print-log option, 2417
print-meta option, 2417
progress-frequency option, 2417
promote-attributes option, 2417
rebuild-indexes option, 2418
restore-data option, 2419
restore-epoch option, 2419
restore-meta option, 2419
restore-privilege-tables option, 2419
rewrite-database option, 2420
skip-broken-objects option, 2421
skip-table-check option, 2421
skip-unknown-objects option, 2421
tab option, 2421
typical and required options, 2407
verbose option, 2422
ndb_select_all, 2349, 2426
database option, 2427
delimiter option, 2428
descending option, 2427
disk option, 2428
gci option, 2428
gci64 option, 2428
header option, 2427
lock option, 2427
nodata option, 2428
order option, 2427
parallelism option, 2427
rowid option, 2428
tupscan option, 2428
useHexFormat option, 2428
ndb_select_count, 2349, 2429
ndb_show_tables, 2349, 2430
database option, 2431
loops option, 2431
parsable option, 2431
show-temp-status option, 2431
type option, 2431
unqualified option, 2431
ndb_size.pl, 2349, 2431
ndb_transid_mysql_connection_map
   INFORMATION_SCHEMA table, 2755
ndb_waiter, 2349, 2434
   no-contact option, 2435
   not-started option, 2435
   nowait-nodes option, 2435
   single-user option, 2435
   timeout option, 2435
   wait-nodes option, 2436
negative values, 1032
neighbor page, 3771
nested queries, 1529
Nested-Loop join algorithm, 891
nested-loop join algorithm, 895
net-buffer-length option
  mysql, 321
  mysqldump, 365
netmask notation
  in account names, 766
network ports
  and NDB Cluster, 2513
net_buffer_length system variable, 579
net_read_timeout system variable, 579
net_retry_count system variable, 580
net_write_timeout system variable, 580
new features, 9
  build configuration, 13
  default storage engine, 10
  diagnostics, 12
  InnoDB, 10
  InnoDB I/O subsystem, 10
  innodb_adaptive_hash_index, 12
  innodb_file_per_table, 12
  innodb_lock_wait_timeout, 12
  innodb_stats_on_metadata, 12
  innodb_use_native_aio, 11
  IPv6 support, 13
  LOAD XML, 13
  metadata locking, 13
  multi-core scalability, 10
  MySQL Enterprise Audit, 9
  MySQL Enterprise Thread Pool, 9
  NDB Cluster, 12
  PAM authentication plugin, 10
  partitioning, 13
  pluggable authentication, 10
  semisynchronous replication, 12
  signals, 13
  Solaris, 12
  TO_SECONDS(), 13
  Unicode support, 12
  Windows authentication plugin, 10
  XML support, 13
new features in NDB Cluster, 2125
new system variable, 580
new users
  adding, 194
  newline (\n), 1030, 1500
next-key lock, 1742, 3771
  InnoDB, 1742, 1825
NFS
  InnoDB, 1762
nice option
  mysqld_safe, 293
no matching rows, 3171
no-auto-rehash option
  mysql, 321
no-autocommit option
  mysqldump, 365
no-beep option
  mysql, 321
  mysqladmin, 343
no-binlog option
  ndb_restore, 2414
no-contact option
  ndb_waiter, 2435
no-create-db option
  mysqldump, 365
no-create-info option
  mysqldump, 365
no-data option
  mysqldump, 365
no-defaults option, 275, 304
  myisamchk, 397
  mysql, 321
  mysqladmin, 343
  mysqlbinlog, 426
  mysqlcheck, 351
  mysqld, 518
  mysqldump, 365
  mysqld_multi, 298
  mysqld_safe, 293
  mysqlimport, 376
  mysqlshow, 381
  mysqlslap, 388
  mysql_plugin, 307
  mysql_upgrade, 313
  my_print_defaults, 445
  NDB client programs, 2440
no-drop option
  mysqlslap, 388
no-log option
  mysqld_multi, 299
no-nodeid-checks option (ndb_mgmd), 2364
no-restore-disk-objects option
  ndb_restore, 2415
no-set-names option
  mysqldump, 365
no-symlinks option
  myisamchk, 401
no-tablespaces option
  mysqldump, 366
no-upgrade option
  ndb_restore, 2415
nodaemon option (ndb_mgmd), 2365
nodata option
  ndb_select_all, 2428
node groups (NDB Cluster), 2121
node logs (NDB Cluster), 2456
NodeGroup, 2212
Nodeid, 2203, 2210, 2284
nodeid option
  ndb_config, 2377
  ndb_restore, 2415
Nodeid1, 2332, 2340, 2343
Nodeid2, 2333, 2340, 2343
NodeidServer, 2340
NODERESTART Events (NDB Cluster), 2461
nodes
  ndbinfo table, 2500
nodes option
  ndb_config, 2377
noindices option
  mysqlhotcopy, 438
non-locking read, 3771
non-repeatable read, 3771
nonblocking I/O, 3771
nondelimited strings, 1034
nondeterministic functions
  optimization, 910
  replication, 910
Nontransactional tables, 3170
NoOfDiskPagesToDiskAfterRestartACC (DEPRECATED), 2251
NoOfDiskPagesToDiskAfterRestartTUP (DEPRECATED), 2251
NoOfDiskPagesToDiskDuringRestartACC, 2251
NoOfDiskPagesToDiskDuringRestartTUP, 2251
NoOfFragmentLogFiles, 2227
NoOfFragmentLogParts, 2269
NoOfReplicas, 2213
nopager command
  mysql, 328
normalized, 3771
NoSQL, 3772
nostart option (ndbd), 2354
nostart option (ndbmttd), 2354
NOT
  logical, 1237
NOT BETWEEN, 1233
not equal (!=), 1232
not equal (<>), 1232
NOT EXISTS
  with subqueries, 1534
NOT IN, 1234
NOT LIKE, 1288
NOT NULL
  constraint, 31
NOT NULL constraint, 3772
NOT REGEXP, 1289
not-started option
  ndb_waiter, 2435
notee command
  mysql, 328
NOW(), 1263
NOWAIT (START BACKUP command), 2450
nowait-nodes option
    ndb_waiter, 2435
nowait-nodes option (ndbd), 2354
nowait-nodes option (ndbmtd), 2354
nowait-nodes option (ndb_mgmd), 2365
nowarning command
    mysql, 328
NO_AUTO_CREATE_USER SQL mode, 653
NO_AUTO_VALUE_ON_ZERO SQL mode, 653
NO_BACKSLASH_ESCAPES SQL mode, 653
NO_DIR_IN_CREATE SQL mode, 653
NO_ENGINE_SUBSTITUTION SQL mode, 653
NO_FIELD_OPTIONS SQL mode, 654
NO_KEY_OPTIONS SQL mode, 654
NO_TABLE_OPTIONS SQL mode, 654
NO_UNSIGNED_SUBTRACTION SQL mode, 654
NO_ZERO_DATE SQL mode, 655
NO_ZERO_IN_DATE SQL mode, 655
NULL, 1030, 1500
NULL, 242, 3168, 3772
    ORDER BY, 904, 1517
    testing for null, 1231, 1233, 1235, 1235, 1240
    thread state, 1018
NULL value, 242, 1038
    ORDER BY, 1038
NULL values
    and AUTO_INCREMENT columns, 3169
    and indexes, 1434
    and TIMESTAMP columns, 3169
    vs. empty values, 3168
NULL-complemented row, 895, 899
null-rejected condition, 899
NULLIF(), 1241
Numa, 2266
number-char-cols option
    mysqlslap, 388
number-int-cols option
    mysqlslap, 389
number-of-queries option
    mysqlslap, 389
numbers, 1032
NUMERIC data type, 1161
numeric data types, 1158
    storage requirements, 1210
numeric literals
    approximate-value, 1032, 1376
    exact-value, 1032, 1376
numeric precision, 1158
numeric scale, 1158
numeric-dump-file option
    resolve_stack_dump, 446
NumGeometries(), 1359
NumInteriorRings(), 1358
NumPoints(), 1357
NVARCHAR data type, 1180

O

objects
  stored, 2655
obtaining information about partitions, 2635
OCT(), 1281
OCTET_LENGTH(), 1281
ODBC compatibility, 602, 1041, 1161, 1226, 1235, 1434, 1524
ODBC.INCLUDES= option
  CMake, 181
ODBC_LIB_DIR option
  CMake, 181
ODirect, 2238
OFF
  plugin activation option, 696
off-page column, 3773
offset option
  mysqlbinlog, 426
OGC (see Open Geospatial Consortium)
OLAP, 1366
old system variable, 581
old-style-user-limits option
  mysql, 518
old_alter_table system variable, 581
OLD_PASSWORD(), 1334
old_passwords system variable, 582
old_server option
  mysqlaccess, 419
  mysqlhotcopy, 438
OLTP, 3773
ON
  plugin activation option, 697
ON DUPLICATE KEY
  INSERT modifier, 1489
ON DUPLICATE KEY UPDATE, 1485
ON versus USING
  joins, 1527
one-database option
  mysql, 321
one-thread option
  mysql, 518
one_shot system variable, 582
online, 3773
online DDL, 3773
online location of manual, 2
online upgrades and downgrades (NDB Cluster), 2454
only-print option
  mysqlslap, 389
ONLY_FULL_GROUP_BY
  SQL mode, 1370
ONLY_FULL_GROUP_BY SQL mode, 656
OPEN, 1583
Open Geospatial Consortium, 1191
Open Source
defined, 5
open tables, 340, 940
open-files-limit option
 mysqlbinlog, 426
mysqld_safe, 293
OpenGIS, 1191
opening
tables, 940
Opening master dump table
 thread state, 1025
Opening mysql.ndb_apply_status
 thread state, 1026
Opening table
 thread state, 1018
Opening tables
 thread state, 1018
opens, 340
OpenSSL, 175, 795
 compared to yaSSL, 806
open_files_limit system variable, 582
operating systems
 file-size limits, 943
 supported, 44
operations
 arithmetic, 1243
operators, 1216
 arithmetic, 1328
 assignment, 1072, 1238
 bit, 1328
 cast, 1242, 1310
 logical, 1236
 precedence, 1229
 string, 1273
 string comparison, 1285
.OPT file, 3772
opt option
 mysqldump, 366
optimistic, 3773
optimization, 878, 951
 benchmarking, 1010
BLOB types, 939
buffering and caching, 977
character and string types, 938
data change statements, 924
data size, 936
DELETE statements, 925
disk I/O, 999
foreign keys, 927
full table scans, 913
full-text queries, 928, 950
indexes, 926
INFORMATION_SCHEMA queries, 918
InnoDB tables, 947
INSERT statements, 924
locking, 989
many tables, 939
MEMORY storage engine, 929
MEMORY tables, 958
memory usage, 1003
MyISAM tables, 954
network usage, 1007
nondeterministic functions, 910
numeric types, 938
Performance Schema queries, 940
PERFORMANCE_SCHEMA, 1012
primary keys, 927
privileges, 925
REPAIR TABLE statements, 957
SELECT statements, 880
spatial queries, 929
SQL statements, 880
subqueries, 914
tips, 925
UPDATE statements, 924
WHERE clauses, 881
optimization (NDB), 889,
optimizations, 886
LIMIT clause, 909
row constructors, 912
optimize option
mysqlcheck, 351
OPTIMIZE TABLE
and partitioning, 2634
OPTIMIZE TABLE statement, 1623
optimizer, 3774
and replication, 2099
controlling, 973
query plan evaluation, 973
switchable optimizations, 974
Optimizer Statistics, 1775
optimizer_prune_level system variable, 583
optimizer_search_depth system variable, 583
optimizer_switch system variable, 584, 974
optimizing
DISTINCT, 908
filesort, 905
GROUP BY, 906
LEFT JOIN, 898
ORDER BY, 902
outer joins, 898
RIGHT JOIN, 898
server configuration, 998
tables, 875
thread state, 1018
option, 3774
option file, 3774
option files, 270, 790
  .my.cnf, 270, 271, 287, 713, 736, 790
  C:\my.cnf, 713
deprecated features, 14
escape sequences, 272
my.cnf, 2083

option prefix
  --disable, 275
  --enable, 275
  --loose, 275
  --maximum, 275
  --skip, 275

option prefixes
deprecated features, 14
options
  boolean, 275
  CMake, 175
command-line
  mysql, 315
  mysqladmin, 340
embedded server, 2818
libmysql, 2818
myisamchk, 396
mysqld, 454
  provided by MySQL, 227
replication, 2083
OR, 256, 886
  bitwise, 1328
  logical, 1237
OR Index Merge optimization, 886
Oracle compatibility, 26, 1366, 1396, 1692
ORACLE SQL mode, 658
ORDER(), 1281
ORDER BY, 239, 1401, 1517
  maximum sort length, 1517
  NULL, 904, 1517
  NULL value, 1038
ORDER BY optimization, 902
order option
  ndb_select_all, 2427
order-by-primary option
  mysqldump, 366
OS X
  installation, 132
Out of resources error
  and partitioned tables, 2643
OUT parameter
  condition handling, 1600
out-dir option
  comp_err, 302
out-file option
  comp_err, 302
out-of-range handling, 1164
outer joins
   optimizing, 898
OUTFILE, 1521
overflow handling, 1164
overflow page, 3774
Overlaps(), 1361
OverloadLimit, 2334, 2341, 2347
overview, 1

P
packages
   list of, 39
PAD SPACE collations, 1114, 1183
   PAD_CHAR_TO_FULL_LENGTH SQL mode, 656
   page, 3774
   page cleaner, 3774
   page size, 3775
      InnoDB, 1733
pager command
   mysql, 328
pager option
   mysql, 322
PAM
   pluggable authentication, 810
PAM authentication plugin
   new features, 10
   .par file, 3774
parallel-recover option
   myisamchk, 401
parallelism option
   ndb_restore, 2415
parameters
   server, 454
PARAMETERS
   INFORMATION_SCHEMA table, 2706
parent table, 3775
parentheses ( and ), 1230
parsable option
   ndb_show_tables, 2431
partial backup, 3775
partial index, 3775
partial updates
   and replication, 2101
PARTITION, 2593
PARTITION BY LIST COLUMNS, 2606
PARTITION BY RANGE COLUMNS, 2606
partition management, 2626
partition option
   mysqld, 518
partition pruning, 2637
partitioning, 2593
   advantages, 2597
   and dates, 2598
and foreign keys, 2644
and FULLTEXT indexes, 2644
and key cache, 2644
and query cache, 2644
and replication, 2099, 2101
and SQL mode, 2101, 2641
and subqueries, 2645
and temporary tables, 2645, 2647
by hash, 2614
by key, 2617
by linear hash, 2616
by linear key, 2618
by list, 2604
by range, 2599
COLUMNS, 2606
concepts, 2595
data type of partitioning key, 2645
enabling, 2593
functions allowed in partitioning expressions, 2651
keys, 2597
limitations, 2640
new features, 13
operators not permitted in partitioning expressions, 2641
operators supported in partitioning expressions, 2641
optimization, 2636, 2637
partitioning expression, 2597
resources, 2595
storage engines (limitations), 2650
subpartitioning, 2645
support, 2593
support in NDB Cluster, 2135
tables, 2593
types, 2598
Partitioning
maximum number of partitions, 2643
partitioning information statements, 2635
partitioning keys and primary keys, 2647
partitioning keys and unique keys, 2647
partitions
adding and dropping, 2626
analyzing, 2634
checking, 2634
managing, 2626
modifying, 2626
optimizing, 2634
repairing, 2634
splitting and merging, 2626
truncating, 2626
PARTITIONS
INFORMATION_SCHEMA table, 2707
partitions (NDB Cluster), 2121
password
root user, 199
password encryption
reversibility of, 1335
password option, 281
mysql, 322
mysqlaccess, 419
mysqladmin, 344
mysqlbinlog, 426
mysqlcheck, 351
mysqldump, 366
mysqld_multi, 299
mysqlhotcopy, 438
mysqlimport, 376
mysqlshow, 381
mysqldump, 389
mysql_convert_table_format, 439
mysql_setpermission, 441
mysql_upgrade, 313
PASSWORD(), 767, 775, 1334, 3155
passwords
administrator guidelines, 737
for users, 750
forgotten, 3158
hashing, 737
logging, 737
lost, 3158
resetting, 3158
security, 735, 749
setting, 775, 1607, 1616
user guidelines, 735
PATH environment variable, 123, 129, 197, 267, 449
path name separators
Windows, 273
pattern matching, 243, 1289
performance, 878
benchmarks, 1012
disk I/O, 999
estimating, 973
Performance Schema, 1856, 2763, 3775
event filtering, 2775
memory use, 2771
Performance Schema queries
optimization, 940
performance_schema
cond_instances table, 2790
events_waits_current table, 2794
events_waits_history table, 2796
events_waits_history_long table, 2797
events_waits_summary_by_instance table, 2797
events_waits_summary_by_thread_by_event_name table, 2797
events_waits_summary_global_by_event_name table, 2797
file_instances table, 2790
file_summary_by_event_name table, 2799
file_summary_by_instance table, 2799
mutex_instances table, 2791
performance_timers table, 2800

3323
rwlock_instances table, 2792
setup_consumers table, 2788
setup_instruments table, 2788
setup_timers table, 2789
threads table, 2800
performance_schema database, 2763
   restrictions, 2811
   TRUNCATE TABLE, 2785, 2811
PERFORMANCE_SCHEMA storage engine, 2763
performance_schema system variable, 2803
Performance_schema_cond_classes_lost status variable, 2808
Performance_schema_cond_instances_lost status variable, 2808
performance_schema_events_waits_history_long_size system variable, 2803
performance_schema_events_waits_history_size system variable, 2803
Performance_schema_file_classes_lost status variable, 2808
Performance_schema_file_handles_lost status variable, 2808
Performance_schema_file_instances_lost status variable, 2809
Performance_schema_locker_lost status variable, 2809
performance_schema_max_cond_classes system variable, 2803
performance_schema_max_cond_instances system variable, 2804
performance_schema_max_file_classes system variable, 2804
performance_schema_max_file_handles system variable, 2804
performance_schema_max_file_instances system variable, 2805
performance_schema_max_mutex_classes system variable, 2805
performance_schema_max_mutex_instances system variable, 2805
performance_schema_max_rwlock_classes system variable, 2806
performance_schema_max_rwlock_instances system variable, 2806
performance_schema_max_table_handles system variable, 2806
performance_schema_max_table_instances system variable, 2807
performance_schema_max_thread_classes system variable, 2807
performance_schema_max_thread_instances system variable, 2807
Performance_schema_mutex_classes_lost status variable, 2809
Performance_schema_mutex_instances_lost status variable, 2809
Performance_schema_rwlock_classes_lost status variable, 2809
Performance_schema_rwlock_instances_lost status variable, 2809
Performance_schema_table_handles_lost status variable, 2809
Performance_schema_table_instances_lost status variable, 2809
Performance_schema_thread_classes_lost status variable, 2809
Performance_schema_thread_instances_lost status variable, 2809
performance_timers table
   performance_schema, 2800
PERIOD_ADD(), 1264
PERIOD_DIFF(), 1264
Perl
   installing, 223
   installing on Windows, 224
Perl API, 2945
Perl DBI/DBD
   installation problems, 225
permission checks
   effect on speed, 925
perror, 266, 446
   help option, 447
   ndb option, 447
silent option, 447
verbose option, 447
version option, 447
pessimistic, 3775
phantom, 3775
phantom rows, 1757
phone book collation, German, 1086, 1130, 1130
physical, 3776
physical backup, 3776
Pi(), 1249
pid-file option
  mysql.server, 297
  mysqld_safe, 293
pid_file system variable, 585
Ping
  thread command, 1014
pipe option, 281
  mysql, 322, 351
  mysqladmin, 344
  mysqldump, 366
  mysqlimport, 376
  mysqlshow, 382
  mysqlslap, 389
  mysql_upgrade, 313
PI() AS CONCAT SQL mode, 656
PITR, 3776
plan option
  mysqlaccess, 419
plan stability, 3776
pluggable authentication
  new features, 10
  PAM, 810
  restrictions, 779
  Windows, 821
plugin
  audit_log, 829
plugin activation options
  FORCE, 697
  FORCE_PLUS_PERMANENT, 697
  OFF, 696
  ON, 697
plugin API, 694, 2949
plugin installing
  audit_log, 831
  MySQL Enterprise Thread Pool, 700
plugin option prefix
  mysqld, 519
plugin service
  my_snprintf, 2996
  my_thd_scheduler, 2996
  thd_alloc, 2996
  thd_wait, 2996
plugin services, 2995
plugin table
system table, 671
plugin-dir option, 281
mysql, 322
mysqladmin, 344
mysqlbinlog, 426
mysqlcheck, 351
mysqladmin, 366
mysqld_safe, 293
mysqlimport, 377
mysqlshow, 382
mysqlslap, 389
mysql_plugin, 307
mysql_upgrade, 313
plugin-ini option
mysql_plugin, 307
plugin-load option
mysqld, 518
plugindir option
mysql_config, 444
plugins
activating, 694
adding, 2949
audit, 2952
authentication, 2952
daemon, 2951
full-text parser, 2950
INFORMATION_SCHEMA, 2951
installing, 694, 1628
security, 807
semisynchronous replication, 2951
server, 694
storage engine, 2950
uninstalling, 694, 1630
PLUGINS
INFORMATION_SCHEMA table, 2711
plug_dir system variable, 585
POINT data type, 1193
Point(), 1353
point-in-time recovery, 868, 3776
InnoDB, 1875
using NDB Cluster replication, 2577
PointFromText(), 1351
PointFromWKB(), 1352
PointN(), 1357
PolyFromText(), 1351
PolyFromWKB(), 1352
POLYGON data type, 1193
Polygon(), 1353
PolygonFromText(), 1351
PolygonFromWKB(), 1352

port option, 281
mysql, 322
mysqladmin, 344
mysqlbinlog, 426

3326
mysqlcheck, 351
mysql, 520
mysqldump, 366
mysqld_safe, 293
mysqlhotcopy, 438
mysqlimport, 377
mysqlshow, 382
mysqlslap, 389
mysql_config, 444
mysql_convert_table_format, 439
mysql_setpermission, 441
mysql_upgrade, 313
port system variable, 585
port-open-timeout option
mysqld, 520
portability, 880
types, 1213
porting
to other systems, 3009
PortNumber, 2204
PortNumber (OBSOLETE), 2336
PortNumberStats, 2207
ports, 285, 448, 734
POSITION(), 1281
post-filtering
Performance Schema, 2775
post-query option
mysqlslap, 389
post-system option
mysqlslap, 389
PostgreSQL compatibility, 27
POSTGRESQL SQL mode, 658
postinstall
multiple servers, 706
postinstallation
setup and testing, 190
POW(), 1249
POWER(), 1249
pre-filtering
Performance Schema, 2775
pre-query option
mysqlslap, 390
pre-system option
mysqlslap, 390
precedence
command options, 268
operator, 1229
precision
arithmetic, 1375
numeric, 1158
precision math, 1375
preload_buffer_size system variable, 586
Prepare
thread command, 1014
PREPARE, 1570, 1573
    XA transactions, 1558
prepared backup, 3776
prepared statement C API
    data structures, 2892
    functions, 2898, 2899
    type codes, 2896
prepared statements, 1570, 1573, 1573, 1574, 2892
    repreparation, 1574
preparing
    thread state, 1018
preserve-trailing-spaces option
    ndb_restore, 2416
preview option
    mysqlaccess, 419
primary key, 3776
    constraint, 30
    deleting, 1398
PRIMARY KEY, 1398, 1436
primary keys
    and partitioning keys, 2647
print command
    mysql, 328
print option
    ndb_restore, 2416
print-data option
    ndb_restore, 2416
print-defaults option, 275
    myisamchk, 397
    mysql, 322
    mysqladmin, 344
    mysqlbinlog, 427
    mysqlcheck, 351
    mysqld, 520
    mysqldump, 366
    mysqlimport, 377
    mysqlshow, 382
    mysqlslap, 390
    mysql_plugin, 307
    mysql_upgrade, 313
    NDB client programs, 2441
print-full-config option (ndb_mgmd), 2367
print-log option
    ndb_restore, 2417
print-meta option
    ndb_restore, 2417
privilege
    changes, 775
    privilege checks
        effect on speed, 925
    privilege information
        location, 758
    privilege system, 749
    privileges
access, 749
adding, 772
ALL, 754
ALL PRIVILEGES, 754
ALTER, 754
ALTER ROUTINE, 754
and replication, 2099
checking, 774
CREATE, 754
CREATE ROUTINE, 754
CREATE TABLESPACE, 754
CREATE TEMPORARY TABLES, 754
CREATE USER, 754
CREATE VIEW, 754
default, 199
DEFINER, 1655, 2676
DELETE, 754
deleting, 1603
display, 1654
DROP, 754
dropping, 1603
EVENT, 754
EXECUTE, 755
FILE, 755
GRANT OPTION, 755
granting, 1603
INDEX, 755
INSERT, 755
INVOKER, 1655, 2676
LOCK TABLES, 755
PROCESS, 755
PROXY, 755
REFERENCES, 756
RELOAD, 756
REPLICATION CLIENT, 756
REPLICATION SLAVE, 756
revoking, 774, 1615
SELECT, 756
SHOW DATABASES, 756
SHOW VIEW, 757
SHUTDOWN, 757
SQL SECURITY, 2676
stored objects, 2676
SUPER, 757
TEMPORARY tables, 754, 1453
TRIGGER, 757
UPDATE, 758
USAGE, 758
problems
access denied errors, 3143
common errors, 3141
compiling, 188
DATE columns, 3167
date values, 1169
installing on Solaris, 163
installing Perl, 225
linking, 2826
lost connection errors, 3148
reporting, 2, 19
starting the server, 195
table locking, 992
time zone, 3165
proc table
  system table, 671
PROCEDURE, 1519
PROCEDURE ANALYSE(), 939
procedures
  stored, 2657
process, 3777
process management (NDB Cluster), 2349
PROCESS privilege, 755
processes
  display, 1661
processing
  arguments, 3002
Processing events
  thread state, 1026
Processing events from schema table
  thread state, 1026
Processlist
  thread command, 1014
PROCESSLIST, 1661
  INFORMATION_SCHEMA table, 2712
  possible inconsistency with INFORMATION_SCHEMA tables, 1851
procs_priv table
  system table, 671, 759
PROFILING
  INFORMATION_SCHEMA table, 2713
profiling system variable, 586
profiling_history_size system variable, 586
program options (NDB Cluster), 2437
program variables
  setting, 276
program-development utilities, 265
programs
  administrative, 264
  client, 263, 2824
  stored, 1574, 2655
  utility, 264
progress-frequency option
  ndb_restore, 2417
promote-attributes option
  ndb_move_data, 2398
  ndb_restore, 2417
prompt command
  mysql, 328
prompt option
  mysql, 323
prompts
   meanings, 230
pronunciation
   MySQL, 5
protocol option, 281
   mysql, 323
   mysqladmin, 344
   mysqlbinlog, 427
   mysqlcheck, 352
   mysqldump, 367
   mysqlimport, 377
   mysqlshow, 382
   mysqlslap, 390
   mysql_upgrade, 313
protocol_version system variable, 586
proxies_priv
   grant table, 783
proxies_priv table
   system table, 199, 671, 759
PROXY privilege, 755
proxy users, 781
   conflict with anonymous users, 785
   default proxy user, 784
   PAM authentication, 817
   PROXY privilege, 783
   system variables, 786
   Windows authentication, 825
proxy_user system variable, 586
pseudo-record, 3777
pseudo_slave_mode system variable, 587
pseudo_thread_id system variable, 587
Pthreads, 3777
purge, 1774, 3777
PURGE BINARY LOGS, 1561
purge buffering, 3777
purge configuration, 1774
purge lag, 3777
PURGE MASTER LOGS, 1561
purge scheduling, 1774
purge thread, 3777
Purging old relay logs
   thread state, 1018
pushdown joins (NDB),
Python, 2816
   third-party driver, 2946

Q
QUARTER(), 1264
queries
   entering, 228
   estimating performance, 973
   examples, 251
   speed of, 880
Query
  thread command, 1014
query, 3777
Query Cache, 982
query cache
  and ndbinfo database tables, 2488
  and partitioned tables, 2644
  thread states, 1023
query end
  thread state, 1018
query execution plan, 959, 3777
query option
  mysqlslap, 390
  ndb_config, 2377, 2378
query option (ndb_index_stat), 2393
query_alloc_block_size system variable, 587
query_cache_limit system variable, 587
query_cache_min_res_unit system variable, 588
query_cache_size system variable, 588
query_cache_type system variable, 589
query_cache_wlock_invalidate system variable, 589
query_prealloc_size system variable, 590
questions, 340
Queueing master event to the relay log
  thread state, 1024
QUICK
  DELETE modifier, 1481
quick option
  myisamchk, 401
  mysql, 323
  mysqlcheck, 352
  mysqldump, 367
quiesce, 3778
quiet option
  mysqlhotcopy, 438
Quit
  thread command, 1014
quit command
  mysql, 328
QUIT command (NDB Cluster), 2447
 quotation marks
  in strings, 1031
QUOTE(), 1031, 1281, 2879
quote-names option
  mysqldump, 367
quoting, 1031
  account names, 765
  column alias, 1039, 3169
  host names in account names, 765
  schema objects, 1606
  user names in account names, 765
quoting binary data, 1031
quoting of identifiers, 1038
R-tree, 3778
RADIANS(), 1249
RAID, 3778
RAND(), 1250
random dive, 3778
rand_seed1 system variable, 590
rand_seed2 system variable, 591
range join type
  optimizer, 965
range partitioning, 2599, 2606
range partitions
  adding and dropping, 2627
  managing, 2627
range_alloc_block_size system variable, 591
raw backup, 3778
raw option
  mysql, 323
raw partitions, 1736
RC
  MySQL releases, 44
re-creating
  grant tables, 194
READ COMMITTED, 3778
  implementation in NDB Cluster, 2137
  transaction isolation level, 1747
read phenomena, 3778
READ UNCOMMITTED, 3779
  transaction isolation level, 1749
read view, 3779
read-ahead, 3779
  linear, 1767
  random, 1767
read-from-remote-server option
  mysqlbinlog, 427
read-only option
  myisamchk, 400
read-only transaction, 3779
Reading event from the relay log
  thread state, 1025
Reading from net
  thread state, 1018
Reading master dump table data
  thread state, 1026
read_buffer_size myisamchk variable, 398
read_buffer_size system variable, 591
read_only system variable, 592
read_rnd_buffer_size system variable, 593
REAL data type, 1162
RealtimeScheduler, 2264
REAL_AS_FLOAT SQL mode, 656
rebuild-indexes option
  ndb_restore, 2418
Rebuilding the index on master dump table
  thread state, 1026
ReceiveBufferMemory, 2336
reconfiguring, 188
reconnect option
  mysql, 323
Reconnecting after a failed binlog dump request
  thread state, 1024
Reconnecting after a failed master event read
  thread state, 1024
reconnection
  automatic, 2942
record lock, 3779
record-level locks
  InnoDB, 1757, 1825
record_buffer
  removed features, 14
record_log_pos option
  mysqlhotcopy, 438
RECOVER
  XA transactions, 1558
recover option
  myisamchk, 401
recovery
  from crash, 871
  incremental, 868
  InnoDB, 1875
  point in time, 868
redo, 3779
redo log, 1739, 1740, 3779
redo log archiving, 3780
RedoBuffer, 2255
RedoOverCommitCounter
data nodes, 2279
RedoOverCommitLimit
data nodes, 2279
reducing
  data size, 936
redundant row format, 1793, 3780
ref join type
  optimizer, 964
references, 1399
REFERENCES privilege, 756
referential integrity, 1698, 3780
REFERENTIAL_CONSTRAINTS
  INFORMATION_SCHEMA table, 2714
Refresh
  thread command, 1014
ref_or_null, 901
ref_or_null join type
  optimizer, 964
REGEXP, 1289
REGEXP operator, 1289
regexp option
mysqlhotcopy, 438
mysql_find_rows, 440
Register Slave
  thread command, 1015
Registering slave on master
  thread state, 1024
regular expression syntax, 1289
rehash command
  mysql, 328
relational, 3780
relational databases
  defined, 5
relative option
  mysqladmin, 344
relay-log-purge option
  mysqld, 2022
relay-log-space-limit option
  mysqld, 2022
relay_log system variable, 2030
relay_log_index system variable, 2031
relay_log_info_file system variable, 2031
relay_log_purge system variable, 593
relay_log_recovery system variable, 2031
relay_log_space_limit system variable, 594
release numbers, 44
RELEASE SAVEPOINT, 1549
releases
  GA, 44
  milestone, 44
  naming scheme, 44
  RC, 44
RELEASE_LOCK(), 1337
relevance, 3780
relnotes option
  mysqlaccess, 419
reload option (ndb_mgmd), 2367
RELOAD privilege, 756
remote administration (NDB Cluster)
  and security issues, 2514
remove option
  mysqld, 520
  MySQLInstallerConsole, 93
remove option (ndbd), 2355
remove option (ndbmd), 2355
remove option (ndb_mgmd), 2367
removed features, 14
  --all, 16
  --config-file, 16
  --default-character-set, 15
  --default-collation, 15
  --default-table-type, 15
  --delay-key-write-for-all-tables, 15
  --enable-locking, 15
  --enable-pstack, 16
--first-slave, 16
--log-long-format, 15
--log-update, 15
--master-xxx, 15
--no-named-commands, 15
--no-pager, 15
--no-tee, 15
--position, 16
--safe-show-database, 15
--set-variable, 16
--skip-locking, 15
--skip-symlink, 15
--sql-bin-update-same, 15
--use-symbolic-links, 15
--warnings, 15
--with-pstack, 16
BACKUP TABLE, 15
FRAC_SECOND, 15
Innodb_buffer_pool_read_ahead_rnd, 15
Innodb_buffer_pool_read_ahead_seq, 15
language, 14
LOAD DATA FROM MASTER, 15
LOAD TABLE ... FROM MASTER, 15
log_bin_trust_routine_creators, 14
myisam_max_extra_sort_file_size, 14
record_buffer, 14
RESTORE TABLE, 15
SHOW INNODB STATUS, 15
SHOW MUTEX STATUS, 15
SHOW PLUGIN, 15
SHOW TABLE TYPES, 15
sql_log_update, 14
table_lock_wait_timeout, 15
table_type, 15
TIMESTAMP, 15
TYPE, 15
Removing duplicates
thread state, 1018
removing tmp table
thread state, 1018
rename
thread state, 1018
rename database, 1477
rename result table
thread state, 1018
RENAME TABLE, 1476
RENAME USER statement, 1615
renaming user accounts, 1615
Reopen tables
thread state, 1018
repair
tables, 345
Repair by sorting
thread state, 1018
Repair done
  thread state, 1019
repair option
  mysqlcheck, 352
repair options
  myisamchk, 400
REPAIR TABLE
  and partitioning, 2634
  and replication, 2099
REPAIR TABLE statement, 1625
  and replication, 1626
  options, 1626
  output, 1627
  partitioning support, 1626, 1626
  storage engine support, 1626
Repair with keycache
  thread state, 1019
repairing
  tables, 873
REPEAT, 1581
  labels, 1575
REPEAT(), 1282
REPEATABLE READ, 3781
  transaction isolation level, 1747
repertoire, 3781
  character set, 1087, 1120
  string, 1087
replace, 266
REPLACE, 1512
replace option
  mysql dump, 367
  mysqlimport, 377
replace utility, 447
REPLACE(), 1282
replicas (NDB Cluster), 2121
replicate-do-db option
  mysqld, 2023
replicate-do-table option
  mysqld, 2025
replicate-ignore-db option
  mysqld, 2024
replicate-ignore-table option
  mysqld, 2026
replicate-rewrite-db option
  mysqld, 2026
replicate-same-server-id option
  mysqld, 2027
replicate-wild-do-table option
  mysqld, 2027
replicate-wild-ignore-table option
  mysqld, 2027
replication, 1991, 3781
  and AUTO_INCREMENT, 2083
  and character sets, 2084
and CHECKSUM TABLE statement, 2085
and CREATE ... IF NOT EXISTS, 2085
and CREATE TABLE ... SELECT, 2085
and DATA DIRECTORY, 2092
and DROP ... IF EXISTS, 2093
and errors on slave, 2101
and floating-point values, 2093
and FLUSH, 2093
and functions, 2093
and INDEX DIRECTORY, 2092
and invoked features, 2095
and LAST_INSERT_ID(), 2083
and LIMIT, 2097
and LOAD DATA, 2097
and max_allowed_packet, 2098
and MEMORY tables, 2098
and mysql (system) database, 2099
and partial updates, 2101
and partitioned tables, 2099
and partitioning, 2101
and privileges, 2099
and query optimizer, 2099
and REPAIR TABLE statement, 1626, 2099
and reserved words, 2099
and scheduled events, 2095, 2096
and slow query log, 2098
and SQL mode, 2101
and stored routines, 2095
and temporary tables, 2102
and time zones, 2103
and TIMESTAMP, 208, 2083, 2102
and transactions, 2102, 2103
and triggers, 2095, 2104
and TRUNCATE TABLE, 2105
and variables, 2105
and views, 2107
attribute demotion, 2089
attribute promotion, 2089
between MySQL server versions, 208, 2102
BLACKHOLE, 2084
circular, 2557
Crashes, 2100
in NDB Cluster, 2553
   (see also NDB Cluster replication)
nondeterministic functions, 910
row-based vs statement-based, 2003
safe and unsafe statements, 2008
semisynchronous, 2078
shutdown and restart, 2100, 2102
statements incompatible with STATEMENT format, 2004
timeouts, 2102
   with differing tables on master and slave, 2087
   with ZFS, 1927
REPLICATION CLIENT privilege, 756
replication filtering options and case sensitivity, 2061
replication formats compared, 2003
replication implementation, 2055
replication limitations, 2083
replication master thread states, 1023
replication masters statements, 1561
replication options, 2083
replication slave thread states, 1024, 1025, 1025
REPLICATION SLAVE privilege, 756
replication slaves statements, 1563
replication, asynchronous (see NDB Cluster replication)
REPORT command (NDB Cluster), 2446
reporting bugs, 2, 19
ers, 19
problems, 2
report_host system variable, 2032
report_password system variable, 2032
report_port system variable, 2032
report_user system variable, 2033
REPRODUCIBLE_BUILD option
CMake, 184
Requesting binlog dump thread state, 1024
REQUIRE option
GRANT statement, 1611
reschedule thread state, 1022
reserved words, 1050
and replication, 2099
ReservedSendBufferMemory, 2278
RESET MASTER, 1562
RESET MASTER statement, 1690
RESET SLAVE, 1567
RESET SLAVE ALL, 1567
RESET SLAVE statement, 1690
Reset stmt thread command, 1015
reset-slave.pl (see NDB Cluster replication)
resetmaster option mysqlhotcopy, 438
resetslave option mysqlhotcopy, 438
RESIGNAL, 1590
resolveip, 266, 448
help option, 448
silent option, 448
version option, 448
resolve_stack_dump, 266, 446
  help option, 446
  numeric-dump-file option, 446
  symbols-file option, 446
  version option, 446
resource limits
  user accounts, 572, 787, 1614
resources
  ndbinfo table, 2502
RESTART command (NDB Cluster), 2446
restarting
  the server, 198
RestartOnErrorInsert, 2239
RestartSubscriberConnectTimeout, 2253
restore, 3781
RESTORE TABLE
  removed features, 15
restore-data option
  ndb_restore, 2419
restore-epoch option
  ndb_restore, 2419
restore-meta option
  ndb_restore, 2419
restore-privilege-tables option
  ndb_restore, 2419
restoring backups
  in NDB Cluster, 2404
restoring from backup
  in NDB Cluster replication, 2572
restrictions
  character sets, 1137
  events, 2685
  InnoDB, 1885
  performance_schema database, 2811
  pluggable authentication, 779
  server-side cursors, 1583
  signals, 1600
  stored routines, 2685
  subqueries, 1541
  triggers, 2685
  views, 2688
  XA transactions, 1560
result-file option
  mysqlbinlog, 427
  mysqldump, 367
retries option
  ndb_desc, 2386
retrieving
  data from tables, 236
RETURN, 1581
return (\r), 1030, 1500
return values
  UDFs, 3004
REVERSE(), 1282
REVOKE statement, 772, 1615
revoking
  privileges, 1615
rewrite-database option
  ndb_restore, 2420
rhost option
  mysqlaccess, 419
RIGHT JOIN, 898, 1522
RIGHT OUTER JOIN, 1522
RIGHT(), 1282
RLIKE, 1289
ROLLBACK, 1545
  XA transactions, 1558
rollback, 3781
rollback option
  mysqlaccess, 419
rollback segment, 3781
ROLLBACK TO SAVEPOINT, 1549
Rolling back
  thread state, 1019
rolling restart (NDB Cluster), 2454
ROLLUP, 1366
root password, 199
root user, 734
  password resetting, 3158
ROUND(), 1251
rounding, 1375
rounding errors, 1160
routines
  stored, 2655, 2657
ROUTINES
  INFORMATION_SCHEMA table, 2715
routines option
  mysqldump, 367
ROW, 1533
row, 3781
row constructors, 1533
  optimizations, 912
row format, 3782
row lock, 3782
row size
  maximum, 945
row subqueries, 1533
row-based replication, 3782
  advantages, 2005
  disadvantages, 2006
row-level locking, 990, 3782
rowid option
  ndb_select_all, 2428
rows
  counting, 245
  deleting, 3170
  matching problems, 3171
  selecting, 237
sorting, 239
rows option
mysql_find_rows, 440
ndb_config, 2377
ROW_COUNT(), 1347
ROW_FORMAT
  COMPACT, 945, 1794
  COMPRESSED, 945, 1777, 1796
  DYNAMIC, 945, 1795
  REDUNDANT, 945, 1793
RPAD(), 1282
rpl_semi_sync_master_clients status variable, 644
rpl_semi_sync_master_enabled system variable, 594
rpl_semi_sync_master_net_avg_wait_time status variable, 644
rpl_semi_sync_master_net_waits status variable, 645
rpl_semi_sync_master_net_wait_time status variable, 644
rpl_semi_sync_master_no_times status variable, 645
rpl_semi_sync_master_no_tx status variable, 645
rpl_semi_sync_master_status status variable, 645
rpl_semi_sync_master_timefunc_failures status variable, 645
rpl_semi_sync_master_timeout system variable, 594
rpl_semi_sync_master_trace_level system variable, 595
RPM file, 147
rpm option
  mysql_install_db, 305
RPM Package Manager, 147
RTRIM(), 1282
Ruby API, 2946
running
  ANSI mode, 24
  batch mode, 250
  multiple servers, 706
  queries, 228
running CMake after prior invocation, 171, 188
rw-lock, 3782
rwlock_instances table
  performance_schema, 2792

S
safe statement (replication)
  defined, 2008
safe-mode option
mysqld, 521
safe-recover option
  myisamchk, 401
safe-updates mode, 335
safe-updates option
  mysql, 323, 335
safe-user-create option
  mysqld, 521
Sakila, 8
same value wins (conflict resolution), 2586
SAVEPOINT, 1549
savepoint, 3783
Saving state
  thread state, 1019
scalability, 3783
scale
  arithmetic, 1375
  numeric, 1158
scale out, 3783
scale up, 3783
SchedulerExecutionTimer, 2264
SchedulerSpinTimer, 2264
schema, 3783
  altering, 1386
  creating, 1411
  deleting, 1471
SCHEMA Events (NDB Cluster), 2463
SCHEMA(), 1348
SCHEMATA
  INFORMATION_SCHEMA table, 2718
SCHEMA_PRIVILEGES
  INFORMATION_SCHEMA table, 2719
SCI (Scalable Coherent Interface) (see NDB Cluster)
script files, 250
scripts, 290, 297
  mysql_install_db, 192
  SQL, 314
search index, 3783
searching
  and case sensitivity, 3165
    full-text, 1296
    MySQL Web pages, 19
    two keys, 256
Searching rows for update
  thread state, 1019
SECOND(), 1264
secondary index, 3784
  InnoDB, 1733
secure connections, 795
  command options, 282
secure-auth option, 282
  mysql, 324
secure_auth system variable, 596
secure_file_priv system variable, 597
securing an NDB Cluster, 2516
security
    against attackers, 743
    and malicious SQL statements, 2515
    and NDB utilities, 2517
    plugins, 807
security system, 749
SEC_TO_TIME(), 1264
segment, 3784
SELECT
    INTO, 1520
    LIMIT, 1514
    optimizing, 959, 1691
    Query Cache, 982
SELECT INTO TABLE, 27
SELECT privilege, 756
select-limit option
    mysql, 324
selecting
    databases, 232
    selectivity, 3784
semi-consistent read, 3784
    InnoDB, 1825
semisynchronous replication, 2078
    administrative interface, 2079
    configuration, 2080
    installation, 2080
    monitoring, 2082
    new features, 12
semisynchronous replication plugins, 2951
SendBufferMemory, 2334
Sending binlog event to slave
    thread state, 1023
sending cached result to client
    thread state, 1023
SendLimit, 2346
SendSignalId, 2335, 2341, 2346
SEQUENCE, 257
sequence emulation, 1346
sequences, 257
SERIAL, 1158, 1160
SERIAL DEFAULT VALUE, 1208
SERIALIZABLE, 3784
    transaction isolation level, 1749
server, 3785
    connecting, 227, 285
    debugging, 3009
    disconnecting, 227
    logs, 672
    restart, 198
    shutdown, 198
    signal handling, 450
    starting, 191
    starting and stopping, 203
starting problems, 195
server administration, 337
server configuration, 454
server connections
    command options, 280
server plugins, 694
server variable (see system variable)
server variables (see system variables)
server-id option
    mysqlbinlog, 427
server-id-bits option
    mysqlbinlog, 427
    mysqld, 2301
server-side cursors
    restrictions, 1583
ServerPort, 2211
servers
    multiple, 706
servers table
    system table, 672
server_id system variable, 2010
server_id_bits system variable, 2314
server_operations
    ndbinfo table, 2503
server_transactions
    ndbinfo table, 2504
service-startup-timeout option
    mysql.server, 297
services
    for plugins, 2995
SESSION
    SET statement, 1630
session variables
    and replication, 2105
SESSION_STATUS
    INFORMATION_SCHEMA table, 2704
SESSION_USER(), 1348
SESSION_VARIABLES
    INFORMATION_SCHEMA table, 2704
SET
    CHARACTER SET, 1099
    NAMES, 1099
    ONE_SHOT, 1634
    size, 1213
SET CHARACTER SET statement, 1634
SET CHARSET statement, 1634
SET data type, 1181, 1189
SET GLOBAL sql_slave_skip_counter, 1568
SET GLOBAL statement, 625
SET NAMES, 1106
SET NAMES statement, 1635
Set option
    thread command, 1015
SET OPTION, 1630
SET PASSWORD statement, 775, 1616
SET SESSION statement, 625
SET sql_log_bin, 1563
SET statement
  assignment operator, 1239
  CHARACTER SET, 1634
  CHARSET, 1634
  NAMES, 1635
  variable assignment, 1630
SET TRANSACTION, 1555
set-auto-increment option
  myisamchk, 402
set-charset option
  mysqlbinlog, 427
  mysqldump, 367
set-collation option
  myisamchk, 401
setting
  passwords, 775
setting passwords, 1616
setting program variables, 276
setup
  postinstallation, 190
  thread state, 1019
setup_consumers table
  performance_schema, 2788
setup_instruments table
  performance_schema, 2788
setup_timers table
  performance_schema, 2789
SHA(), 1335
SHA1(), 1335
SHA2(), 1335
shared lock, 1742, 3785
shared memory transporter (see NDB Cluster)
shared tablespace, 3785
shared-memory-base-name option, 282
  mysql, 324
  mysqladmin, 344
  mysqlbinlog, 427
  mysqlcheck, 352
  mysqldump, 368
  mysqlimport, 377
  mysqlshow, 382
  mysqslap, 390
  mysql_upgrade, 313
SharedBufferSize, 2345
SharedGlobalMemory, 2273
shared_memory system variable, 598
shared_memory_base_name system variable, 598
sharp checkpoint, 3785
shell syntax, 4
ShmKey, 2341
ShmSize, 2342
short-form option
- `mysqlbinlog`, 427

SHOW
- in NDB Cluster management client, 2175
- AUTHORS, 1636
- deprecated features, 14
- AUTHORS statement, 1635
- BINARY LOGS statement, 1635, 1636
- BINLOG EVENTS statement, 1635, 1637
- CHARACTER SET statement, 1635, 1638
- COLLATION statement, 1635, 1638
- COLUMNS statement, 1635, 1639
- command (NDB Cluster), 2445
- CONTRIBUTORS, 1641
- deprecated features, 14
- CONTRIBUTORS statement, 1635
- CREATE DATABASE statement, 1635, 1641
- CREATE EVENT statement, 1635
- CREATE FUNCTION statement, 1635, 1642
- CREATE PROCEDURE statement, 1635, 1643
- CREATE SCHEMA statement, 1635, 1641
- CREATE TABLE statement, 1635, 1643
- CREATE TRIGGER statement, 1635, 1644
- CREATE VIEW statement, 1635, 1644
- DATABASES privilege, 756
- DATABASES statement, 1635, 1645
- ENGINE
  - and NDB Cluster, 2483
- ENGINE INNODB STATUS
  - innodb_use_sys_malloc, 1769
- ENGINE INNODB STATUS statement, 1645
- ENGINE NDB STATUS, 1645, 2483
- ENGINE NDBCLUSTER STATUS, 1645, 2483
- ENGINE statement, 1635, 1645
- ENGINES
  - and NDB Cluster, 2484
- ENGINES statement, 1635, 1649
- ERRORS statement, 1635, 1651
- EVENTS statement, 1635, 1652
- extensions, 2761
- FIELDS statement, 1635, 1639
- FUNCTION CODE statement, 1635, 1654
- FUNCTION STATUS statement, 1635, 1654
- GRANTS statement, 1635, 1654
- INDEX statement, 1635, 1655
- INNODB STATUS
  - removed features, 15
- KEYS statement, 1635, 1655
- MASTER LOGS statement, 1635, 1636
- MASTER STATUS statement, 1635, 1657
- MUTEX STATUS
  - removed features, 15
- OPEN TABLES statement, 1635, 1657
- PLUGIN
removed features, 15
SHOW PLUGINS statement, 1635, 1658
SHOW PRIVILEGES statement, 1635, 1659
SHOW PROCEDURE CODE statement, 1635, 1659
SHOW PROCEDURE STATUS statement, 1635, 1660
SHOW PROCESSLIST statement, 1635, 1661
SHOW PROFILE statement, 1635, 1663
SHOW PROFILES statement, 1635, 1663, 1665
SHOW RELAYLOG EVENTS statement, 1635, 1665
SHOW SCHEDULER STATUS, 2669
SHOW SCHEMAS statement, 1645
SHOW SLAVE HOSTS statement, 1635, 1666
SHOW SLAVE STATUS statement, 1635, 1666
SHOW STATUS
    and NDB Cluster, 2485
SHOW STATUS statement, 1635, 1672
SHOW STORAGE ENGINES statement, 1649
SHOW TABLE STATUS statement, 1635, 1673
SHOW TABLE TYPES
    removed features, 15
SHOW TABLES statement, 1635, 1676
SHOW TRIGGERS statement, 1635, 1677
SHOW VARIABLES
    and NDB Cluster, 2484
SHOW VARIABLES statement, 1635, 1678
SHOW VIEW privilege, 757
SHOW WARNINGS statement, 1635, 1680
SHOW with WHERE, 2691, 2761
show-slave-auth-info option
    mysql, 2015
show-table-type option
    mysqlshow, 382
show-temp-status option
    ndb_show_tables, 2431
show-warnings option
    mysql, 324
showing
    database information, 378
shutdown, 3785
    server, 668
Shutdown
    thread command, 1015
SHUTDOWN command (NDB Cluster), 2447
SHUTDOWN privilege, 757
shutdown_timeout variable, 345
shutting down
    the server, 198
Shutting down
    thread state, 1026
SIGHUP signal
    log maintenance, 693
    server response, 450, 1685
SIGINT signal
    client response, 451
mysql client, 324
server response, 450, 3012
sigint-ignore option
  mysql, 324
SIGN(), 1252
SIGNAL, 1594
signal handling, 450
signals
  client response, 451
  new features, 13
  restrictions, 1600
  server response, 450
SigNum, 2342
SIGPIPE signal
  client response, 451, 2827, 2876
SIGTERM signal
  server response, 450
silent column changes, 1463
silent option
  myisamchk, 397
  myisampack, 412
  mysql, 324
  mysqladmin, 344
  mysqlcheck, 352
  mysqld_multi, 299
  mysqlimport, 377
  mysqlslap, 390
  perror, 447
  resolveip, 448
SIN(), 1252
single quote (\' ), 1030
single user mode (NDB Cluster), 2447, 2482
  and ndb_restore, 2404
single-transaction option
  mysqldump, 368
single-user option
  ndb_waiter, 2435
SINGLEUSER Events (NDB Cluster), 2464
size of tables, 943
sizes
  display, 1158
--skip option prefix, 275
skip-broken-objects option
  ndb_restore, 2421
skip-column-names option
  mysql, 324
skip-comments option
  mysqldump, 368
skip-grant-tables option
  mysqld, 521
skip-host-cache option
  mysqld, 522
skip-innodb option
  mysqld, 522, 1809
skip-kill-mysqld option
  mysql_safe, 294
skip-line-numbers option
  mysql, 324
skip-name-resolve option
  mysql_install_db, 305
skip-ndbcluster option
  mysqld, 2302
skip-new option
  mysqld, 522
skip-nodegroup option (ndb_error_reporter), 2390
skip-opt option
  mysqldump, 368
skip-partition option
  mysqld, 522
skip-show-database option
  mysqld, 522
skip-slave-start option
  mysqld, 2028
skip-ssl option, 283
skip-stack-trace option
  mysqld, 523
skip-symbolic-links option
  mysqld, 525
skip-syslog option
  mysql_safe, 294
skip-table-check option
  ndb_restore, 2421
skip-thread-priority option
  mysqld, 523
skip-unknown-objects option
  ndb_restore, 2421
skip-use-db option
  mysql_find_rows, 440
skip_external_locking system variable, 599
skip_name_resolve system variable, 599
skip_networking system variable, 599
skip_show_database system variable, 600
Slave has read all relay log; waiting for the slave I/O thread to update it
  thread state, 1025
slave server, 3785
slave_skip-errors option
  mysqld, 2028
slave_allow_batching, 2568
slave_compressed_protocol option
  mysqld, 2028
slave_compressed_protocol system variable, 2033
slave_exec_mode system variable, 2034
slave_load_tmpdir system variable, 2034
slave_max_allowed_packet system variable, 2035
slave_net_timeout system variable, 2035
slave_skip_errors system variable, 2036
slave_transaction_retries system variable, 2036
slave_type_conversions system variable, 2036
Sleep
  thread command, 1015
sleep option
  mysqladmin, 345
SLEEP(), 1373
slow queries, 340
slow query log, 690, 3785
  and replication, 2098
slow shutdown, 3786
slow-start-timeout option
  mysqld, 523
slow_launch_time system variable, 600
slow_log table
  system table, 671
slow_query_log system variable, 600
slow_query_log_file system variable, 601
SMALLINT data type, 1160
snapshot, 3786
SNAPSHOTEND (START BACKUP command), 2450
SNAPSHOTSTART (START BACKUP command), 2450
socket option, 282
  mysql, 324
  mysqladmin, 345
  mysqlbinlog, 427
  mysqldcheck, 352
  mysqld, 523
  mysqldump, 368
  mysqld_safe, 294
  mysqlhotcopy, 438
  mysqlimport, 377
  mysqlshow, 382
  mysqlslap, 390
  mysql_config, 444
  mysql_convert_table_format, 439
  mysql_setpermission, 441
  mysql_upgrade, 314
socket system variable, 601
Solaris
  installation, 163
    new features, 12
Solaris installation problems, 163
Solaris troubleshooting, 189
Solaris x86_64 issues, 951
SOME, 1532
sort buffer, 3786
sort-index option
  myisamchk, 402
sort-records option
  myisamchk, 402
sort-recover option
  myisamchk, 401
sorting
  data, 239
  grant tables, 768, 770
table rows, 239
Sorting for group
  thread state, 1019
Sorting for order
  thread state, 1019
Sorting index
  thread state, 1019
Sorting result
  thread state, 1019
sort_buffer_size myisamchk variable, 398
sort_buffer_size system variable, 601
sort_key_blocks myisamchk variable, 398
SOUNDEX(), 1282
SOUNDS LIKE, 1283
source (mysql client command), 251, 334
source command
  mysql, 328
source distribution
  installing, 166
space ID, 3786
SPACE(), 1283
sparse file, 3786
spassword option
  mysqlaccess, 419
spatial data types, 1191
  storage requirements, 1213
spatial extensions in MySQL, 1191
spatial functions, 1348
spatial queries
  optimization, 929
speed
  increasing with replication, 1991
  inserting, 924
  of queries, 880
spin, 3786
sporadic-binlog-dump-fail option
  mysqld, 2043
SQL, 3786
  defined, 5
SQL mode, 650
  ALLOW_INVALID_DATES, 652
  and partitioning, 2101, 2641
  and replication, 2101
  ANSI, 651, 657
  ANSI_QUOTES, 652
  DB2, 657
  ERROR_FOR_DIVISION_BY_ZERO, 652
  HIGH_NOT_PRECEDENCE, 652
  IGNORE_SPACE, 653
  MAXDB, 657
  MSSQL, 657
  MYSQL323, 657
  MYSQL40, 657
  NO_AUTO_CREATE_USER, 653
NO_AUTO_VALUE_ON_ZERO, 653
NO_BACKSLASH_ESCAPES, 653
NO_DIR_IN_CREATE, 653
NO_ENGINE_SUBSTITUTION, 653
NO_FIELD_OPTIONS, 654
NO_KEY_OPTIONS, 654
NO_TABLE_OPTIONS, 654
NO_UNSIGNED_SUBTRACTION, 654
NO_ZERO_DATE, 655
NO_ZERO_IN_DATE, 655
ONLY_FULL_GROUP_BY, 656, 1370
ORACLE, 658
PAD_CHAR_TO_FULL_LENGTH, 656
PIPES_AS_CONCAT, 656
POSTGRESQL, 658
REAL_AS_FLOAT, 656
strict, 652
STRICT_ALL_TABLES, 656
STRICT_TRANS_TABLES, 651, 657
TRADITIONAL, 651, 658

SQL node (NDB Cluster)
defined, 2118
SQL nodes (NDB Cluster), 2453
SQL scripts, 314
SQL SECURITY
effect on privileges, 2676
SQL statements
replication masters, 1561
replication slaves, 1563
SQL statements relating to NDB Cluster, 2483
SQL-92
extensions to, 23
sql-mode option
mysql, 524
sql_auto_is_null system variable, 602
SQL_BIG_RESULT
SELECT modifier, 1520
sql_big_selects system variable, 603
SQL_BUFFER_RESULT
SELECT modifier, 1520
sql_buffer_result system variable, 603
SQL_CACHE, 986
SELECT modifier, 1520
SQL_CALC_FOUND_ROWS, 909
SELECT modifier, 1520
sql_log_bin system variable, 603
sql_log_off system variable, 604
sql_log_update
removed features, 14
sql_mode system variable, 604
sql_notes system variable, 606
SQL_NO_CACHE, 986
SELECT modifier, 1520
sql_quote_show_create system variable, 606
sql_safe_updates system variable, 335, 606
sql_select_limit system variable, 335, 607
sql_slave_skip_counter, 1568
sql_slave_skip_counter system variable, 2037
SQL_SMALL_RESULT
  SELECT modifier, 1520
sql_warnings system variable, 607
SQRT(), 1252
square brackets, 1158
srcdir option
  mysql_install_db, 305
SRID values
  handling by spatial functions, 1351
SRID(), 1355
SSD, 1776, 3786
SSH, 806
SSL, 795
  command options, 282
  establishing connections, 796
  OpenSSL compared to yaSSL, 806
  X.509 Basics, 795
SSL library
  configuring, 175
ssl option, 283
SSL options
  mysql, 325
  mysqladmin, 345
  mysqlbinlog, 428
  mysqlcheck, 352
  mysqld, 525
  mysql_dump, 368
  mysqlimport, 377
  mysqlshow, 382
  mysqlslap, 390
  mysql_upgrade, 314
SSL related options
  GRANT statement, 1611
ssl-ca option, 283
ssl-capath option, 284
ssl-cert option, 284
ssl-cipher option, 284
ssl-key option, 284
ssl-mode option, 285
ssl-verify-server-cert option, 285
ssl_ca system variable, 607
ssl_capath system variable, 607
ssl_cert system variable, 608
ssl_cipher system variable, 608
ssl_key system variable, 608
staging-tries option
  ndb_move_data, 2398
standalone option
  mysqld, 525
Standard Monitor, 1860, 1863, 1867
Standard SQL
  differences from, 27, 1614
  extensions to, 23, 24
  standards compatibility, 23
START
  XA transactions, 1558
START BACKUP
  NOWAIT, 2450
  SNAPSHOTEND, 2450
  SNAPSHOTSTART, 2450
  syntax, 2449
  WAIT COMPLETED, 2450
  WAIT STARTED, 2450
START command (NDB Cluster), 2445
START SLAVE, 1568
START TRANSACTION, 1545
start-datetime option
  mysqlbinlog, 428
start-position option
  mysqlbinlog, 428
StartConnectBackoffMaxTime, 2292
StartFailRetryDelay, 2280
StartFailureTimeout, 2242
starting
  comments, 29
  mysqld, 746
  the server, 191
  the server automatically, 203
Starting many servers, 706
StartNoNodeGroupTimeout, 2242
StartPartialTimeout, 2241
StartPartitionedTimeout, 2241
StartPoint(), 1357
startup, 3787
STARTUP Events (NDB Cluster), 2460
startup options
  default, 270
startup parameters, 454
  mysql, 315
  mysqladmin, 340
  tuning, 998
StartupStatusReportFrequency, 2259
start_row option
  mysql_find_rows, 440
state-file option
  comp_err, 302
statement termination
  Control+C, 315, 324
statement-based replication, 3787
  advantages, 2004
  disadvantages, 2004
  unsafe statements, 2004
statements
  compound, 1574
CREATE USER, 772
DROP USER, 772
GRANT, 772
replication masters, 1561
replication slaves, 1563
REVOKE, 772
Statistics
  thread command, 1015
statistics, 3787
    thread state, 1019
STATISTICS
  INFORMATION_SCHEMA table, 2719
STATISTICS Events (NDB Cluster), 2462
stats option
  myisam_ftdump, 393
stats_method myisamchk variable, 398
status
  tables, 1673
status command
  mysql, 329
  results, 340
STATUS command (NDB Cluster), 2446
status option
  MySQLInstallerConsole, 93
  mysqlshow, 383
status variable
  Performance_schema_cond_classes_lost, 2808
  Performance_schema_cond_instances_lost, 2808
  Performance_schema_file_classes_lost, 2808
  Performance_schema_file_handles_lost, 2808
  Performance_schema_file_instances_lost, 2809
  Performance_schema_locker_lost, 2809
  Performance_schema_mutex_classes_lost, 2809
  Performance_schema_mutex_instances_lost, 2809
  Performance_schema_rwlock_classes_lost, 2809
  Performance_schema_rwlock_instances_lost, 2809
  Performance_schema_table_handles_lost, 2809
  Performance_schema_table_instances_lost, 2809
  Performance_schema_thread_classes_lost, 2809
  Performance_schema_thread_instances_lost, 2809
  Rpl_semi_sync_master_clients, 644
  Rpl_semi_sync_master_net_avg_wait_time, 644
  Rpl_semi_sync_master_net_waits, 645
  Rpl_semi_sync_master_net_wait_time, 644
  Rpl_semi_sync_master_no_times, 645
  Rpl_semi_sync_master_no_tx, 645
  Rpl_semi_sync_master_status, 645
  Rpl_semi_sync_master_timefunc_failures, 645
  Rpl_semi_sync_master_tx_avg_wait_time, 645
  Rpl_semi_sync_master_tx_waits, 645
  Rpl_semi_sync_master_tx_wait_time, 645
  Rpl_semi_sync_master_wait_pos_backtraverse, 645
  Rpl_semi_sync_master_wait_sessions, 646
  Rpl_semi_sync_master_yes_tx, 646
stored objects, 2655
stored procedures, 2657
stored program, 3788
stored programs, 1574, 2655
stored routine, 3788
stored routines, 2655, 2657
   and replication, 2095
   LAST_INSERT_ID(), 2659
   metadata, 2659
   restrictions, 2685
storing result in query cache
   thread state, 1023
storing row into queue
   thread state, 1022
STRAIGHT_JOIN, 898, 959, 971, 1522, 1692
   SELECT modifier, 1520
STRCMP(), 1288
strict mode, 3788
strict SQL mode, 652
STRICT_ALL_TABLES SQL mode, 656
STRICT_TRANS_TABLES SQL mode, 651, 657
string collating, 1142
string comparison functions, 1285
string comparison operators, 1285
string comparisons
   case sensitivity, 1286
string concatenation, 1029, 1276
string data types, 1178
   storage requirements, 1211
string functions, 1273
string literal introducer, 1030, 1094
string literals, 1029
string operators, 1273
string replacement
   replace utility, 447
string types, 1178
StringMemory, 2218
strings
   defined, 1029
   escape sequences, 1029
   nondelimited, 1034
   repertoire, 1087
striping
   defined, 999
STR_TO_DATE(), 1264
SUBDATE(), 1266
sublist, 3788
SUBPARTITION BY KEY
   known issues, 2645
subpartitioning, 2618
subpartitions, 2618
   known issues, 2645
subqueries, 1529
   correlated, 1535
errors, 1538
in FROM clause (see derived tables)
optimization, 914
restrictions, 1541
rewriting as joins, 1541
with ALL, 1532
with ANY, IN, SOME, 1532
with EXISTS, 1534
with NOT EXISTS, 1534
with row constructors, 1533
subquery (see subqueries)
subselects, 1529
SUBSTR(), 1283
SUBSTRING(), 1283
SUBSTRING_INDEX(), 1284
SUBTIME(), 1266
subtraction (-), 1243
suffix option
  mysqlhotcopy, 439
SUM(), 1366
SUM(DISTINCT), 1366
SUPER privilege, 757
super-large-pages option
  mysql, 525
superuser, 199
superuser option
  mysqlaccess, 419
support
  for operating systems, 44
suppression
  default values, 31
supremum record, 3788
surrogate key, 3788
symbolic links, 1000, 1002
databases, 1000
tables, 1001
Windows, 1002
symbolic-links option
  mysql, 525
symbols-file option
  resolve_stack_dump, 446
synchronization of master and slave
  in NDB Cluster Replication, 2574
Syncing ndb table schema operation and binlog
  thread state, 1026
sync_binlog system variable, 2051
sync_frm system variable, 609
sync_master_info system variable, 2037
sync_relay_log system variable, 2038
sync_relay_log_info system variable, 2038
syntax
  regular expression, 1289
syntax conventions, 2
synthetic key, 3788
sys-check option (ndb_index_stat), 2394
sys-create option (ndb_index_stat), 2394
sys-create-if-not-exist option (ndb_index_stat), 2394
sys-create-if-not-valid option (ndb_index_stat), 2394
sys-drop option (ndb_index_stat), 2393
sys-skip-events option (ndb_index_stat), 2395
sys-skip-tables option (ndb_index_stat), 2395
SYSCONFDIR option
  CMake, 182
SYSDATE(), 1266
sysdate-is-now option
  mysql, 526
syslog option
  mysqld_safe, 294
syslog-tag option
  mysqld_safe, 294
system
  privilege, 749
  security, 734
system command
  mysql, 329
System lock
  thread state, 1019
system optimization, 998
system option
  ndb_config, 2378
system table
  optimizer, 963, 1520
system tables
  columns_priv table, 671, 759
  db table, 199, 671, 759
  event table, 671
  func table, 671
  general_log table, 671
  help tables, 671
  help_category table, 672
  help_keyword table, 672
  help_relation table, 672
  help_topic table, 672
  host table, 671, 759
  ndb_binlog_index table, 672, 2563
  plugin table, 671
  proc table, 671
  procs_priv table, 671, 759
  proxies_priv table, 199, 671, 759
  servers table, 672
  slow_log table, 671
  tables_priv table, 671, 759
  time zone tables, 672
  time_zone table, 672
  time_zone_leap_second table, 672
  time_zone_name table, 672
  time_zone_transition table, 672
  time_zone_transition_type table, 672
user table, 199, 671, 759
system tablespace, 3788
system variable, 1678
and replication, 2105
audit_log_buffer_size, 847
audit_log_file, 847
audit_log_flush, 848
audit_log_format, 848
audit_log_policy, 849
audit_log_rotate_on_size, 849
audit_log_strategy, 850
authentication_windows_log_level, 529
authentication_windows_use_principal_name, 530
autocommit, 530
automatic_sp_privileges, 531
auto_increment_increment, 2016
auto_increment_offset, 2019
back_log, 532
basedir, 532
big_tables, 532
binlog_cache_size, 2043
binlog_direct_non_transactional_updates, 2044
binlog_format, 2045
binlog_stmt_cache_size, 2046
bulk_insert_buffer_size, 533, 1897
character_sets_dir, 536
character_set_client, 533
character_set_connection, 534
character_set_database, 534
character_set_filesystem, 534
character_set_results, 535
character_set_server, 535
character_set_system, 535
collation_connection, 536
collation_database, 536
collation_server, 536
completion_type, 537
concurrent_insert, 538
connect_timeout, 538
datadir, 539
datetime_format, 539
date_format, 539
debug, 539
debug_sync, 540
default_storage_engine, 541
default_week_format, 541
delayed_insert_limit, 542
delayed_insert_timeout, 543
delayed_queue_size, 543
delay_key_write, 541, 1897
div_precision_increment, 544
engine_condition_pushdown, 544
error_count, 545
event_scheduler, 545
expire_logs_days, 545
external_user, 546
flush, 546
flush_time, 546
foreign_key_checks, 547
ft_boolean_syntax, 548
ft_max_word_len, 548
ft_min_word_len, 548
ft_query_expansion_limit, 549
ft_stopword_file, 549
general_log, 550
general_log_file, 550
group_concat_max_len, 550
have_compress, 551
have_crypt, 551
have_csv, 551
have_dynamic_loading, 551
have_geometry, 551
have_innodb, 551
have_openssl, 551
have_partitioning, 551
have_profiling, 551
have_query_cache, 551
have_rtree_keys, 551
have_ssl, 552
have_symlink, 552
hostname, 552
identity, 552
ignore_builtin_innodb, 1809
init_connect, 552
init_file, 553
init_slave, 2029
innodb_adaptive_flushing, 1809
innodb_adaptive_hash_index, 1809
innodb_additional_mem_pool_size, 1810
innodb_autoextend_increment, 1810
innodb_autoinc_lock_mode, 1811
innodb_buffer_pool_instances, 1811
innodb_buffer_pool_size, 1812
innodb_change_buffering, 1813
innodb_change_buffering_debug, 1813
innodb_checksums, 1814
innodb_commit_concurrency, 1814
innodb_concurrency_tickets, 1814
innodb_data_file_path, 1815
innodb_data_home_dir, 1816
innodb_doublewrite, 1816
innodb_fast_shutdown, 1817
innodb_file_format, 1817
innodb_file_format_check, 1818
innodb_file_format_max, 1818
innodb_file_per_table, 1819
innodb_flush_log_at_trx_commit, 1819
innodb_flush_method, 1820
innodb_force_recovery, 1823
innodb_io_capacity, 1823
innodb_limit_optimistic_insert_debug, 1824
innodb_locks_unsafe_for_binlog, 1825
innodb_lock_wait_timeout, 1824
innodb_log_buffer_size, 1827
innodb_log_files_in_group, 1828
innodb_log_file_size, 1828
innodb_log_group_home_dir, 1829
innodb_max_dirty_pages_pct, 1829
innodb_max_purge_lag, 1830
innodb_mirrored_log_groups, 1830
innodb_old_blocks_pct, 1830
innodb_old_blocks_time, 1830
innodb_open_files, 1831
innodb_purge_batch_size, 1832
innodb_purge_threads, 1832
innodb_read_ahead_threshold, 1833
innodb_read_io_threads, 1834
innodb_replication_delay, 1834
innodb_rollback_on_timeout, 1835
innodb_spin_wait_delay, 1836
innodb_stats_method, 1836
innodb_stats_on_metadata, 1837
innodb_stats_sample_pages, 1837
innodb_strict_mode, 1838
innodb_support_xa, 1839
innodb_thread_concurrency, 1840
innodb_thread_sleep_delay, 1841
innodb_trx_purge_view_update_only_debug, 1842
innodb_trx_rseg_n_slots_debug, 1843
innodb_use_native_aio, 1842
innodb_use_sys_malloc, 1843
innodb_version, 1843
insert_id, 553
interactive_timeout, 553
join_buffer_size, 554
keep_files_on_create, 554
key_buffer_size, 555
key_cache_age_threshold, 556
key_cache_block_size, 557
key_cache_division_limit, 557
language, 557
large_files_support, 558
large_pages, 558
large_page_size, 558
last_insert_id, 559
lc_messages, 559
lc_messages_dir, 559
lc_time_names, 559
license, 559
local_infile, 560
locked_in_memory, 561
lock_wait_timeout, 560
log, 561
log_bin, 2047
log_bin_trust_function_creators, 2047
log_bin_use_v1_row_events, 2048
log_error, 561
log_output, 562
log_queries_not_using_indexes, 562
log_slave_updates, 2048
log_slow_queries, 563
log_warnings, 563
log_query_time, 564
lower_case_file_system, 564
lower_case_table_names, 565
low_priority_updates, 564
max_allowed_packet, 565
max_binlog_cache_size, 2049
max_binlog_size, 2050
max_binlog_stmt_cache_size, 2050
max_connections, 567
max_connect_errors, 566
max_delayed_threads, 567
max_error_count, 567
max_heap_table_size, 568
max_insert_delayed_threads, 568
max_join_size, 335, 569
max_length_for_sort_data, 569
max_long_data_size, 569
max_prepared_stmt_count, 570
max_relay_log_size, 570
max_seeks_for_key, 571
max_sort_length, 571
max_sp_recursion_depth, 572
max_tmp_tables, 572
max_user_connections, 572
max_write_lock_count, 573
metadata_locks_cache_size, 573
min_examined_row_limit, 573
myisam_data_pointer_size, 574
myisam_max_sort_file_size, 575, 1897
myisam_mmap_size, 575
myisam_recover_options, 576, 1897
myisam_repair_threads, 577
myisam_sort_buffer_size, 577, 1897
myisam_stats_method, 578
myisam_use_mmap, 578
named_pipe, 579
ndb_log_empty_epochs, 2309
ndb_log_empty_update, 2309
ndb_log_orig, 2310
ndb_log_transaction_id, 2310
net_buffer_length, 579
net_read_timeout, 579
net_retry_count, 580
net_write_timeout, 580
new, 580
old, 581
old_alter_table, 581
old_passwords, 582
one_shot, 582
open_files_limit, 582
optimizer_prune_level, 583
optimizer_search_depth, 583
optimizer_switch, 584
performance_schema, 2803
performance_schema_events_waits_history_long_size, 2803
performance_schema_events_waits_history_size, 2803
performance_schema_max_cond_classes, 2803
performance_schema_max_cond_instances, 2804
performance_schema_max_file_classes, 2804
performance_schema_max_file_handles, 2804
performance_schema_max_file_instances, 2805
performance_schema_max_mutex_classes, 2805
performance_schema_max_mutex_instances, 2805
performance_schema_max_rwlock_classes, 2806
performance_schema_max_rwlock_instances, 2806
performance_schema_max_table_handles, 2806
performance_schema_max_table_instances, 2807
performance_schema_max_thread_classes, 2807
performance_schema_max_thread_instances, 2807
pid_file, 585
plugin_dir, 585
port, 585
preload_buffer_size, 586
profiling, 586
profiling_history_size, 586
protocol_version, 586
proxy_user, 586
pseudo_slave_mode, 587
pseudo_thread_id, 587
query_alloc_block_size, 587
query_cache_limit, 587
query_cache_min_res_unit, 588
query_cache_size, 588
query_cache_type, 589
query_cache_wlock_invalidate, 589
query_prealloc_size, 590
rand_seed1, 590
rand_seed2, 591
range_alloc_block_size, 591
read_buffer_size, 591
read_only, 592
read_rnd_buffer_size, 593
relay_log, 2030
relay_log_index, 2031
relay_log_info_file, 2031
relay_log_purge, 593
relay_log_recovery, 2031
relay_log_space_limit, 594
report_host, 2032
report_password, 2032
report_port, 2032
report_user, 2033
rpl_semi_sync_master_enabled, 594
rpl_semi_sync_master_timeout, 594
rpl_semi_sync_master_trace_level, 595
rpl_semi_sync_master_wait_no_slave, 595
rpl_semi_sync_slave_enabled, 596
rpl_semi_sync_slave_trace_level, 596
secure_auth, 596
secure_file_priv, 597
server_id, 2010
server_id_bits, 2314
shared_memory, 598
shared_memory_base_name, 598
skip_external_locking, 599
skip_name_resolve, 599
skip_networking, 599
skip_show_database, 600
slave_compressed_protocol, 2033
slave_exec_mode, 2034
slave_load_tmpdir, 2034
slave_max_allowed_packet, 2035
slave_net_timeout, 2035
slave_skip_errors, 2036
slave_transaction_retries, 2036
slave_type_conversions, 2036
slow_launch_time, 600
slow_query_log, 600
slow_query_log_file, 601
socket, 601
sort_buffer_size, 601
sql_auto_is_null, 602
sql_big_selects, 603
sql_buffer_result, 603
sql_log_bin, 603
sql_log_off, 604
sql_mode, 604
sql_notes, 606
sql_quote_show_create, 606
sql_safe_updates, 335, 606
sql_select_limit, 335, 607
sql_slave_skip_counter, 2037
sql_warnings, 607
ssl_ca, 607
ssl_capath, 607
ssl_cert, 608
ssl_cipher, 608
ssl_key, 608
storage_engine, 609
sync_binlog, 2051
sync_frm, 609
sync_master_info, 2037
sync_relay_log, 2038
sync_relay_log_info, 2038
system_time_zone, 610
sysvar_stored_program_cache, 609
table_definition_cache, 610
table_open_cache, 610
thread_cache_size, 611
thread_concurrency, 611
thread_handling, 612
thread_pool_algorithm, 612
thread_pool_high_priority_connection, 613
thread_pool_max_unused_threads, 613
thread_pool_prio_kickup_timer, 614
thread_pool_size, 614
thread_pool_stall_limit, 615
thread_stack, 615
timed_mutexes, 616
timestamp, 617
time_format, 616
time_zone, 616
tmpdir, 618
tmp_table_size, 617
transaction_alloc_block_size, 618
transaction_allow_batching, 2315
transaction_prealloc_size, 619
tx_isolation, 619
unique_checks, 620
updatable_views_with_limit, 620
version, 621
version_comment, 621
version_compile_machine, 621
version_compile_os, 621
wait_timeout, 621
warning_count, 622
system variables, 528, 622
mysql, 454
privileges required, 625
system_time_zone system variable, 610
SYSTEM_USER(), 1348
sysvar_stored_program_cache system variable, 609

T

tab (\t), 1030, 1500
tab option
   mysqlldump, 369
   ndb_restore, 2421
table, 3789
   changing, 1391, 1398, 3173
deleting, 1474
rebuilding, 216
repair, 216
row size, 1209
Table 'mysql.proxies_priv' doesn't exist, 206
table aliases, 1516
table cache, 940
table definition
  retention, 1451
table description
  myisamchk, 402
Table Dump
  thread command, 1015
table is full, 533, 3154
Table is full errors (NDB Cluster), 2216
table lock, 3789
Table Monitor, 1860, 1870
table names
  case sensitivity, 25, 1042
table option
  mysql, 325
  mysqlaccess, 419
  ndb_desc, 2386
table scan, 1766
table type, 3790
  choosing, 1887
table-level locking, 990	
tables
  BLACKHOLE, 1910
  checking, 399
  cloning, 1453
  closing, 940
  compressed, 411
  compressed format, 1900
  const, 963
  constant, 882
  copying, 1454
  counting rows, 245
  creating, 233
  CSV, 1907
defragment, 1899
defragmenting, 876, 1623
deleting rows, 3170
displaying, 378
displaying status, 1673
dumping, 353, 436
dynamic, 1899
eroress checking, 872
EXAMPLE, 1923
FEDERATED, 1918
flush, 340
fragmentation, 1623
HEAP, 1902
host, 771
improving performance, 936
information, 402

3368
information about, 249
InnoDB, 1698
loading data, 235
maintenance, 345
maintenance schedule, 876
maximum size, 943
MEMORY, 1902
MERGE, 1913
merging, 1913
multiple, 247
MyISAM, 1894
names, 1038
open, 940
opening, 940
optimizing, 875
partitioning, 1913
repair, 345
repairing, 873
retrieving data, 236
selecting columns, 238
selecting rows, 237
sorting rows, 239
symbolic links, 1001
system, 963
TEMPORARY, 1453
too many, 941
unique ID for last row, 2944
TABLES
  INFORMATION_SCHEMA table, 2721
tables option
    mysqlcheck, 352
    mysqldump, 369
tablespace, 1737, 3790
Tablespace Monitor, 1860, 1868
  InnoDB, 1799, 1875
TABLESPACES
  INFORMATION_SCHEMA table, 2725
tables_priv table
    system table, 671, 759
TABLE_CONSTRAINTS
  INFORMATION_SCHEMA table, 2726
table_definition_cache system variable, 610
table_lock_wait_timeout
    removed features, 15
table_open_cache, 940
table_open_cache system variable, 610
TABLE_PRIVILEGES
  INFORMATION_SCHEMA table, 2726
table_type
    removed features, 15
TAN(), 1252
tar
  problems on Solaris, 163, 163
tc-heuristic-recover option
mysqld, 526
Tcl API, 2946
tcmalloc
  memory allocation library, 292
tcp-ip option
tcpd_multi, 299
TCP/IP, 120, 126, 285, 322, 448, 1007
TCP_MAXSEG_SIZE, 2337
TCP_RCV_BUF_SIZE, 2336
TCP_SND_BUF_SIZE, 2336
tee command
  mysql, 329
tee option
  mysql, 325
temp-pool option
  mysql, 526
temporal interval syntax, 1077
temporary file
  write access, 193
temporary files, 3163
temporary table, 3790
TEMPORARY table privileges, 754, 1453
temporary tables
  and replication, 2102
  internal, 941
  problems, 3174
TEMPORARY tables, 1453
  renaming, 1477
temporary tablespace, 3790
terminal monitor
  defined, 227
test option
  myisampack, 412
testing
  connection to the server, 767
  installation, 191
  postinstallation, 190
testing mysqld
  mysqltest, 2948
test_plugin_server authentication plugin, 828
TEXT
  size, 1212
text collection, 3790
TEXT columns
  default values, 1185
  indexes, 1418, 1418
  indexing, 928, 1433
TEXT data type, 1180, 1184
text files
  importing, 334, 372, 1494
thd_alloc service, 2996
thd_wait service, 2996
The used command is not allowed with this MySQL version
  error message, 748
thread, 3791
thread cache, 1007

thread command
   Binlog Dump, 1013
   Change user, 1013
   Close stmt, 1013
   Connect, 1013
   Connect Out, 1013
   Create DB, 1013
   Daemon, 1013
   Debug, 1014
   Delayed insert, 1014
   Drop DB, 1014
   Error, 1014
   Execute, 1014
   Fetch, 1014
   Field List, 1014
   Init DB, 1014
   Kill, 1014
   Long Data, 1014
   Ping, 1014
   Prepare, 1014
   Processlist, 1014
   Query, 1014
   Quit, 1014
   Refresh, 1014
   Register Slave, 1015
   Reset stmt, 1015
   Set option, 1015
   Shutdown, 1015
   Sleep, 1015
   Statistics, 1015
   Table Dump, 1015
   Time, 1015

thread commands, 1013

thread state
   After create, 1015
   allocating local table, 1022
   Analyzing, 1015
   Changing master, 1025
   Checking master version, 1024
   checking permissions, 1015
   checking privileges on cached query, 1023
   checking query cache for query, 1023
   Checking table, 1015
   cleaning up, 1016
   Clearing, 1026
   closing tables, 1016
   Committing events to binlog, 1026
   Connecting to master, 1024
   converting HEAP to MyISAM, 1016
   copy to tmp table, 1016
   Copying to group table, 1016
   Copying to tmp table, 1016
Copying to tmp table on disk, 1016
Creating delayed handler, 1022
Creating index, 1016
Creating sort index, 1016
creating table, 1016
Creating tmp table, 1016
deleting from main table, 1016
deleting from reference tables, 1016
discard_or_import_tablespace, 1017
end, 1017
executing, 1017
Execution of init_command, 1017
Finished reading one binlog; switching to next binlog, 1023
freeing items, 1017
FULLTEXT initialization, 1017
got handler lock, 1022
got old table, 1022
init, 1017
Initialized, 1027
insert, 1022
invalidating query cache entries, 1023
Killed, 1017
Killing slave, 1025
logging slow query, 1017
login, 1017
Making temp file, 1025
manage keys, 1018
Master has sent all binlog to slave; waiting for binlog to be updated, 1023
NULL, 1018
Opening master dump table, 1025
Opening mysql.ndb_apply_status, 1026
Opening table, 1018
Opening tables, 1018
optimizing, 1018
preparing, 1018
Processing events, 1026
Processing events from schema table, 1026
Purging old relay logs, 1018
query end, 1018
Queueing master event to the relay log, 1024
Reading event from the relay log, 1025
Reading from net, 1018
Reading master dump table data, 1026
Rebuilding the index on master dump table, 1026
Reconnecting after a failed binlog dump request, 1024
Reconnecting after a failed master event read, 1024
Registering slave on master, 1024
Removing duplicates, 1018
removing tmp table, 1018
rename, 1018
rename result table, 1018
Reopen tables, 1018
Repair by sorting, 1018
Repair done, 1019
Repair with keycache, 1019
Requesting binlog dump, 1024
reschedule, 1022
Rolling back, 1019
Saving state, 1019
Searching rows for update, 1019
Sending binlog event to slave, 1023
sending cached result to client, 1023
setup, 1019
Shutting down, 1026
Slave has read all relay log; waiting for the slave I/O thread to update it, 1025
Sorting for group, 1019
Sorting for order, 1019
Sorting index, 1019
Sorting result, 1019
statistics, 1019
storing result in query cache, 1023
storing row into queue, 1022
Syncing ndb table schema operation and binlog, 1026
System lock, 1019
update, 1020
Updating, 1020
updating main table, 1020
updating reference tables, 1020
upgrading lock, 1022
User lock, 1020
User sleep, 1020
Waiting for allowed to take ndbcluster global schema lock, 1026
Waiting for commit lock, 1020
waiting for delay_list, 1022
Waiting for event from ndbcluster, 1026
Waiting for first event from ndbcluster, 1026
Waiting for global metadata lock, 1021
Waiting for global read lock, 1020, 1021
waiting for handler insert, 1022
waiting for handler lock, 1022
waiting for handler open, 1022
Waiting for INSERT, 1022
Waiting for master to send event, 1024
Waiting for master update, 1024
Waiting for ndbcluster binlog update to reach current position, 1026
Waiting for ndbcluster global schema lock, 1026
Waiting for ndbcluster to start, 1026
Waiting for next activation, 1027
Waiting for query cache lock, 1023
Waiting for scheduler to stop, 1027
Waiting for schema epoch, 1026
Waiting for schema metadata lock, 1021
Waiting for slave mutex on exit, 1024, 1025
Waiting for stored function metadata lock, 1021
Waiting for stored procedure metadata lock, 1021
Waiting for table, 1020
Waiting for table flush, 1021
Waiting for table level lock, 1021
Waiting for table metadata lock, 1021
Waiting for tables, 1020
Waiting for the next event in relay log, 1025
Waiting for the slave SQL thread to free enough relay log space, 1024
Waiting for trigger metadata lock, 1021
Waiting on cond, 1021
Waiting on empty queue, 1027
Waiting to finalize termination, 1023
Waiting to reconnect after a failed binlog dump request, 1025
Waiting to reconnect after a failed master event read, 1025
Writing to net, 1021
thread states, 1012
delayed inserts, 1021
event scheduler, 1026
general, 1015
NDB Cluster, 1026
query cache, 1023
replication master, 1023
replication slave, 1024, 1025, 1025
threadblocks
ndbinfo table, 2506
ThreadConfig, 2269
threaded clients, 2827
ThreadPool (see DiskIOTThreadPool)
threads, 340, 1661, 2947
display, 1661
monitoring, 1012, 1661, 1661, 2712
threads table
performance_schema, 2800
threadstat
ndbinfo table, 2506
thread_cache_size system variable, 611
thread_concurrency system variable, 611
thread_handling system variable, 612
thread_pool_algorithm system variable, 612
thread_pool_high_priority_connection system variable, 613
thread_pool_max_unused_threads system variable, 613
thread_pool_prio_kickup_timer system variable, 614
thread_pool_size system variable, 614
thread_pool_stall_limit system variable, 615
thread_stack system variable, 615
Time
thread command, 1015
TIME data type, 1168, 1170
time data types
storage requirements, 1211
time literals, 1032
time representation
Event Scheduler, 2668
time zone problems, 3165
time zone tables, 308
system tables, 672
time zones
and replication, 2103
leap seconds, 666
support, 662
upgrading, 665
TIME(), 1267
TimeBetweenEpochs, 2247
TimeBetweenEpochsTimeout, 2247
TimeBetweenGlobalCheckpoints, 2246, 2278
TimeBetweenGlobalCheckpointsTimeout, 2246
TimeBetweenInactiveTransactionAbortCheck, 2249
TimeBetweenLocalCheckpoints, 2245
TimeBetweenWatchDogCheck, 2240
TimeBetweenWatchDogCheckInitial, 2240
TIMEDIFF(), 1267
timed_mutexes
deprecated features, 14
timed_mutexes system variable, 616
timeout, 538, 1336, 1494
connect_timeout variable, 345
shutdown_timeout variable, 345
timeout option
ndb_waiter, 2435
timeouts (replication), 2102
TIMESTAMP
and logs, 208
and NULL values, 3169
and replication, 208, 2083, 2102
indexes, 934
initialization and updating, 1173
removed features, 15
TIMESTAMP data type, 1168, 1169
timestamp system variable, 617
TIMESTAMP(), 1267
TIMESTAMPADD(), 1268
TIMESTAMPDIFF(), 1268
timezone option
mysql_safe, 294
time_format system variable, 616
TIME_FORMAT(), 1268
TIME_TO_SEC(), 1268
time_zone system variable, 616
time_zone table
system table, 672
time_zone_leap_second table
system table, 672
time_zone_name table
system table, 672
time_zone_transition table
system table, 672
time_zone_transition_type table
system table, 672
TINYBLOB data type, 1180
TINYINT data type, 1159
TINYTEXT data type, 1180
tips
optimization, 925
TLS, 795
  command options, 282
  establishing connections, 796
TMPDIR environment variable, 193, 266, 449, 3163
TMPDIR option
  CMake, 182
tmpdir option
  myisamchk, 402
  myisampack, 412
  mysqld, 527
  mysqlhotcopy, 439
  mysql_upgrade, 314
tmpdir system variable, 618
tmp_table_size system variable, 617
to-last-log option
  mysqlbinlog, 428
tools
  command-line, 90, 314
  list of, 39
  mysqld_multi, 297
  mysqld_safe, 290
torn page, 1798, 3791
TotalSendBufferMemory
  API and SQL nodes, 2289
  data nodes, 2278
  management nodes, 2208
Touches(), 1360
TO_DAYS(), 1268
TO SECONDS(), 1269
  new features, 13
TPS, 3791
TP_THREAD_GROUP_STATE
  INFORMATION_SCHEMA table, 2756
TP_THREAD_GROUP_STATS
  INFORMATION_SCHEMA table, 2758
TP_THREAD_STATE
  INFORMATION_SCHEMA table, 2760
trace DBI method, 3013
trace files
  ndbmtd, 2359
trace files (NDB Cluster), 2356
TRADITIONAL SQL mode, 651, 658
trailing spaces
  CHAR, 1179, 1181
  ENUM, 1187
  in comparisons, 1181
  SET, 1189
  VARCHAR, 1180, 1181
transaction, 3791
transaction ID, 3791
transaction isolation level, 1555
  NDB Cluster, 2137
  READ COMMITTED, 1747
READ UNCOMMITTED, 1749
REPEATABLE READ, 1747
SERIALIZABLE, 1749
transaction-isolation option
  mysql, 527
transaction-safe tables, 1698
transactional option
  ndb_delete_all, 2382
TransactionBufferMemory, 2223
TransactionDeadlockDetectionTimeout, 2249
TransactionInactiveTimeout, 2249
transactions, 1741
  and replication, 2102, 2103
  isolation levels, 1746
  metadata locking, 994
  support, 1698
transaction_alloc_block_size system variable, 618
transaction_allow_batching session variable (NDB Cluster), 2315
transaction_prealloc_size system variable, 619
Translators
  list of, 37
transparent page compression, 3791
transportable tablespace, 3791
transporters
  ndbinfo table, 2507
.TRG file, 3789
TRIGGER privilege, 757
triggers, 1465, 1476, 1677, 2655, 2659
  and INSERT DELAYED, 1488
  and replication, 2095, 2104
  LAST_INSERT_ID(), 2659
  metadata, 2664
  restrictions, 2685
TRIGGERS
  INFORMATION_SCHEMA table, 2727
triggers option
  mysql, 369
TRIM(), 1284
.TRN file, 3789
troubleshooting, 3077, 3791
  C API, 2943
  FreeBSD, 189
  InnoDB deadlocks, 1758, 1759
  InnoDB errors, 1883
  InnoDB recovery problems, 1880
  InnoDB table fragmentation, 1800
  Solaris, 189
  with MySQL Enterprise Monitor, 3021
TRUE, 1032, 1038
  testing for, 1234, 1235
truncate, 3792
TRUNCATE TABLE, 1477
  and NDB Cluster, 2136
  and replication, 2105
performance_schema database, 2785, 2811
TRUNCATE(), 1252
tuning, 878
  InnoDB compressed tables, 1778
tuple, 3792
tupscan option
  ndb_select_all, 2428
tutorial, 227
twiddle option
  ndb_redo_log_reader, 2403	
two-phase commit, 1839, 3792
TwoPassInitialNodeRestartCopy, 2265
tx_isolation system variable, 619
TYPE
  removed features, 15
type codes
  prepared statement C API, 2896
type conversions, 1225, 1231
type option
  mysql_convert_table_format, 440
  ndb_config, 2378
  ndb_show_tables, 2431
types
  columns, 1157, 1213
data, 1157
date and time, 1166
numeric, 1158
of tables, 1887
portability, 1213
string, 1178
typographical conventions, 2
TZ environment variable, 449, 663, 3165
tz-utc option
  mysqldump, 369

U
UCASE(), 1284
UCS-2, 1084
ucs2 character set, 1121
  as client character set, 1101
UDF API, 705
UDFs, 705, 1627, 1628
  compiling, 3005
defined, 2996
  installing, 705
return values, 3004
  uninstalling, 705
ulimit, 3157
UMASK environment variable, 449, 3158
UMASK_DIR environment variable, 449, 3158
unary minus (-), 1243
unbuffered option
  mysql, 325
UNCOMPRESS(), 1336
UNCOMPRESSED_LENGTH(), 1336
undo, 3792
undo log, 3792
undo log segment, 3792
undo tablespace, 3793
UndoDataBuffer, 2254
UndoIndexBuffer, 2253
UNHEX(), 1285
Unicode, 1084
Unicode Collation Algorithm, 1126
Unicode support
  new features, 12
UNINSTALL PLUGIN statement, 1630
uninstalling plugins, 694, 1630
uninstalling UDFs, 705
UNION, 256, 1528
UNIQUE, 1398
unique constraint, 3793
unique ID, 2944
unique index, 3793
unique key, 3793
  constraint, 30
unique keys
  and partitioning keys, 2647
unique_checks system variable, 620
unique_subquery join type
  optimizer, 964
Unix
  compiling clients on, 2824
Unix signal handling, 450
UNIX_TIMESTAMP(), 1270
UNKNOWN
  testing for, 1234, 1235
Unknown column ... in 'on clause', 1527, 1528
unloading
  tables, 236
UNLOCK TABLES, 1550
unnamed views, 1535
unpack option
  myisamchk, 402
unqualified option
  ndb_desc, 2387
  ndb_show_tables, 2431
unsafe statement (replication)
  defined, 2008
unsafe statements (replication), 2009
UNSIGNED, 1158, 1163
UNTIL, 1581
updatable views, 2674
updatable_views_with_limit system variable, 620
UPDATE, 28, 1543
update
  thread state, 1020
update option
  MySQLInstallerConsole, 93
update option (ndb_index_stat), 2393
UPDATE privilege, 758
update-state option
  myisamchk, 400
UpdateXML(), 1320
Upgrading
    thread state, 1020
updating main table
    thread state, 1020
updating reference tables
    thread state, 1020
upgrade option
  MySQLInstallerConsole, 93
upgrade-system-tables option
  mysql_upgrade, 314
upgrades
  NDB Cluster, 2171, 2454
upgrades and downgrades (NDB Cluster)
    compatibility between versions, 2171
upgrading, 204
    different architecture, 217
to &current-series;, 205
upgrading lock
    thread state, 1022
upgrading MySQL, 308
UPPER(), 1285
uptime, 340
URLs for downloading MySQL, 45
usage option
  ndb_config, 2379
usage option (NDB Cluster programs), 2439
USAGE privilege, 758
USE, 1695
use command
  mysql, 329
USE INDEX, 975
USE KEY, 975
use-frm option
  mysqlcheck, 352
use-threads option
  mysqlimport, 378
useHexFormat option
  ndb_select_all, 2428
user accounts
  creating, 772, 1600
renaming, 1615
    resource limits, 572, 787, 1614
USER environment variable, 288, 449
User lock
    thread state, 1020
user management, 749
user names
and passwords, 750
in account names, 765
in default accounts, 199
user option, 282
mysql, 325
mysqlaccess, 420
mysqladmin, 345
mysqlbinlog, 428
mysqlcheck, 352
mysqld, 527
mysqldump, 369
mysqld_multi, 299
mysqld_safe, 294
mysqlhotcopy, 439
mysqlimport, 377
mysqlshow, 383
mysqsla, 390
mysql_convert_table_format, 440
mysql_install_db, 305
mysql_setpermission, 442
mysql_upgrade, 314
user privileges
adding, 772
checking, 774
deleting, 1603
dropping, 1603
revoking, 774
User sleep
thread state, 1020
user table
sorting, 768
system table, 199, 671, 759
user variables
and replication, 2105
USER(), 1348
user-defined functions (see UDFs)
adding, 2996, 2997
User-defined functions, 1627, 1628
user-defined variables, 1072
users
adding, 194
deleting, 775, 1603
root, 199
USER_PRIVILEGES
INFORMATION_SCHEMA table, 2729
USING HASH
with NDB tables, 1420
using multiple disks to start data, 1002
using NDB Cluster programs, 2349
USING versus ON
joins, 1527
UTC_DATE(), 1271
UTC_TIME(), 1271
UTC_TIMESTAMP(), 1271
UTF-8, 1084
  database object metadata, 1088
utf16 character set, 1121
  as client character set, 1101
utf16_bin collation, 1128
utf32 character set, 1121
  as client character set, 1101
utf8 character set, 1120
  alias for utf8mb3, 1120, 1120
utf8mb3 character set, 1120
  utf8 alias, 1120, 1120
utf8mb4 character set, 1119
utilities
  program-development, 265
utility programs, 264
UUID(), 1374
UUID_SHORT(), 1374

V
valid numbers
  examples, 1032
VALUES(), 1375
VARBINARY data type, 1180, 1183
VARCHAR
  size, 1212
VARCHAR data type, 1178, 1180
VARCHARACTER data type, 1180
variable option
  mysql_config, 444
variable-length type, 3793
variables
  and replication, 2105
  environment, 266
  server, 1678
  status, 634, 1672
  system, 528, 622, 1678
  user defined, 1072
VARIANCE(), 1366
VAR_POP(), 1366
VAR_SAMP(), 1366
verbose option
  myisamchk, 397
  myisampack, 412
  myisam_ftdump, 393
  mysql, 325
  mysqladmin, 345
  mysqlbinlog, 429
  mysqlcheck, 353
  mysqld, 528
  mysqldump, 369
  mysqldumps, 436
  mysqld_multi, 300
  mysqlimport, 378
mysqlshow, 383
mysqlslap, 391
mysql_convert_table_format, 440
mysql_install_db, 305
mysql_plugin, 307
mysql_upgrade, 314
mysql_waitpid, 442
my_print_defaults, 446
ndb_blob_tool, 2371
ndb_move_data, 2398
ndb_restore, 2422
perror, 447
verbose option (ndbd), 2355
verbose option (ndbmtld), 2355
verbose option (ndb_index_stat), 2395
verbose option (ndb_mgmd), 2368
version
  choosing, 44
  latest, 45
VERSION file
  CMake, 189
version option
  comp_err, 302
  myisamchk, 397
  myisampack, 412
  mysql, 325
  mysqlaccess, 420
  mysqladmin, 345
  mysqlbinlog, 429
  mysqlcheck, 353
  mysqlld, 528
  mysqldump, 369
  mysqld_multi, 300
  mysqlimport, 378
  mysqlshow, 383
  mysqlslap, 391
  mysql_config, 444
  mysql_convert_table_format, 440
  mysql_plugin, 307
  mysql_waitpid, 442
  my_print_defaults, 446
  ndb_config, 2379
  perror, 447
  resolveip, 448
  resolve_stack_dump, 446
version option (NDB Cluster programs), 2441
version system variable, 621
VERSION(), 1348
version-check option
  mysql_upgrade, 314
version_comment system variable, 621
version_compile_machine system variable, 621
version_compile_os system variable, 621
vertical option
mysql, 325
mysqldadmin, 345
victim, 3793
Vietnamese, 3052
view, 3794
views, 1467, 2655, 2672
  algorithms, 2673
  and replication, 2107
  limitations, 2689
  metadata, 2676
  privileges, 2689
  problems, 2689
  restrictions, 2688
  updatable, 1467, 2674
VIEWS
  INFORMATION_SCHEMA table, 2729

W
wait, 3794
WAIT COMPLETED (START BACKUP command), 2450
wait option
  myisamchk, 398
  myisampack, 412
  mysql, 325
  mysqldadmin, 345
WAIT STARTED (START BACKUP command), 2450
wait-nodes option
  ndb_waiter, 2436
Waiting for allowed to take ndbcluster global schema lock
  thread state, 1026
Waiting for commit lock
  thread state, 1020
waiting for delay_list
  thread state, 1022
Waiting for event from ndbcluster
  thread state, 1026
Waiting for event metadata lock
  thread state, 1021
Waiting for event read lock
  thread state, 1021
Waiting for first event from ndbcluster
  thread state, 1026
Waiting for global metadata lock
  thread state, 1021
Waiting for global read lock
  thread state, 1020, 1021
waiting for handler insert
  thread state, 1022
waiting for handler lock
  thread state, 1022
waiting for handler open
  thread state, 1022
Waiting for INSERT
thread state, 1022
Waiting for master to send event
  thread state, 1024
Waiting for master update
  thread state, 1024
Waiting for ndbcluster binlog update to reach current position
  thread state, 1026
Waiting for ndbcluster global schema lock
  thread state, 1026
Waiting for ndbcluster to start
  thread state, 1026
Waiting for next activation
  thread state, 1027
Waiting for query cache lock
  thread state, 1023
Waiting for scheduler to stop
  thread state, 1027
Waiting for schema epoch
  thread state, 1026
Waiting for schema metadata lock
  thread state, 1021
Waiting for slave mutex on exit
  thread state, 1024, 1025
Waiting for stored function metadata lock
  thread state, 1021
Waiting for stored procedure metadata lock
  thread state, 1021
Waiting for table
  thread state, 1020
Waiting for table flush
  thread state, 1021
Waiting for table level lock
  thread state, 1021
Waiting for table metadata lock
  thread state, 1021
Waiting for tables
  thread state, 1020
Waiting for the next event in relay log
  thread state, 1025
Waiting for the slave SQL thread to free enough relay log space
  thread state, 1024
Waiting for trigger metadata lock
  thread state, 1021
Waiting on cond
  thread state, 1021
Waiting on empty queue
  thread state, 1027
Waiting to finalize termination
  thread state, 1023
Waiting to reconnect after a failed binlog dump request
  thread state, 1025
Waiting to reconnect after a failed master event read
  thread state, 1025
wait_timeout system variable, 621
Wan, 2207, 2291
warm backup, 3794
warm up, 3794
warnings command
  mysql, 329
warning_count system variable, 622
WARN_COND_ITEM_TRUNCATED error code, 3126
WARN_DATA_TRUNCATED error code, 3099
WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED error code, 3125
WARN_NO_MASTER_INFO error code, 3124
WARN_OPTION_BELOW_LIMIT error code, 3132
WARN_OPTION_IGNORED error code, 3124
WARN_PLUGIN_BUSY error code, 3124
WARN_PLUGIN_DELETE_BUILTIN error code, 3124
websites
  MySQL, 18
WEEK(), 1272
WEEKDAY(), 1273
WEEKOFYEAR(), 1273
Well-Known Binary format
  geometry values, 1201
Well-Known Text format
  geometry values, 1200
WHERE, 881
  with SHOW, 2691, 2761
where option
  mysql_dump, 370
WHILE, 1582
  labels, 1575
widths
  display, 1158
Wildcard character (%), 1031
Wildcard character (_), 1031
wildcards
  and LIKE, 932
  in account names, 766
  in mysql.columns_priv table, 770
  in mysql.db table, 770
  in mysql.host table, 770
  in mysql.procs_priv table, 770
  in mysql.tables_priv table, 770
Windows
  compiling clients on, 2825
MySQL restrictions, 130
  path name separators, 273
  pluggable authentication, 821
  upgrading, 213
Windows authentication plugin
  new features, 10
windows option
  mysql_install_db, 305
WITH ROLLUP, 1366
Within(), 1362
WITH ASAN option
<table>
<thead>
<tr>
<th>Option</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>WITH_BUNDLED_LIBEVENT option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_BUNDLED_MEMCACHED option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_CLASSPATH option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_DEBUG option</td>
<td>184</td>
</tr>
<tr>
<td>WITH_EMBEDDED_SERVER option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_EMBEDDED_SHARED_LIBRARY option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_ERROR_INSERT option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_EXTRA_CHARSETS option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_LIBEDIT option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_LIBWRAP option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_NDBCLUSTER option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_NDBCLUSTER_STORAGE_ENGINE option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_NDBMTD option</td>
<td>187</td>
</tr>
<tr>
<td>WITH_NDB_BINLOG option</td>
<td>188</td>
</tr>
<tr>
<td>WITH_NDB_DEBUG option</td>
<td>188</td>
</tr>
<tr>
<td>WITH_NDB_JAVA option</td>
<td>188</td>
</tr>
<tr>
<td>WITH_NDB_PORT option</td>
<td>188</td>
</tr>
<tr>
<td>WITH_NDB_TEST option</td>
<td>188</td>
</tr>
<tr>
<td>WITH_READLINE option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_SSL option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_UNIT_TESTS option</td>
<td>185</td>
</tr>
<tr>
<td>WITH_UNIXODBC option</td>
<td>186</td>
</tr>
<tr>
<td>WITH_VALGRIND option</td>
<td>186</td>
</tr>
<tr>
<td>WITH_ZLIB option</td>
<td>186</td>
</tr>
<tr>
<td>WKB format</td>
<td></td>
</tr>
<tr>
<td>geometry values, 1201</td>
<td></td>
</tr>
<tr>
<td>WKT format</td>
<td></td>
</tr>
<tr>
<td>geometry values, 1200</td>
<td></td>
</tr>
<tr>
<td>workload, 3794</td>
<td></td>
</tr>
</tbody>
</table>
wrappers
  Eiffel, 2946
write access
tmp, 193
write combining, 3794
write-binlog option
  mysqlcheck, 353
  mysql_upgrade, 314
write_buffer_size myisamchk variable, 398
Writing to net
  thread state, 1021

X
X(), 1355
X.509/Certificate, 796
XA, 3794
XA BEGIN, 1558
XA COMMIT, 1558
XA PREPARE, 1558
XA RECOVER, 1558
XA ROLLBACK, 1558
XA START, 1558
XA transactions, 1557
  restrictions, 1560
  transaction identifiers, 1558
xid
  XA transaction identifier, 1558
xml option
  mysql, 325
  mysqldump, 370
  ndb_config, 2379
XML support
  new features, 13
XOR
  bitwise, 1328
  logical, 1237

Y
Y(), 1355
yaSSL, 175, 795
  compared to OpenSSL, 806
YEAR data type, 1168, 1171
YEAR(), 1273
YEAR(2)
  deprecated features, 14
YEARWEEK(), 1273
Yen sign (Japanese), 3052
young, 3795

Z
ZEROFILL, 1158, 1163, 2942
ZFS, 1927

3388
C Function Index

my_init()
Section 23.7.5, “C API Function Overview”
Section 23.7.11.1, “my_init()”
Section 23.7.11.3, “mysql_thread_init()”

mysql_affected_rows()
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 13.2.1, “CALL Statement”
Section 12.15, “Information Functions”
Section 13.2.5, “INSERT Statement”
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.48, “mysql_num_rows()”
Section 23.7.10.1, “mysql_stmt_affected_rows()”
Section 23.7.6.71, “mysql_use_result()”
Section 13.2.8, “REPLACE Statement”
Section 23.7.20.2, “What Results You Can Get from a Query”

mysql_autocommit()
Section 23.7.5, “C API Function Overview”

mysql_change_user()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.3, “mysql_change_user()”

mysql_character_set_name()
Section 23.7.5, “C API Function Overview”

mysql_client_find_plugin()
Section 23.7.5, “C API Function Overview”

mysql_client_register_plugin()
Section 23.7.5, “C API Function Overview”

mysql_close()
Section 23.7.5, “C API Function Overview”
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section 23.7.6.5, “mysql_close()”
Section 23.7.6.6, “mysql_commit()”
Section 23.7.6.7, “mysql_connect()”
Section 23.7.6.36, “mysql_init()”
Section 23.7.6.57, “mysql_rollback()”

mysql_commit()
Section 23.7.5, “C API Function Overview”

mysql_connect()
Section 23.7.5, “C API Function Overview”
mysql_create_db()
Section 23.7.5, “C API Function Overview”

mysql_data_seek()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.9, “mysql_data_seek()”
Section 23.7.6.58, “mysql_row_seek()”
Section 23.7.6.71, “mysql_use_result()”

mysql_debug()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.10, “mysql_debug()”

mysql_drop_db()
Section 23.7.5, “C API Function Overview”

mysql_dump_debug_info()
Section 23.7.5, “C API Function Overview”

mysql_eof()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.13, “mysql_eof()”

mysql_errno()
Section 6.4.2.3, “Audit Log File Formats”
Section 23.7.6, “C API Function Descriptions”
Section 23.7.5, “C API Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.13.1, “mysql_client_find_plugin()”
Section 23.7.13.2, “mysql_client_register_plugin()”
Section 23.7.6.7, “mysql_connect()”
Section 23.7.6.13, “mysql_eof()”
Section 23.7.6.14, “mysql_errno()”
Section 23.7.6.21, “mysql_fetch_row()”
Section 23.7.6.22, “mysql_field_count()”
Section 23.7.13.3, “mysql_load_plugin()”
Section 23.7.6.47, “mysql_num_fields()”
Section 23.7.6.66, “mysql_sqlstate()”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.8, “mysql_stmt_errno()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 13.6.7.4, “SIGNAL Statement”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

**mysql_error()**
Section 23.7.6, “C API Function Descriptions”
Section 23.7.5, “C API Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.13.1, “mysql_client_find_plugin()”
Section 23.7.13.2, “mysql_client_register_plugin()”
Section 23.7.6.7, “mysql_connect()”
Section 23.7.6.13, “mysql_eof()”
Section 23.7.6.15, “mysql_error()”
Section 23.7.6.21, “mysql_fetch_row()”
Section 23.7.13.3, “mysql_load_plugin()”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.9, “mysql_stmt_error()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 13.6.7.4, “SIGNAL Statement”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

**mysql_escape_string()**
Section 23.7.5, “C API Function Overview”
Section 23.7.6.16, “mysql_escape_string()”

**mysql_fetch_field()**
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.17, “mysql_fetch_field()”
Section 23.7.6.23, “mysql_field_seek()”
Section 23.7.6.24, “mysql_field_tell()”
Section 23.7.10.23, “mysql_stmt_result_metadata()”

**mysql_fetch_field_direct()**
Section 23.7.5, “C API Function Overview”
Section 23.7.10.23, “mysql_stmt_result_metadata()”

**mysql_fetch_fields()**
Section 23.7.5, “C API Function Overview”
Section 23.7.10.23, “mysql_stmt_result_metadata()”

**mysql_fetch_lengths()**
Section 23.7.5, “C API Function Overview”
Section 23.7.6.20, “mysql_fetch_lengths()”
Section 23.7.6.21, “mysql_fetch_row()”

**mysql_fetch_row()**
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 15.9.1, “FEDERATED Storage Engine Overview”
mysql_field_count()

mysql_field_seek()

mysql_field_tell()

mysql_free_result()

mysql_get_character_set_info()

mysql_get_client_info()
Section 23.7.6, “mysql_connect()”

**mysql_get_client_version()**
Section 23.7.5, “C API Function Overview”
Section 23.7.3.4, “C API Server Version and Client Library Version”

**mysql_get_host_info()**
Section 23.7.5, “C API Function Overview”

**mysql_get_proto_info()**
Section 23.7.5, “C API Function Overview”

**mysql_get_server_info()**
Section 23.7.5, “C API Function Overview”
Section 23.7.3.4, “C API Server Version and Client Library Version”

**mysql_get_server_version()**
Section 23.7.5, “C API Function Overview”
Section 23.7.3.4, “C API Server Version and Client Library Version”

**mysql_get_ssl_cipher()**
Section 23.7.14, “C API Encrypted Connection Support”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.33, “mysql_get_ssl_cipher()”

**mysql_hex_string()**
Section 23.7.5, “C API Function Overview”
Section 23.7.6.34, “mysql_hex_string()”

**mysql_info()**
Section 13.1.7, “ALTER TABLE Statement”
Section 23.7.5, “C API Function Overview”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 13.2.6, “LOAD DATA Statement”
Section 23.7.6.35, “mysql_info()”
Section 23.7.6.49, “mysql_options()”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 13.2.11, “UPDATE Statement”
Section 23.7.20.2, “What Results You Can Get from a Query”

**mysql_init()**
Section 23.7.5, “C API Function Overview”
Section 23.7.11.1, “my_init()”
Section 23.7.6.5, “mysql_close()”
Section 23.7.6.33, “mysql_get_ssl_cipher()”
Section 23.7.6.36, “mysql_init()”
Section 23.7.6.40, “mysql_library_init()”
Section 23.7.6.49, “mysql_options()”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.6.67, “mysql_ssl_set()”
Section 23.7.11.3, “mysql_thread_init()”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

`mysql_insert_id()`
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 13.1.17, “CREATE TABLE Statement”
Section 23.7.20.3, “How to Get the Unique ID for the Last Inserted Row”
Section 12.15, “Information Functions”
Section 13.2.5, “INSERT Statement”
Section 23.7.6.37, “mysql_insert_id()”
Section 5.1.7, “Server System Variables”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 23.7.20.2, “What Results You Can Get from a Query”

`mysql_kill()`
Section 23.7.19, “C API Automatic Reconnection Control”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.70, “mysql_thread_id()”

`mysql_library_end()`
Section 23.7.12, “C API Embedded Server Function Descriptions”
Section 23.7.5, “C API Function Overview”
Section 23.6, “libmysqld, the Embedded MySQL Server Library”
Section 23.7.6.39, “mysql_library_end()”
Section 23.7.6.40, “mysql_library_init()”
Section 23.7.12.1, “mysql_server_end()”
Section 23.7.12.2, “mysql_server_init()”

`mysql_library_init()`
Section 23.7.12, “C API Embedded Server Function Descriptions”
Section 23.7.5, “C API Function Overview”
Section 23.6, “libmysqld, the Embedded MySQL Server Library”
Section 23.7.11.1, “my_init()”
Section 23.7.6.36, “mysql_init()”
Section 23.7.6.40, “mysql_library_init()”
Section 23.7.13.3, “mysql_load_plugin()”
Section 23.7.12.2, “mysql_server_init()”
Section 23.7.11.3, “mysql_thread_init()”
Section 23.6.3, “Options with the Embedded Server”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

`mysql_list_dbs()`
Section 23.7.5, “C API Function Overview”
Section 23.7.6.25, “mysql_free_result()”
Section 23.7.6.41, “mysql_list_dbs()”

`mysql_list_fields()`
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.42, “mysql_list_fields()”

`mysql_list_processes()`
Section 23.7.5, “C API Function Overview”
mysql_list_tables()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.44, “mysql_list_tables()”

mysql_load_plugin()
Section 23.7.5, “C API Function Overview”
Client Plugin Descriptors
Section 23.7.13.4, “mysql_load_plugin_v()”

mysql_load_plugin_v()
Section 23.7.5, “C API Function Overview”

mysql_more_results()
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 23.7.6.45, “mysql_more_results()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.10.17, “mysql_stmt_next_result()”

mysql_next_result()
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Statement”
Section 23.7.6.45, “mysql_more_results()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.6.64, “mysql_set_server_option()”
Section 23.7.6.69, “mysql_store_result()”

mysql_num_fields()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.18, “mysql_fetch_field_direct()”
Section 23.7.6.21, “mysql_fetch_row()”
Section 23.7.10.23, “mysql_stmt_result_metadata()”

mysql_num_rows()
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.9, “mysql_data_seek()”
Section 23.7.6.48, “mysql_num_rows()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 23.7.20.2, “What Results You Can Get from a Query”

mysql_options()
Section 6.2.1, “Account User Names and Passwords”
Section 23.7.19, “C API Automatic Reconnection Control”
Section 23.7.13, “C API Client Plugin Functions”
Section 23.7.14, “C API Encrypted Connection Support”
Section 23.7.5, “C API Function Overview”
Section 23.7.8, “C API Prepared Statement Data Structures”
Client Plugin Descriptors
Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 10.4, “Connection Character Sets and Collations”
Section 4.2.5, “Connection Compression Control”
Section B.4.2.9, “MySQL server has gone away”
Section 23.7.6.49, “mysql_options()”
Section 23.7.6.50, “mysql_ping()”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 24.2.3, “Plugin API Components”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”

Using the Authentication Plugins

mysql_ping()
Section 23.7.19, “C API Automatic Reconnection Control”
Section 23.7.5, “C API Function Overview”
Section B.4.2.9, “MySQL server has gone away”
Section 23.7.6.50, “mysql_ping()”
Section 23.7.6.70, “mysql_thread_id()”

mysql_plugin_options()
Section 23.7.5, “C API Function Overview”

mysql_query()
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Statement”
Section 23.7.20.3, “How to Get the Unique ID for the Last Inserted Row”
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.8, “mysql_create_db()”
Section 23.7.6.11, “mysql_drop_db()”
Section 23.7.6.17, “mysql_fetch_field()”
Section 23.7.6.38, “mysql_kill()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.51, “mysql_query()”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.6.54, “mysql_real_query()”
Section 23.7.6.56, “mysql_reload()”
Section 23.7.6.63, “mysql_set_local_infile_handler()”
Section 23.7.6.64, “mysql_set_server_option()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

mysql_real_connect()
Section 23.7.14, “C API Encrypted Connection Support”
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Statement”
Chapter 12, Functions and Operators
<table>
<thead>
<tr>
<th>Section 12.15, “Information Functions”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”</td>
</tr>
<tr>
<td>Section 13.2.5, “INSERT Statement”</td>
</tr>
<tr>
<td>Section 23.7.6.1, “mysql_affected_rows()”</td>
</tr>
<tr>
<td>Section 23.7.6.3, “mysql_change_user()”</td>
</tr>
<tr>
<td>Section 23.7.6.7, “mysql_connect()”</td>
</tr>
<tr>
<td>Section 23.7.6.36, “mysql_init()”</td>
</tr>
<tr>
<td>Section 23.7.6.46, “mysql_next_result()”</td>
</tr>
<tr>
<td>Section 23.7.6.49, “mysql_options()”</td>
</tr>
<tr>
<td>Section 23.7.6.52, “mysql_real_connect()”</td>
</tr>
<tr>
<td>Section 23.7.6.64, “mysql_set_server_option()”</td>
</tr>
<tr>
<td>Section 23.7.6.66, “mysql_sqlstate()”</td>
</tr>
<tr>
<td>Section 23.7.6.67, “mysql_ssl_set()”</td>
</tr>
<tr>
<td>Section 13.5, “Prepared Statements”</td>
</tr>
<tr>
<td>Section 5.1.7, “Server System Variables”</td>
</tr>
<tr>
<td>Section 20.2.1, “Stored Routine Syntax”</td>
</tr>
<tr>
<td>Section 4.10, “Unix Signal Handling in MySQL”</td>
</tr>
<tr>
<td>Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”</td>
</tr>
</tbody>
</table>

### `mysql_real_escape_string()`

- Section 23.7.5, “C API Function Overview”
- Section 23.7.6.16, “mysql_escape_string()”
- Section 23.7.6.53, “mysql_real_escape_string()”
- Section 23.7.6.61, “mysql_set_character_set()”
- Section 11.4.5, “Populating Spatial Columns”
- Section 9.1.1, “String Literals”

### `mysql_real_query()`

- Section 23.7.5, “C API Function Overview”
- Section 23.7.15, “C API Multiple Statement Execution Support”
- Section 13.2.1, “CALL Statement”
- Section 15.9.1, “FEDERATED Storage Engine Overview”
- Section 23.7.6.1, “mysql_affected_rows()”
- Section 23.7.6.46, “mysql_next_result()”
- Section 23.7.6.51, “mysql_query()”
- Section 23.7.6.52, “mysql_real_connect()”
- Section 23.7.6.54, “mysql_real_query()”
- Section 23.7.6.64, “mysql_set_server_option()”
- Section 23.7.6.69, “mysql_store_result()”
- Section 23.7.6.71, “mysql_use_result()”

### `mysql_refresh()`

- Section 23.7.5, “C API Function Overview”

### `mysql_reload()`

- Section 23.7.5, “C API Function Overview”

### `mysql_rollback()`

- Section 23.7.5, “C API Function Overview”

### `mysql_row_seek()`

- Section 23.7.5, “C API Function Overview”
mysql_row_tell()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.58, “mysql_row_seek()”
Section 23.7.6.59, “mysql_row_tell()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”

mysql_select_db()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.60, “mysql_select_db()”

mysql_server_end()
Section 23.7.5, “C API Function Overview”
Section 23.7.12.1, “mysql_server_end()”
Section 23.7.12.2, “mysql_server_init()”

mysql_server_init()
Section 23.7.5, “C API Function Overview”
Section 23.7.11.1, “my_init()”
Section 23.7.12.2, “mysql_server_init()”
Section 23.7.11.3, “mysql_thread_init()”

mysql_set_character_set()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.26, “mysql_get_character_set_info()”
Section 23.7.6.53, “mysql_real_escape_string()”

mysql_set_local_infile_default()
Section 23.7.5, “C API Function Overview”

mysql_set_local_infile_handler()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.62, “mysql_set_local_infile_default()”
Section 23.7.6.63, “mysql_set_local_infile_handler()”

mysql_set_server_option()
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 23.7.6.64, “mysql_set_server_option()”

mysql_shutdown()
Section 23.7.5, “C API Function Overview”
Section 23.7.6.65, “mysql_shutdown()”
Section 6.2.2, “Privileges Provided by MySQL”

mysql_sqlstate()
Section 23.7.5, “C API Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.6.14, “mysql_errno()”
Section 23.7.6.66, “mysql_sqlstate()”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.27, “mysql_stmt_sqlstate()”
Section 13.6.7.4, “SIGNAL Statement”

`mysql_ssl_set()`
Section 23.7.14, “C API Encrypted Connection Support”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.6.67, “mysql_ssl_set()”

`mysql_stat()`
Section 23.7.5, “C API Function Overview”

`mysql_stmt_affected_rows()`
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.1, “mysql_stmt_affected_rows()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.17, “mysql_stmt_next_result()”
Section 23.7.10.18, “mysql_stmt_num_rows()”

`mysql_stmt_attr_get()`
Section 23.7.9, “C API Prepared Statement Function Overview”

`mysql_stmt_attr_set()`
Section 23.7.4, “C API Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.8.2, “C API Prepared Statement Type Conversions”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.28, “mysql_stmt_store_result()”
Section 13.6.6.5, “Restrictions on Server-Side Cursors”

`mysql_stmt_bind_param()`
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.16, “C API Prepared Statement Handling of Date and Time Values”
Section 23.7.10.4, “mysql_stmt_bind_param()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.21, “mysql_stmt_prepare()”
Section 23.7.10.26, “mysql_stmt_send_long_data()”

`mysql_stmt_bind_result()`
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.16, “C API Prepared Statement Handling of Date and Time Values”
Section 23.7.10.5, “mysql_stmt_bind_result()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.12, “mysql_stmt_fetch_column()”
Section 23.7.10.17, “mysql_stmt_next_result()”
Section 23.7.10.28, “mysql_stmt_store_result()”
mysql_stmt_close()
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.8, “mysql_stmt_errno()”
Section 23.7.10.9, “mysql_stmt_error()”
Section 23.7.10.15, “mysql_stmt_init()”
Section 23.7.10.27, “mysql_stmt_sqlstate()”

mysql_stmt_data_seek()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.7, “mysql_stmt_data_seek()”
Section 23.7.10.24, “mysql_stmt_row_seek()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_errno()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.8, “mysql_stmt_errno()”
Section 23.7.10.11, “mysql_stmt_fetch()”

mysql_stmt_error()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.9, “mysql_stmt_error()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.21, “mysql_stmt_prepare()”

mysql_stmt_execute()
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.16, “C API Prepared Statement Handling of Date and Time Values”
Section 23.7.8.2, “C API Prepared Statement Type Conversions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.7.10.1, “mysql_stmt_affected_rows()”
Section 23.7.10.3, “mysql_stmt_attr_set()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.17, “mysql_stmt_next_result()”
Section 23.7.10.26, “mysql_stmt_send_long_data()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_fetch()
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.8.2, “C API Prepared Statement Type Conversions”
Section B.3.2, “Client Error Message Reference”
Section 23.7.10.5, “mysql_stmt_bind_result()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.23, “mysql_stmt_result_metadata()”
mysql_stmt_fetch_column()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.25, “mysql_stmt_row_tell()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_field_count()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.13, “mysql_stmt_field_count()”

mysql_stmt_free_result()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.3, “mysql_stmt_attr_set()”
Section 23.7.10.14, “mysql_stmt_free_result()”
Section 23.7.10.17, “mysql_stmt_next_result()”

mysql_stmt_init()
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.12, “mysql_stmt_prepare()”
Section 23.7.10.21, “mysql_stmt_prepare()”

mysql_stmt_insert_id()
Section 23.7.9, “C API Prepared Statement Function Overview”

mysql_stmt_next_result()
Section 23.7.17, “C API Prepared CALL Statement Support”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 13.2.1, “CALL Statement”
Section 23.7.10.17, “mysql_stmt_next_result()”

mysql_stmt_num_rows()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.7, “mysql_stmt_data_seek()”
Section 23.7.10.18, “mysql_stmt_num_rows()”

mysql_stmt_param_count()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.10, “mysql_stmt_execute()”

mysql_stmt_param_metadata()
Section 23.7.9, “C API Prepared Statement Function Overview”

mysql_stmt_prepare()
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 23.7.8, “C API Prepared Statement Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.16, “C API Prepared Statement Handling of Date and Time Values”
mysql_stmt_reset()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.3, “mysql_stmt_attr_set()”
Section 23.7.10.26, “mysql_stmt_send_long_data()”

mysql_stmt_result_metadata()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.8.2, “C API Prepared Statement Type Conversions”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.23, “mysql_stmt_result_metadata()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_row_seek()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.24, “mysql_stmt_row_seek()”
Section 23.7.10.25, “mysql_stmt_row_tell()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_row_tell()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.24, “mysql_stmt_row_seek()”
Section 23.7.10.25, “mysql_stmt_row_tell()”
Section 23.7.10.28, “mysql_stmt_store_result()”

mysql_stmt_send_long_data()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section B.3.2, “Client Error Message Reference”
Section 23.7.10.22, “mysql_stmt_reset()”
Section 23.7.10.26, “mysql_stmt_send_long_data()”
Section 5.1.7, “Server System Variables”

mysql_stmt_sqlstate()
Section 23.7.9, “C API Prepared Statement Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.10.6, “mysql_stmt_close()”
Section 23.7.10.27, “mysql_stmt_sqlstate()”

mysql_stmt_store_result()
Section 23.7.4, “C API Data Structures”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 23.7.10.3, “mysql_stmt_attr_set()”
Section 23.7.10.7, “mysql_stmt_data_seek()”
Section 23.7.10.11, “mysql_stmt_fetch()”
Section 23.7.10.18, “mysql_stmt_num_rows()”
mysql_store_result()

Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section B.4.2.14, “Commands out of sync”
Section 15.9.1, “FEDERATED Storage Engine Overview”
Section 4.5.1, “mysql — The MySQL Command-Line Client”
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.9, “mysql_data_seek()”
Section 23.7.6.13, “mysql_eof()”
Section 23.7.6.17, “mysql_fetch_field()”
Section 23.7.6.21, “mysql_fetch_row()”
Section 23.7.6.22, “mysql_field_count()”
Section 23.7.6.25, “mysql_free_result()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.47, “mysql_num_fields()”
Section 23.7.6.48, “mysql_num_rows()”
Section 23.7.6.58, “mysql_row_seek()”
Section 23.7.6.59, “mysql_row_tell()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.10.23, “mysql_stmt_result_metadata()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 23.7.20.2, “What Results You Can Get from a Query”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

mysql_thread_end()

Section 23.7.5, “C API Function Overview”
Section 23.6, “libmysqld, the Embedded MySQL Server Library”
Section 23.7.11.2, “mysql_thread_end()”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

mysql_thread_id()

Section 23.7.19, “C API Automatic Reconnection Control”
Section 23.7.5, “C API Function Overview”
Section 23.7.6.50, “mysql_ping()”
Section 23.7.6.70, “mysql_thread_id()”

mysql_thread_init()

Section 23.7.5, “C API Function Overview”
Section 23.6, “libmysqld, the Embedded MySQL Server Library”
Section 23.7.11.1, “my_init()”
Section 23.7.11.2, “mysql_thread_end()”
Section 23.7.11.3, “mysql_thread_init()”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

mysql_thread_safe()

Section 23.7.5, “C API Function Overview”
mysql_use_result()
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section B.4.2.14, “Commands out of sync”
Section 4.5.1, “mysql — The MySQL Command-Line Client”
Section 23.7.6.9, “mysql_data_seek()”
Section 23.7.6.13, “mysql_eof()”
Section 23.7.6.21, “mysql_fetch_row()”
Section 23.7.6.25, “mysql_free_result()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.47, “mysql_num_fields()”
Section 23.7.6.48, “mysql_num_rows()”
Section 23.7.6.58, “mysql_row_seek()”
Section 23.7.6.59, “mysql_row_tell()”
Section 23.7.10.10, “mysql_stmt_execute()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section B.4.2.8, “Out of memory”
Section 23.7.20.2, “What Results You Can Get from a Query”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

mysql_warning_count()
Section 23.7.5, “C API Function Overview”
Section B.2, “Error Information Interfaces”
Section 23.7.6.46, “mysql_next_result()”
Section 13.7.5.41, “SHOW WARNINGS Statement”

Command Index

A | B | C | D | E | G | H | I | K | L | M | N | O | P | R | S | T | U | V | W | Y | Z

A

[ index top ]

Access
Section 13.2.2, “DELETE Statement”

addgroup
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

addr2line
Section 24.5.1.5, “Using a Stack Trace”

adduser
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

APF
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”
apt-get
Section 16.2.1, “Installing memcached”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 16.2.3.3, “Using libmemcached with C and C++”

B

bash
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 4.2.1, “Invoking MySQL Programs”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 4.2.6, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

bison
Section 1.8.1, “Contributors to MySQL”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 2.9.2, “Source Installation Prerequisites”

C

[ index top ]

c++filt
Section 24.5.1.5, “Using a Stack Trace”

cat
Section 4.5.1.1, “mysql Client Options”

cd
Resetting the Root Password: Windows Systems

chkconfig
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 4.3.3, “mysql.server — MySQL Server Startup Script”

chroot
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

clang
Section 23.7.3.1, “Building C API Client Programs”

CMake
Section 10.13, “Adding a Character Set”
Section 24.4.2, “Adding a User-Defined Function”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section B.4.2.17, “Can't initialize character set”
Section 2.11.3, “Changes in MySQL 5.5”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 10.5, “Configuring Application Character Set and Collation”
Section 2.9.6, “Configuring SSL Library Support”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 4.9, “Environment Variables”
Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 2.9, “Installing MySQL from Source”
Section 2.9.5, “Installing MySQL Using a Development Source Tree”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Chapter 18, *MySQL NDB Cluster 7.2*
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 24.3, “MySQL Services for Plugins”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 22.2, “Performance Schema Build Configuration”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 10.3.2, “Server Character Set and Collation”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 2.9.2, “Source Installation Prerequisites”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 15.10, “The EXAMPLE Storage Engine”
Section 15.9, “The FEDERATED Storage Engine”
Section 1.3.2, “The Main Features of MySQL”
Section 5.8, “Tracing mysqld Using DTrace”
Section 4.2.2.2, “Using Option Files”
Section 1.4, “What Is New in MySQL 5.5”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

**cmake**
Section 24.4.2, “Adding a User-Defined Function”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”

**cmd**
Resetting the Root Password: Windows Systems

**cmd.exe**
Section 4.2.1, “Invoking MySQL Programs”
Section 1.2, “Typographical and Syntax Conventions”

**command.com**
Section 4.2.1, “Invoking MySQL Programs”
Section 1.2, “Typographical and Syntax Conventions”

**comp_err**
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.1, “Overview of MySQL Programs”
configure
Section 1.6, “How to Report Bugs or Problems"
Section 16.2.1, “Installing memcached”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 1.2, “Typographical and Syntax Conventions”
Section 16.2.3.3, “Using libmemcached with C and C++”
Section 16.2.3.6, “Using MySQL and memcached with PHP”
Section 1.4, “What Is New in MySQL 5.5”

copy
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
coreadm
Section 2.7, “Installing MySQL on Solaris”
Section 5.1.6, “Server Command Options”
cp
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
crash-me
Section 8.13.2, “The MySQL Benchmark Suite”
cron
Section B.4.2.2, “Can’t connect to [local] MySQL server”
Section 13.7.2.2, “CHECK TABLE Statement”
Section 15.3.1, “MyISAM Startup Options”
Section 5.4.7, “Server Log Maintenance”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 3.5, “Using mysql in Batch Mode”
csh
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.6, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”
D
[index top]
date
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
df
Section B.4.1, “How to Determine What Is Causing a Problem”

Directory Utility
Section 2.4.1, “General Notes on Installing MySQL on OS X”
**docker exec**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

**docker inspect**
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

**docker logs mysqld-container**
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

**docker ps**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

**docker pull**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

**docker rm**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

**docker run**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

**docker stop**
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

**dump**
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

E

emerge
Section 16.2.1, “Installing memcached”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”

G

gcc
Section 24.4.2, “Adding a User-Defined Function”
Section 23.7.3.1, “Building C API Client Programs”
Section 23.6.1, “Compiling Programs with libmysqld”
Section 2.13.3, “Problems Using the Perl DBI/DBD Interface”
Section 1.8.4, “Tools that were used to create MySQL”
Section 1.4, “What Is New in MySQL 5.5”

**gdb**
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 24.5.1.4, “Debugging mysqld under gdb”
Section 1.8.4, “Tools that were used to create MySQL”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

**git branch**
Section 2.9.5, “Installing MySQL Using a Development Source Tree”

**git checkout**
Section 2.9.5, “Installing MySQL Using a Development Source Tree”

**git checkout 5.7**
Section 2.9.5, “Installing MySQL Using a Development Source Tree”

**gmake**
Section 2.8, “Installing MySQL on FreeBSD”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.9.2, “Source Installation Prerequisites”

**GnuPG**
Section 2.1.3.2, “Signature Checking Using GnuPG”

**gnutar**
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.2, “Source Installation Prerequisites”

**gogoc**
Section 5.1.11.5, “Obtaining an IPv6 Address from a Broker”

**gpg**
Section 2.1.3.2, “Signature Checking Using GnuPG”

**grep**
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 3.3.4.7, “Pattern Matching”

**groupadd**
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

**gtar**
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.2, “Source Installation Prerequisites”

**gunzip**
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”

**gzip**
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 1.6, “How to Report Bugs or Problems”
Section 2.4, “Installing MySQL on OS X”
H

help contents
Section 4.5.1.4, “mysql Client Server-Side Help”

hostname
Section B.4.2.2, “Can't connect to [local] MySQL server”

I

icc
Section 2.1.5, “Compiler-Specific Build Characteristics”
Section 24.5, “Debugging and Porting MySQL”

ifconfig
Section 5.1.11.1, “Verifying System Support for IPv6”

innochecksum
Section 13.7.2.2, “CHECK TABLE Statement”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
MySQL Glossary
Section 4.1, “Overview of MySQL Programs”

install.rb
Section 16.2.3.7, “Using MySQL and memcached with Ruby”

iptables
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”

K

kill
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 13.3.7.3, “Restrictions on XA Transactions”
Section 4.10, “Unix Signal Handling in MySQL”

ksh
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.6, “Setting Environment Variables”

kswapd
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
ldconfig
Section 24.4.2, “Adding a User-Defined Function"

ldd libmysqlclient.so
Section 23.7.3.1, “Building C API Client Programs”

less
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”

libmemcached
libmemcached Command-Line Utilities

ln
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

logger
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

lsof +L1
Section B.4.3.5, “Where MySQL Stores Temporary Files”

m4
Section 2.9.2, “Source Installation Prerequisites”

make
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 16.2.1, “Installing memcached”
Section 2.8, “Installing MySQL on FreeBSD”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.13.3, “Problems Using the Perl DBI/DBD Interface”
Section 2.9.2, “Source Installation Prerequisites”

make && make install
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”

make install
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 16.2.1, “Installing memcached”
Section 2.9.7, “MySQL Source-Configuration Options”
make package
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.9.7, “MySQL Source-Configuration Options”

make test
Section 2.9.5, “Installing MySQL Using a Development Source Tree”
Section 2.13.1, “Installing Perl on Unix”
Section 24.1.2, “The MySQL Test Suite”

make VERbose=1
Section 2.9.8, “Dealing with Problems Compiling MySQL”

md5
Section 2.1.3.1, “Verifying the MD5 Checksum”

md5.exe
Section 2.1.3.1, “Verifying the MD5 Checksum”

md5sum
Section 2.1.3.1, “Verifying the MD5 Checksum”

memcache
Section 16.2.2.5, “memcached Hashing/Distribution Types”
Section 16.2.3.5, “Using MySQL and memcached with Python”

memcached
Section 16.2.3.1, “Basic memcached Operations”
Section 16.2.2.4, “Data Expiry”
Section 16.2.3, “Developing a memcached Application”
Section 16.2.4, “Getting memcached Statistics”
Section 16.2.1, “Installing memcached”
libmemcached Command-Line Utilities
libmemcached Set Functions
Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.2.2, “memcached Deployment”
Section 16.2.4.5, “memcached Detail Statistics”
Section 16.2.5, “memcached FAQ”
Section 16.2.4.1, “memcached General Statistics”
Section 16.2.2.5, “memcached Hashing/Distribution Types”
Section 16.2.4.3, “memcached Item Statistics”
Section 16.2.2.9, “memcached Logs”
Section 16.2.4.4, “memcached Size Statistics”
Section 16.2.4.2, “memcached Slabs Statistics”
Section 16.2.2.8, “memcached Thread Support”
Section 16.2.2.7, “Memory Allocation within memcached”
MySQL Glossary
Section 2.9.7, “MySQL Source-Configuration Options”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 16.2.3.3, “Using libmemcached with C and C++”
Section 16.2.2, “Using memcached”
Section 16.2.2.6, “Using memcached and DTrace”
Section 16.2.3.2, “Using memcached as a MySQL Caching Layer”
Section 16.2.4.6, “Using memcached-tool”
Section 16.2.3.8, “Using MySQL and memcached with Java”
Section 16.2.3.4, “Using MySQL and memcached with Perl”
Section 16.2.3.6, “Using MySQL and memcached with PHP”
Section 16.2.3.5, “Using MySQL and memcached with Python”
Section 16.2.3.7, “Using MySQL and memcached with Ruby”
Section 16.2, “Using MySQL with memcached”
Section 16.2.2.3, “Using Namespaces”
Section 16.2.3.9, “Using the memcached TCP Text Protocol”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

memcached-1.2.5 directory:
Section 16.2.1, “Installing memcached”

memcached-tool
Section 16.2.4, “Getting memcached Statistics”
Section 16.2.4.6, “Using memcached-tool”

memcat
libmemcached Command-Line Utilities

memcp
libmemcached Command-Line Utilities

memflush
libmemcached Command-Line Utilities

memrm
libmemcached Command-Line Utilities

memslap
libmemcached Command-Line Utilities

mgmd
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2, “NDB Cluster Installation”

mkdir
Section 13.1.10, “CREATE DATABASE Statement”

mklink
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”

more
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”

msiexec.exe
Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

msql2mysql
Section 4.7.1, “msql2mysql — Convert mSQL Programs for Use with MySQL”
Section 4.1, “Overview of MySQL Programs”
Section 4.8.2, “replace — A String-Replacement Utility”

mv
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.3, “The General Query Log”

my_print_defaults
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.1, “Overview of MySQL Programs”
Section 4.7, “Program Development Utilities”

myisam_ftdump
Section 12.9, “Full-Text Search Functions”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.1, “Overview of MySQL Programs”

myisamchk
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 13.7.2.2, “CHECK TABLE Statement”
Choosing an Install Type
Section 15.3.3.3, “Compressed Table Characteristics”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.2.2, “DELETE Statement”
Section 15.3.3.2, “Dynamic Table Characteristics”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.11.5, “External Locking”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 8.4.6, “Limits on Table Size”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Statement”
Section 19.3.3, “Maintenance of Partitions”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 15.3.1, “MyISAM Startup Options”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 7.6.4, “MyISAM Table Optimization”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”
Section 4.6.5, “mysampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 4.6.3.4, “Other myisamchk Options”
Section 4.1, “Overview of MySQL Programs”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 13.7.2.5, “REPAIR TABLE Statement”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.7, “Server System Variables”
Section 7.6.5, “Setting up a MyISAM Table Maintenance Schedule”
Section 13.7.5.23, “SHOW INDEX Statement”
Section 13.7.5.37, “SHOW TABLE STATUS Statement”
Section 15.3.3.1, “Static (Fixed-Length) Table Characteristics”
Section 8.12.1, “System Factors”
Section 21.21, “The INFORMATION_SCHEMA STATISTICS Table”
Section 21.22, “The INFORMATION_SCHEMA TABLES Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.3, “The MyISAM Storage Engine”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 8.12.3.3, “What to Do If MySQL Keeps Crashing”

myisamchk *.MYI
Section 7.6.3, “How to Repair MyISAM Tables”

myisamchk tbl_name
Section 7.6.2, “How to Check MyISAM Tables for Errors”

myisamlog
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.1, “Overview of MySQL Programs”

myisampack
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 15.3.3.3, “Compressed Table Characteristics”
Section 13.1.17, “CREATE TABLE Statement”
Section 8.11.5, “External Locking”
Section 8.4.6, “Limits on Table Size”
Section 15.8.1, “MERGE Table Advantages and Disadvantages”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 8.4.1, “Optimizing Data Size”
Section 4.1, “Overview of MySQL Programs”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 15.8, “The MERGE Storage Engine”
Section 15.3, “The MyISAM Storage Engine”

mysql
Section 1.7.2.4, “‘--’ as the Start of a Comment”
mysql ...
Section 24.5.1.1, “Compiling MySQL for Debugging”

mysql-server
Section 2.8, “Installing MySQL on FreeBSD”

mysql-test-run.pl
Section 24.1.2, “The MySQL Test Suite”

mysql-test-run.pl test_name
Section 24.1.2, “The MySQL Test Suite”

mysql.exe
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”

mysql.server
Section 2.5, “Installing MySQL on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.3.3, “mysql.server — MySQL Server Startup Script”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.1, “Overview of MySQL Programs”
Section 5.1.6, “Server Command Options”
Section 2.10.5, “Starting and Stopping MySQL Automatically”
Section B.4.3.7, “Time Zone Problems”

mysql.server stop
Section 4.3.3, “mysql.server — MySQL Server Startup Script”

mysql_config
Section 23.7.3.1, “Building C API Client Programs”
Section 23.6.1, “Compiling Programs with libmysqld”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 23.7.1, “MySQL C API Implementations”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Section 4.1, “Overview of MySQL Programs”
Section 4.2.3, “Plugin API Components”

mysql_config_editor
Section 4.2.2.2, “Using Option Files”

mysql_convert_table_format
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.1, “Overview of MySQL Programs”

mysql_find_rows
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 4.1, “Overview of MySQL Programs”
mysql_fix_extensions
Section 4.6.12, "mysql_fix_extensions — Normalize Table File Name Extensions"
Section 4.1, “Overview of MySQL Programs”

mysql_install_db
Section 2.10.1, “Initializing the Data Directory”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.4.3, "mysql_install_db — Initialize MySQL Data Directory”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 5.1.6, “Server Command Options”

mysql_plugin
Section 4.4.4, "mysql_plugin — Configure MySQL Server Plugins”
Section 4.1, “Overview of MySQL Programs”

mysql_secure_installation
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”
Section 4.4.5, "mysql_secure_installation — Improve MySQL Installation Security”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.4, “Securing the Initial MySQL Accounts”

mysql_setpermission
Section 1.8.1, “Contributors to MySQL”
Section 4.6.13, "mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.2, “Starting the Server”

mysql_setpermissions
Section 4.6.13, "mysql_setpermission — Interactively Set Permissions in Grant Tables”

mysql_stmt_execute()
Section 5.1.9, “Server Status Variables”

mysql_stmt_prepare()
Section 5.1.9, “Server Status Variables”

mysql_tzinfo_to_sql
Section 5.1.12, “MySQL Server Time Zone Support”
Section 4.4.6, "mysql_tzinfo_to_sql — Load the Time Zone Tables”
Section 4.1, “Overview of MySQL Programs”

mysql_upgrade
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 13.1.1, “ALTER DATABASE Statement”
Section 2.11.3, “Changes in MySQL 5.5”
Section 2.12.3, “Downgrade Notes”
Section 2.12.4, “Downgrading MySQL Binary and Package Installations on Unix/Linux”
Section 6.2.3, “Grant Tables”
Section B.4.2.15, “Ignoring user”
Section 2.10.1, “Initializing the Data Directory”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.1, “Overview of MySQL Programs”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”
Section 5.1.6, “Server Command Options”
Section B.3.1, “Server Error Message Reference”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”
Section 2.11.5, “Upgrading MySQL on Windows”

mysql_waitpid
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.1, “Overview of MySQL Programs”

mysql_waitpid()
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”

mysql_zap
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.1, “Overview of MySQL Programs”

mysqlaccess
Section 1.8.1, “Contributors to MySQL”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.2, “Starting the Server”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

mysqladmin
Section 6.2.9, “Assigning Account Passwords”
Section 17.3.1.1, “Backing Up a Slave Using mysqldump”
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 5.1.1, “Configuring the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 10.4, “Connection Character Sets and Collations”
Section 1.8.1, “Contributors to MySQL”
Section 13.1.10, “CREATE DATABASE Statement”
Section 2.3.6.6, “Customizing the PATH for MySQL Tools”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.1.21, “DROP DATABASE Statement”
Section 23.7.2, “Example C API Client Programs”
Section 13.7.6.3, “FLUSH Statement”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section B.4.1, “How to Determine What Is Causing a Problem”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 2.3.3.1, “MySQL Installer Initial Setup”
Section 5.4, “MySQL Server Logs”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.1, “Overview of MySQL Programs”
Section 6.2.10, “Pluggable Authentication”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section 2.3.6.5, “Starting MySQL from the Windows Command Line”
Section 2.10.3, “Testing the Server”
Section 1.3.2, “The Main Features of MySQL”
Section 5.1.14, “The Server Shutdown Process”
Section 2.11.5, “Upgrading MySQL on Windows”
Section 4.2.2.2, “Using Option Files”
Section 4.2.2.1, “Using Options on the Command Line”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

`mysqladmin debug`
Section 24.5.1, “Debugging a MySQL Server”
Section 20.4.5, “Event Scheduler Status”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

`mysqladmin extended-status`
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.7.5.36, “SHOW STATUS Statement”

`mysqladmin flush-hosts`
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section B.4.2.6, “Host 'host_name' is blocked”
Section 5.1.7, “Server System Variables”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

`mysqladmin flush-logs`
Section 7.3.3, “Backup Strategy Summary”
Section 2.11.3, “Changes in MySQL 5.5”
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 7.3.1, “Establishing a Backup Policy”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.4, “The Binary Log”
Section 17.2.2.1, “The Slave Relay Log”

`mysqladmin flush-privileges`
Section 2.11.8, “Copying MySQL Databases to Another Machine”
Section 6.2.3, “Grant Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 5.1.6, “Server Command Options”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 6.2.8, “When Privilege Changes Take Effect”

`mysqladmin flush-tables`
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.11.5, “External Locking”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 7.6.1, “Using myamchk for Crash Recovery”

`mysqladmin flush-xxx`
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”

`mysqladmin kill`
Section B.4.3.4, “How MySQL Handles a Full Disk”
Section 13.7.6.4, “KILL Statement”
Section 12.14, “Locking Functions”
Section B.4.2.9, “MySQL server has gone away”
Section 6.2.2, “Privileges Provided by MySQL”

`mysqladmin password`
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

`mysqladmin processlist`
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 8.14, “Examining Thread Information”
Section 13.7.6.4, “KILL Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 24.1.1, “MySQL Threads”
Section 23.7.6.43, “mysql_list_processes()”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”

`mysqladmin processlist status`
Section 24.5.1, “Debugging a MySQL Server”

`mysqladmin refresh`
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 5.4.7, “Server Log Maintenance”

`mysqladmin reload`
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 6.2.3, “Grant Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 5.1.6, “Server Command Options”
Section 6.2.12, “Setting Account Resource Limits”
Section 6.2.8, “When Privilege Changes Take Effect”

`mysqladmin reload version`
Section 1.6, “How to Report Bugs or Problems”

`mysqladmin shutdown`
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 24.5.1.2, “Creating Trace Files”
Section 13.7.1.3, “GRANT Statement”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.3.3, “mysql.server — MySQL Server Startup Script”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section 5.1.14, “The Server Shutdown Process”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

**mysqladmin status**
Section B.4.3.1, “How MySQL Opens and Closes Tables”
Section 23.7.6.68, “mysql_stat()”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

**mysqladmin variables**
Section B.4.2.9, “MySQL server has gone away”
Section 13.7.5.40, “SHOW VARIABLES Statement”

**mysqladmin variables extended-status processlist**
Section 1.6, “How to Report Bugs or Problems”

**mysqladmin ver**
Section 24.5.1.1, “Compiling MySQL for Debugging”

**mysqladmin version**
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 1.6, “How to Report Bugs or Problems”
Section B.4.2.9, “MySQL server has gone away”
Section 2.10.3, “Testing the Server”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

**mysqlanalyze**
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

**mysqldump**
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 14.21.1, “InnoDB Backup”
MySQL Glossary
Section 4.5.4, “mysqldump — A Database Backup Program”

**mysqlbinlog**
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.7.6.1, “BINLOG Statement”
Section 5.8.1.2, “Command Probes”
Section 17.4.5, “How to Report Replication Bugs or Problems”
Section 14.21.2, “InnoDB Recovery”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 12.15, “Information Functions”
Section 18.2.3, “Initial Configuration of NDB Cluster”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 14.21.1, “InnoDB Backup”
Section 14.15.1, “InnoDB Disk I/O”
Section 14.21.2, “InnoDB Recovery”
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.23, “InnoDB Troubleshooting”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.4.2, “Installing MySQL on OS X Using Native Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 13.7.6.4, “KILL Statement”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 13.2.6, “LOAD DATA Statement”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 18.5, “Management of NDB Cluster”
Section 12.18, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 15.3.1, “MyISAM Startup Options”
Section 4.6.3.2, “mysqschck Check Options”
Section 4.6.3.1, “mysqschck General Options”
Section 4.6.3, “mysqschck — MyISAM Table-Maintenance Utility”
Section 4.6.5, “mysqshpack — Generate Compressed, Read-Only MyISAM Tables”
Section A.1, “MySQL 5.5 FAQ: General”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 4.5.1.6, “mysql Client Tips”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Glossary
Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”
Chapter 18, MySQL NDB Cluster 7.2
Chapter 5, MySQL Server Administration
Section B.4.2.9, “MySQL server has gone away”
Section 5.4, “MySQL Server Logs”
MySQL Server Options for NDB Cluster
Section 5.1.12, “MySQL Server Time Zone Support”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 18.1.6, “MySQL Server Using InnoDB Compared with NDB Cluster”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 1.7, “MySQL Standards Compliance”
Section 24.1.1, “MySQL Threads”
Section 4.3.3, "mysql.server — MySQL Server Startup Script"
Section 23.7.6.1, "mysql_affected_rows()"
Section 4.4.3, "mysql_install_db — Initialize MySQL Data Directory"
Section 23.7.6.49, "mysql_options()"
Section 4.4.4, "mysql_plugin — Configure MySQL Server Plugins"
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.3.1, "mysqld — The MySQL Server"
Section 4.3.4, "mysqlldMulti — Manage Multiple MySQL Servers"
Section 4.3.2, "mysqlld_safe — MySQL Server Startup Script"
Section 4.5.4, "mysqlldump — A Database Backup Program"
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"
Section 18.5.16, "NDB API Statistics Counters and Variables"
Section 18.5.11.3, "NDB Cluster and MySQL Security Procedures"
Section 18.3.3.1, "NDB Cluster Configuration: Basic Example"
Section 18.3.1, "NDB Cluster Core Concepts"
Section 18.2, "NDB Cluster Installation"
Section 18.3.2.5, "NDB Cluster mysqld Option and Variable Reference"
Section 18.1.2, "NDB Cluster Nodes, Node Groups, Replicas, and Partitions"
Section 18.1, "NDB Cluster Overview"
Section 18.4, "NDB Cluster Programs"
Section 18.6, "NDB Cluster Replication"
Section 18.6.11, "NDB Cluster Replication Conflict Resolution"
Section 18.6.4, "NDB Cluster Replication Schema and Tables"
Section 18.6.10, "NDB Cluster Replication: Multi-Master and Circular Replication"
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"
Section 18.5.10, "ndbinfo: The NDB Cluster Information Database"
Section 13.7.2.4, "OPTIMIZE TABLE Statement"
Section B.4.5, "Optimizer-Related Issues"
Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs"
Section 23.6.3, "Options with the Embedded Server"
Section 18.1.5, "Options, Variables, and Parameters Added, Deprecated or Removed in NDB 7.2"
Section 4.1, "Overview of MySQL Programs"
Section 18.3.2, "Overview of NDB Cluster Configuration Parameters, Options, and Variables"
Section B.4.2.10, "Packet Too Large"
Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster"
Section 18.6.5, "Preparing the NDB Cluster for Replication"
Section 15.3.4.2, "Problems from Tables Not Being Closed Properly"
Section 2.10.1.1, "Problems Running mysql_install_db"
Section B.4.3.1, "Problems with File Permissions"
Section 4.2.2.4, "Program Option Modifiers"
Section 8.10.3.3, "Query Cache Configuration"
Section 18.3.3.2, "Recommended Starting Configuration for NDB Cluster"
Section 14.9.6, "Redo Log"
Section 13.7.2.5, "REPAIR TABLE Statement"
Section 17.1.3.1, "Replication and Binary Logging Option and Variable Reference"
Section 17.1.3, "Replication and Binary Logging Options and Variables"
Section 17.1.3.2, "Replication Master Options and Variables"
Section 17.1.3.3, "Replication Slave Options and Variables"
Section 2.11.5, “Upgrading MySQL on Windows”
Section 24.5.1.5, “Using a Stack Trace”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 4.2.2.2, “Using Option Files”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”
Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”
Section 1.4, “What Is New in MySQL 5.5”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”
Section 6.2.8, “When Privilege Changes Take Effect”
Section B.4.3.5, “Where MySQL Stores Temporary Files”
Section 2.1.1, “Which MySQL Version and Distribution to Install”
Section 24.2.4, “Writing Plugins”

**mysqld mysqld.trace**
Section 24.5.1.2, “Creating Trace Files”

**mysqld-debug**
Section 24.5.1.2, “Creating Trace Files”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 4.3.1, “mysqld — The MySQL Server”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 2.3.6.3, “Selecting a MySQL Server Type”

**mysqld.exe**
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

**mysqld_multi**
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.1, “Overview of MySQL Programs”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 1.4, “What Is New in MySQL 5.5”

**mysqld_safe**
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 5.1.1, “Configuring the Server”
Section 8.12.4.2, “Enabling Large Page Support”
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”
Section 5.4.2.3, “Error Logging to the System Log”
Section B.4.2.18, “File Not Found and Similar Errors”
Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 14.23, “InnoDB Troubleshooting”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 5.1.12, “MySQL Server Time Zone Support”
Section 4.3.3, “mysql.server — MySQL Server Startup Script”
Section 1.6, “How to Report Bugs or Problems”
Section 17.1.1, “How to Set Up Replication”
Section 9.2.3, “Identifier Case Sensitivity”
Section 4.6.1, “innocHECKSUM — Offline InnoDB File Checksum Utility”
Section 14.21.1, “InnoDB Backup”
Section 2.6, “Installing MySQL Using Unbreakable Linux Network (ULN)”
Section 13.2.6, “LOAD DATA Statement”
Section 13.2.7, “LOAD XML Statement”
Section 7.4.5.1, “Making a Copy of a Database”
Section 9.2.4, “Mapping of Identifiers to File Names”
Section 14.9.1.2, “Moving or Copying InnoDB Tables”
Section 4.5.1.1, “mysql Client Options”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 5.4, “MySQL Server Logs”
Section 7.4.5, “mysqldump Tips”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.1, “NDB Cluster Overview”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 18.5.3, “Online Backup of NDB Cluster”
Section 4.1, “Overview of MySQL Programs”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section B.4.4.8, “Problems with Floating-Point Values”
Section 14.11.9, “Purge Configuration”
Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Restoring to More Nodes Than the Original
Section 22.16, “Restrictions on Performance Schema”
Section 20.9, “Restrictions on Views”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section B.4.4.7, “Solving Problems with No Matching Rows”
Section 4.2.2, “Specifying Program Options”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section 2.3.5.1, “Starting the MySQL Server Instance Configuration Wizard”
Section 11.3.4, “The BLOB and TEXT Types”
Section 1.3.2, “The Main Features of MySQL”
Section 14.9.3.1, “The System Tablespace”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 13.7.3.4, “UNINSTALL PLUGIN Statement”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”
Section 7.4, “Using mysqldump for Backups”
Section 4.2.2.2, “Using Option Files”
Section 17.3.1, “Using Replication for Backups”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 1.4, “What Is New in MySQL 5.5”
Section 12.11, “XML Functions”

**mysql**
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

**mysqldumpslow**
Section 4.6.8, “**mysqldumpslow** — Summarize Slow Query Log Files”
Section 4.1, “Overview of MySQL Programs”
Section 5.4.5, “The Slow Query Log”

**mysqlhotcopy**
Chapter 7, *Backup and Recovery*
Section 7.1, “Backup and Recovery Types”
Section 1.8.1, “Contributors to MySQL”
Section 7.2, “Database Backup Methods”
Section 4.5.4, “**mysqldump** — A Database Backup Program”
Section 4.6.9, “**mysqlhotcopy** — A Database Backup Program”
Section 4.1, “Overview of MySQL Programs”
Section 1.4, “What Is New in MySQL 5.5”

**mysqlimport**
Section 7.1, “Backup and Recovery Types”
Section 10.4, “Connection Character Sets and Collations”
Section 2.11.8, “Copying MySQL Databases to Another Machine”
Section 7.2, “Database Backup Methods”
Section 2.12.6, “Downgrade Troubleshooting”
Section 13.2.6, “LOAD DATA Statement”
Section 4.5.5, “**mysqlimport** — A Data Import Program”
Section 4.1, “Overview of MySQL Programs”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 6.4.1.3, “Security Issues with LOAD DATA LOCAL”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

**MySQLInstallerConsole.exe**
Section 2.3.3.5, “MySQLInstallerConsole Reference”

**MySQLInstanceConfig.exe**
Section 2.3.5.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”

**mysqloptimize**
Section 4.5.3, “**mysqlcheck** — A Table Maintenance Program”

**mysqlrepair**
Section 4.5.3, “**mysqlcheck** — A Table Maintenance Program”

**mysqlshow**
Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 10.4, “Connection Character Sets and Collations”
Section 23.7.2, “Example C API Client Programs”
Section 4.5.6, “**mysqlshow** — Display Database, Table, and Column Information”
Section 4.1, “Overview of MySQL Programs”
Section 13.7.5.15, “SHOW DATABASES Statement”
Section 13.7.5.23, “SHOW INDEX Statement”
Section 13.7.5.37, “SHOW TABLE STATUS Statement”
Section 2.3.6.8, “Testing The MySQL Installation”
Section 2.10.3, “Testing the Server”
Section 2.3.8, “Windows Postinstallation Procedures”

`mysqlshow db_name`
Section 13.7.5.38, “SHOW TABLES Statement”

`mysqlshow db_name tbl_name`
Section 13.7.5.6, “SHOW COLUMNS Statement”

`mysqlslap`
Section 6.4.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.1, “Overview of MySQL Programs”
Section 8.13.3, “Using Your Own Benchmarks”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

`mysqltest`
Section 24.1.2, “The MySQL Test Suite”

N

[index top]

`nbdmtd`
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”

NDB
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”

`ndb_blob_tool`
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

`ndb_config`
Section 18.4, “NDB Cluster Programs”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”

`ndb_cpcd`
Section 18.4.8, “ndb_cpcd — Automate Testing for NDB Development”

`ndb_delete_all`
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”

`ndb_desc`
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

**ndb_print_file**

Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”

**ndb_print_schema_file**

Section 18.4.16, “ndb_print_backup_file — Print NDB Backup File Contents”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.18, “ndb_print_schema_file — Print NDB Schema File Contents”
Section 18.4.19, “ndb_print_sys_file — Print NDB System File Contents”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

**ndb_print_sys_file**

Section 18.4.16, “ndb_print_backup_file — Print NDB Backup File Contents”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.18, “ndb_print_schema_file — Print NDB Schema File Contents”
Section 18.4.19, “ndb_print_sys_file — Print NDB System File Contents”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

**ndb_redo_log_reader**

Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”

**ndb_restore**

Section 7.1, “Backup and Recovery Types”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.1, “NDB Cluster Overview”
Section 18.4, “NDB Cluster Programs”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.5.8, “NDB Cluster Single User Mode”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.5.3, “Online Backup of NDB Cluster”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original

**ndb_select_all**

Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

**ndb_select_count**

Section 18.4.23, “ndb_select_count — Print Row Counts for NDB Tables”
**ndb_show_tables**

MySQL Server Options for NDB Cluster

Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.4, “NDB Cluster Programs”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”

**ndb_size.pl**

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”
Section 2.13, “Perl Installation Notes”

**ndb_waiter**

Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

**ndbd**

Section 18.5.14.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.1.3, “Installing NDB Cluster Using .deb Files”
Section 18.5, “Management of NDB Cluster”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”
Section 18.2, “NDB Cluster Installation”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.4, “NDB Cluster Programs”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.4.3, “ndbmtkd — The NDB Cluster Data Node Daemon (Multi-Threaded)”
Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.3.1, “Quick Test Setup of NDB Cluster”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”
Section 18.5.1, “Summary of NDB Cluster Start Phases”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”
Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”

**ndbd.exe**
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

**ndbd_redo_log_reader**
Section 18.4.20, “ndbd_redo_log_reader — Check and Print Content of Cluster Redo Log”

**ndbinfo_select_all**
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”

**ndbmtd**
Section 18.5.14.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.4, “NDB Cluster Programs”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.4.3, “ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Restoring to Fewer Nodes Than the Original
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 18.5.10.14, “The ndbinfo resources Table”

**ndbmtd.exe**
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

**NET**
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

**NET START**
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”

**NET START mysql_service_name**
Section 2.3.6.7, “Starting MySQL as a Windows Service”
NET STOP
Section 18.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”

NET STOP mysqld_service_name
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section 2.11.5, “Upgrading MySQL on Windows”

NET STOP service_name
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”

nm
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 24.5.1.5, “Using a Stack Trace”

numactl
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”

O

openssl
Section 6.3.3, “Creating SSL Certificates and Keys Using openssl”

openssl md5 package_name
Section 2.1.3.1, “Verifying the MD5 Checksum”

otool
Section 23.7.3.1, “Building C API Client Programs”

P

pfexec
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

PGP
Section 2.1.3.2, “Signature Checking Using GnuPG”
ping6
Section 5.1.11.5, “Obtaining an IPv6 Address from a Broker”

pkgadd
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”

pkgrm
Section 2.7.1, "Installing MySQL on Solaris Using a Solaris PKG"

ppm
Section 2.13, “Perl Installation Notes”

ps
Section 6.2.9, “Assigning Account Passwords”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.12.4.1, “How to Determine What Is Causing a Problem”
Section 4.6.15, "mysql_zap — Kill Processes That Match a Pattern"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”

ps xa | grep mysqld
Section B.4.2.2, “Can't connect to [local] MySQL server”

R

(rename)
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.3, “The General Query Log”

replace
Section 4.7.1, "msql2mysql — Convert mSQL Programs for Use with MySQL"
Section 4.1, “Overview of MySQL Programs”
Section 4.8.2, "replace — A String-Replacement Utility"
Section 17.3.3, “Using Replication for Scale-Out”

resolve_stack_dump
Section 4.1, “Overview of MySQL Programs”
Section 4.7.4, "resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols"
Section 24.5.1.5, “Using a Stack Trace”

resolveip
Section 4.1, “Overview of MySQL Programs”
Section 4.8.3, "resolveip — Resolve Host name to IP Address or Vice Versa”

rm
Section 13.4.1.1, “PURGE BINARY LOGS Statement”
rpm
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.1.3.4, “Signature Checking Using RPM”

rpmbuild
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.9.2, “Source Installation Prerequisites”

rsync
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”

S
[index top]

SC
Section 2.3.6.7, “Starting MySQL as a Windows Service”

SC DELETE
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

SC DELETE mysqld_service_name
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

SC DELETE service_name
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

SC START
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”

SC START mysqld_service_name
Section 2.3.7, “Troubleshooting a Microsoft Windows MySQL Server Installation”
Section 2.11.5, “Upgrading MySQL on Windows”

sc start mysqld_service_name
Section 2.3.6.7, “Starting MySQL as a Windows Service”

SC STOP
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”

SC STOP mysqld_service_name
Section 2.3.6.7, “Starting MySQL as a Windows Service”
sc stop mysqld_service_name
Section 2.3.6.7, “Starting MySQL as a Windows Service”

SC STOP service_name
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”

scp
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

sed
Section 3.3.4.7, “Pattern Matching”

SELECT
Section 18.2.5, “NDB Cluster Example with Tables and Data”

service
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”

Service Control Manager
Section 2.3, “Installing MySQL on Microsoft Windows”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

Services
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

setenv
Section 4.2.6, “Setting Environment Variables”

setrlimit
Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.2, “Using memcached”

sh
Section B.4.2.18, “File Not Found and Similar Errors”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.6, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

SHOW
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.3.1, “Quick Test Setup of NDB Cluster”

SHOW ERRORS
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”

SHOW WARNINGS
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
sleep
Section 4.3.2, "mysqld_safe — MySQL Server Startup Script"

ssh
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”
Section 16.1.1, “Using ZFS for File System Replication”

Start>Run>cmd.exe
Section 6.3.3, “Creating SSL Certificates and Keys Using openssl”

strings
Section 6.1.1, “Security Guidelines”

su root
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”

sudo
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

System Preferences...
Section 2.4.4, "Installing and Using the MySQL Preference Pane"

T

[<index top>]

tax
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 3.3, “Creating and Using a Database”
Section 1.6, “How to Report Bugs or Problems”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.4, “Installing MySQL on OS X”
Section 2.7, “Installing MySQL on Solaris”
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 2.13.1, “Installing Perl on Unix”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 2.9.1, “Source Installation Methods”
Section 2.9.2, “Source Installation Prerequisites”
Section 2.1.1, “Which MySQL Version and Distribution to Install”

tcpdump
Section 6.1.1, “Security Guidelines”

tcsh
Section B.4.2.18, “File Not Found and Similar Errors”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.6, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

**tee**
Section 4.5.1.2, “mysql Client Commands”

**Telnet**
Section 16.2.4, “Getting **memcached** Statistics”

**telnet**
Section 16.2.4, “Getting **memcached** Statistics”
Section 6.1.1, “Security Guidelines”

**Terminal**
Section 2.4, “Installing MySQL on OS X”

**Text in this style**
Section 1.2, “Typographical and Syntax Conventions”

**top**
Section B.4.1, “How to Determine What Is Causing a Problem”

**U**

[index top]

**ulimit**
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 8.12.4.2, “Enabling Large Page Support”
Section B.4.2.18, “File Not Found and Similar Errors”
Section 16.2.2.1, “**memcached** Command-Line Options”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section B.4.2.10, “Packet Too Large”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

**unix_chkpwd**
Section 6.4.1.4, “PAM Pluggable Authentication”

**update-rc.d**
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”

**useradd**
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
usermod
Section 2.5.1, "Installing MySQL on Linux Using RPM Packages"

V

vi
Section 18.2.3, "Initial Configuration of NDB Cluster"
Section 4.5.1.2, "mysql Client Commands"
Section 3.3.4.7, "Pattern Matching"

vmstat
Section 16.2.2.1, "memcached Command-Line Options"

W

WinDbg
Section 24.5.1.3, "Using WER with PDB to create a Windows crashdump"

windbg.exe
Section 24.5.1.3, "Using WER with PDB to create a Windows crashdump"

winMd5Sum
Section 2.1.3.1, "Verifying the MD5 Checksum"

WinZip
Section 17.3.1.2, "Backing Up Raw Data from a Slave"
Section 2.9.4, "Installing MySQL Using a Standard Source Distribution"
Section 2.9.2, "Source Installation Prerequisites"

WordPad
Section 13.2.6, "LOAD DATA Statement"

Y

yacc
Section 2.9.8, "Dealing with Problems Compiling MySQL"
Section 9.3, "Keywords and Reserved Words"

yum
Section 16.2.1, "Installing memcached"
Section 2.5.4, "Installing MySQL on Linux Using Native Package Managers"
Section 2.5.1, "Installing MySQL on Linux Using RPM Packages"
Section 16.2.3.3, "Using libmemcached with C and C++"

yum install MySQL*rpm
Section 2.5.1, "Installing MySQL on Linux Using RPM Packages"
Z

zfs recv
Section 16.1.1, “Using ZFS for File System Replication”

zip
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 1.6, “How to Report Bugs or Problems”

zsh
Section 4.2.6, “Setting Environment Variables”

Function Index

Symbols | A | B | C | D | E | F | G | H | I | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y

Symbols

%  
Section 1.7.1, “MySQL Extensions to Standard SQL”

A

ABS()  
Section 24.4, “Adding Functions to MySQL”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 12.5.2, “Mathematical Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

ACOS()  
Section 12.5.2, “Mathematical Functions”

add()  
Section 16.2.3.1, “Basic memcached Operations”

ADDDATE()  
Section 12.6, “Date and Time Functions”

addslashes()  

ADDTIME()  
Section 12.6, “Date and Time Functions”
AES_DECRYPT()  
Section 12.13, “Encryption and Compression Functions”

AES_ENCRYPT()  
Section 12.13, “Encryption and Compression Functions”

Area()  
Section 12.16.7, “Geometry Property Functions”
Section 12.16.7.4, “Polygon and MultiPolygon Property Functions”

AsBinary()  
Section 11.4.6, “Fetching Spatial Data”
Section 12.16.6, “Geometry Format Conversion Functions”

ASCII()  
Section 13.8.3, “HELP Statement”
Section 12.7, “String Functions and Operators”

ASIN()  
Section 12.5.2, “Mathematical Functions”

AsText()  
Section 11.4.6, “Fetching Spatial Data”
Section 12.16.6, “Geometry Format Conversion Functions”

AsWKB()  
Section 12.16.6, “Geometry Format Conversion Functions”

AsWKT()  
Section 12.16.6, “Geometry Format Conversion Functions”

ATAN()  
Section 12.5.2, “Mathematical Functions”

ATAN2()  
Section 12.5.2, “Mathematical Functions”

AVG()  
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 11.2.1, “Date and Time Data Type Syntax”
Section 8.2.1.11, “GROUP BY Optimization”
Section 11.3.5, “The ENUM Type”
Section 1.3.2, “The Main Features of MySQL”
Section 11.3.6, “The SET Type”

B  
[index top]

BENCHMARK()  
Section 13.2.10.8, “Derived Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.15, “Information Functions”
Section 8.13.1, “Measuring the Speed of Expressions and Functions”
Section 13.2.10.10, “Optimizing Subqueries”

**BIN()**
Section 9.1.5, “Bit-Value Literals”
Section 12.7, “String Functions and Operators”

**BIT_AND()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

**BIT_COUNT()**
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

**BIT_LENGTH()**
Section 12.7, “String Functions and Operators”

**BIT_OR()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

**BIT_XOR()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

**C**

[index top]

**CAST()**
Section 9.1.5, “Bit-Value Literals”
Section 12.10, “Cast Functions and Operators”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”
Section 11.2.8, “Conversion Between Date and Time Types”
Section 12.6, “Date and Time Functions”
Section 9.5, “Expressions”
Section 9.1.4, “Hexadecimal Literals”
Section 1.7.2, “MySQL Differences from Standard SQL”
Section 11.2.2, “The DATE, DATETIME, and TIMESTAMP Types”
Section 12.2, “Type Conversion in Expression Evaluation”
Section 9.4, “User-Defined Variables”

**CEIL()**
Section 12.5.2, “Mathematical Functions”
CEILING()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.5.2, “Mathematical Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

Centroid()
Section 12.16.7.4, “Polygon and MultiPolygon Property Functions”

CHAR()
Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.7, “String Functions and Operators”

CHAR_LENGTH()
Section 12.7, “String Functions and Operators”
Section 10.10.1, “Unicode Character Sets”

CHARACTER_LENGTH()
Section 12.7, “String Functions and Operators”

CHARSET()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.15, “Information Functions”

COALESCE()
Section 12.3.2, “Comparison Functions and Operators”
Section 13.2.9.2, “JOIN Clause”

COERCIBILITY()
Section 10.8.4, “Collation Coercibility in Expressions”
Section 12.15, “Information Functions”

COLLATION()
Section B.4.4.1, “Case Sensitivity in String Searches”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.15, “Information Functions”

COMPRESS()
Section 12.13, “Encryption and Compression Functions”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.7, “Server System Variables”

CONCAT()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.10, “Cast Functions and Operators”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 10.2.1, “Character Set Repertoire”
Section 10.8.4, “Collation Coercibility in Expressions”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
CONCAT_WS()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.7, “String Functions and Operators”

CONNECTION_ID()
Section 6.4.2.3, “Audit Log File Formats”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.15, “Information Functions”
Section 13.7.6.4, “KILL Statement”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 22.10.6.2, “The threads Table”

Contains()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

CONV()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.5.2, “Mathematical Functions”
Section 12.7, “String Functions and Operators”

CONVERT()
Section 12.10, “Cast Functions and Operators”
Section 10.3.8, “Character Set Introducers”
Section 10.3.6, “Character String Literal Character Set and Collation”
Section 12.3.2, “Comparison Functions and Operators”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

CONVERT_TZ()
Section 12.6, “Date and Time Functions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.3.9, “Indexed Lookups from TIMESTAMP Columns”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”

COS()
Section 12.5.2, “Mathematical Functions”

COT()
Section 12.5.2, “Mathematical Functions”

COUNT()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 3.3.4.8, “Counting Rows”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 8.2.1.11, “GROUP BY Optimization”
Section 14.25, “InnoDB Restrictions and Limitations”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”
NDB Cluster Status Variables
Section B.4.4.3, “Problems with NULL Values”
Section 5.1.10, “Server SQL Modes”
Section 1.3.2, “The Main Features of MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 8.2.1.1, “WHERE Clause Optimization”

CRC32()
Section 12.5.2, “Mathematical Functions”

Crosses()
Section 12.16.9.1, “Spatial Relation Functions That Use Object Shapes”

crypt()
Section 12.13, “Encryption and Compression Functions”
Section 5.1.7, “Server System Variables”

CURDATE()
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_DATE
Section 11.5, “Data Type Default Values”
Section 12.6, “Date and Time Functions”

CURRENT_DATE()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_TIME
Section 12.6, “Date and Time Functions”

CURRENT_TIME()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_TIMESTAMP
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 13.1.11, “CREATE EVENT Statement”
Section 11.5, “Data Type Default Values”
CURRENT_TIMESTAMP()

Section 11.2.6, “Automatic Initialization and Updating for_TIMESTAMP”
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_USER

Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 6.2.3, “Grant Tables”
Section 12.15, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 6.2.4, “Specifying Account Names”
Section 20.6, “Stored Object Access Control”

CURRENT_USER()

Section 6.2.5, “Access Control, Stage 1: Connection Verification”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 8.10.3.1, “How the Query Cache Operates”
Implementing Proxy User Support in Authentication Plugins
Section 12.15, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 6.2.11, “Proxy Users”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.7.1.6, “SET PASSWORD Statement”
Section 6.2.4, “Specifying Account Names”
Section 6.2.14, “SQL-Based Account Activity Auditing”
Section 20.6, “Stored Object Access Control”
Section 10.2.2, “UTF-8 for Metadata”
Writing the Server-Side Authentication Plugin

CURTIME()

Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 5.1.12, “MySQL Server Time Zone Support”

D

[null]

DATABASE()

Section 17.1.3.4, “Binary Log Options and Variables”
Section 3.3.1, “Creating and Selecting a Database”
Section 13.1.21, “DROP DATABASE Statement”
Section 3.4, “Getting Information About Databases and Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.15, “Information Functions”
Section B.4.7, “Known Issues in MySQL”
Section 10.2.2, “UTF-8 for Metadata”

DATE()
Section 12.6, “Date and Time Functions”

DATE_ADD()
Section 12.5.1, “Arithmetic Operators”
Section 11.2, “Date and Time Data Types”
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 9.5, “Expressions”

DATE_FORMAT()
Section 23.7.18, “C API Prepared Statement Problems”
Section 12.10, “Cast Functions and Operators”
Section 12.6, “Date and Time Functions”
Section 10.16, “MySQL Server Locale Support”
Section 5.1.7, “Server System Variables”

DATE_SUB()
Section 11.2, “Date and Time Data Types”
Section 12.6, “Date and Time Functions”
Section 9.5, “Expressions”

DATEDIFF()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAY()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAYNAME()
Section 12.6, “Date and Time Functions”
Section 10.16, “MySQL Server Locale Support”
Section 5.1.7, “Server System Variables”

DAYOFMONTH()
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAYOFWEEK()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
DAYOFYEAR()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

DECODE()
Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

decl()
Section 16.2.3.1, “Basic memcached Operations”

DEFAULT()
Section 11.5, “Data Type Default Values”
Section 13.2.5, “INSERT Statement”
Section 12.18, “Miscellaneous Functions”
Section 13.2.8, “REPLACE Statement”

DEGREES()
Section 12.5.2, “Mathematical Functions”

delete()
Section 16.2.3.1, “Basic memcached Operations”

DES_DECRYPT()
Section 12.13, “Encryption and Compression Functions”
Section 5.1.6, “Server Command Options”

DES_ENCRYPT()
Section 12.13, “Encryption and Compression Functions”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.1.6, “Server Command Options”

Dimension()
Section 12.16.7.1, “General Geometry Property Functions”

Disjoint()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

E

[INDEX TOP]

ELT()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 8.4.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.7, “String Functions and Operators”

ENCODE()
Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

**ENCRIPT()**
Section 1.8.1, “Contributors to MySQL”
Section 12.13, “Encryption and Compression Functions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 10.11, “Restrictions on Character Sets”
Section 5.1.7, “Server System Variables”

**EndPoint()**
Section 12.16.7.3, “LineString and MultiLineString Property Functions”
Section 12.16.8, “Spatial Operator Functions”

**Envelope()**
Section 12.16.7.1, “General Geometry Property Functions”
Section 12.16.8, “Spatial Operator Functions”

**Equals()**
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

**EXP()**
Section 12.5.2, “Mathematical Functions”

**EXPORT_SET()**
Section 12.7, “String Functions and Operators”

**ExteriorRing()**
Section 12.16.7.4, “Polygon and MultiPolygon Property Functions”
Section 12.16.8, “Spatial Operator Functions”

**EXTRACT()**
Section 12.10, “Cast Functions and Operators”
Section 12.6, “Date and Time Functions”
Section 9.5, “Expressions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

**ExtractValue()**
Section 12.11, “XML Functions”

**F**

[3456]
FLOOR()
Section 12.5.2, “Mathematical Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

flush_all
Section 16.2.3.1, “Basic memcached Operations”

FORMAT()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.5.2, “Mathematical Functions”
Section 12.18, “Miscellaneous Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 10.16, “MySQL Server Locale Support”
Section 12.7, “String Functions and Operators”

FOUND_ROWS()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.15, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”

FROM_DAYS()
Section 12.6, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

FROM_UNIXTIME()
Section 6.4.2.4, “Audit Log Logging Control”
Section 1.8.1, “Contributors to MySQL”
Section 12.6, “Date and Time Functions”
Section 8.3.9, “Indexed Lookups from TIMESTAMP Columns”
Section 17.4.1.33, “Replication and Time Zones”

G
[index top]

GeomCollFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

GeomCollFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

GeometryCollection()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”

GeometryCollectionFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

GeometryCollectionFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”
GeometryFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

GeometryFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

GeometryN()
Section 12.16.7.5, “GeometryCollection Property Functions”
Section 12.16.8, “Spatial Operator Functions”

GeometryType()
Section 12.16.7.1, “General Geometry Property Functions”

GeomFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”
Section 11.4.5, “Populating Spatial Columns”
Section 11.4.3, “Supported Spatial Data Formats”

GeomFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

get()
Section 16.2.3.1, “Basic memcached Operations”

GET_FORMAT()
Section 12.6, “Date and Time Functions”
Section 10.16, “MySQL Server Locale Support”

GET_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 23.7.19, “C API Automatic Reconnection Control”
Section 13.1.11, “CREATE EVENT Statement”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 20.4.1, “Event Scheduler Overview”
Section 8.14.2, “General Thread States”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.11.1, “Internal Locking Methods”
Section 13.7.6.4, “KILL Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 12.14, “Locking Functions”
Section 23.7.6.3, “mysql_change_user()”
Section 17.4.1.14, “Replication and System Functions”

gethostbyaddr()
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

gethostbyname()
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

getrusage()
Section 18.5.10.18, “The ndbinfo threadstat Table”
gettimeofday()
Section 18.5.10.18, “The ndbinfo threadstat Table”

GLength()
Section 12.16.7.3, “LineString and MultiLineString Property Functions”
Section 11.4, “Spatial Data Types”
Section 12.7, “String Functions and Operators”

GREATEST()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”

GROUP_CONCAT()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section B.4.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 5.1.7, “Server System Variables”
Section 1.3.2, “The Main Features of MySQL”

H

[ index top ]

HEX()
Section 9.1.5, “Bit-Value Literals”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 10.3.6, “Character String Literal Character Set and Collation”
Section 9.1.4, “Hexadecimal Literals”
Section 12.5.2, “Mathematical Functions”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 12.7, “String Functions and Operators”

HOUR()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

I

[ index top ]

IF()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.4, “Control Flow Functions”
Section 13.6.5.2, “IF Statement”
Section B.4.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”

IFNULL()
Section 12.4, “Control Flow Functions”
Section B.4.4.3, “Problems with NULL Values”
incr()  
Section 16.2.3.1, “Basic memcached Operations”

INET_ATON()  
Section 12.18, “Miscellaneous Functions”

INET_NTOA()  
Section 12.18, “Miscellaneous Functions”

INSERT()  
Section 12.7, “String Functions and Operators”

INSTR()  
Section 12.7.3, “Character Set and Collation of Function Results”  
Section 12.7, “String Functions and Operators”

InteriorRingN()  
Section 12.16.7.4, “Polygon and MultiPolygon Property Functions”  
Section 12.16.8, “Spatial Operator Functions”

Intersects()  
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

INTERVAL()  
Section 12.3.2, “Comparison Functions and Operators”

IS_FREE_LOCK()  
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”  
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”  
Section 8.10.3.1, “How the Query Cache Operates”  
Section 12.14, “Locking Functions”  
Section 17.4.1.14, “Replication and System Functions”

IS_USED_LOCK()  
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”  
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”  
Section 8.10.3.1, “How the Query Cache Operates”  
Section 12.14, “Locking Functions”  
Section 17.4.1.14, “Replication and System Functions”

IsClosed()  
Section 12.16.7.3, “LineString and MultiLineString Property Functions”

IsEmpty()  
Section 12.16.7.1, “General Geometry Property Functions”

ISNULL()  
Section 12.3.2, “Comparison Functions and Operators”

IsSimple()  
Section 12.16.7.1, “General Geometry Property Functions”
LAST_DAY()
Section 12.6, “Date and Time Functions”

LAST_INSERT_ID()
Section 23.7.19, “C API Automatic Reconnection Control”
Section 12.3.2, “Comparison Functions and Operators”
Section 13.1.17, “CREATE TABLE Statement”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.7.20.3, “How to Get the Unique ID for the Last Inserted Row”
Section 12.15, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.7.6.37, “mysql_insert_id()”
Section 23.7.10.16, “mysql_stmt_insert_id()”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.7, “Server System Variables”
Section 20.2.4, “Stored Procedures, Functions, Triggers, and LAST_INSERT_ID()”
Section 17.4.4, “Troubleshooting Replication”
Section 20.5.3, “Updatable and Insertable Views”
Section 3.6.9, “Using AUTO_INCREMENT”

LCASE()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

LEAST()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”

LEFT()
Section 12.7, “String Functions and Operators”

LENGTH()
Section 11.6, “Data Type Storage Requirements”
Section 12.7, “String Functions and Operators”
Section 11.4.3, “Supported Spatial Data Formats”

Length()
Section 12.16.7.3, “LineString and MultiLineString Property Functions”
Section 11.4, “Spatial Data Types”

LineFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”
LineFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

LineString()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”

LineStringFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

LineStringFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

LN()
Section 12.5.2, “Mathematical Functions”

LOAD_FILE()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 13.2.7, “LOAD XML Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 8.2.2, “Privileges Provided by MySQL”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.7, “Server System Variables”
Section 12.7, “String Functions and Operators”

LOCALTIME
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.6, “Date and Time Functions”

LOCALTIME()
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

LOCALTIMESTAMP
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.6, “Date and Time Functions”

LOCALTIMESTAMP()
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

LOCATE()
Section 12.7, “String Functions and Operators”

LOG()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.5.2, “Mathematical Functions”
LOG10()
Section 12.5.2, “Mathematical Functions”

LOG2()
Section 12.5.2, “Mathematical Functions”

LOWER()
Section 12.10, “Cast Functions and Operators”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”
Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”

LPAD()
Section 12.7, “String Functions and Operators”

LTRIM()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

MATCH
Section 9.5, “Expressions”

MATCH()
Section 12.9, “Full-Text Search Functions”

MATCH()
Section 12.9.2, “Boolean Full-Text Searches”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 12.9.5, “Full-Text Restrictions”
MAX()
Section 11.2.9, “2-Digit Years in Dates”
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.3.1, “How MySQL Uses Indexes”
Section B.4.7, “Known Issues in MySQL”
Section 11.1.1, “Numeric Data Type Syntax”
Section 13.2.10.10, “Optimizing Subqueries”
Section 5.1.10, “Server SQL Modes”
Section 21.31.1, “The INFORMATION_SCHEMA TP Thread GROUP STATE Table”
Section 1.3.2, “The Main Features of MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 20.5.2, “View Processing Algorithms”

MBRContains()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”
Section 11.4.9, “Using Spatial Indexes”

MBRDissjoint()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBREqual()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRIntersects()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBROverlaps()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRTouches()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRWithin()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”
Section 11.4.9, “Using Spatial Indexes”

MD5()
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 19.2.5, “KEY Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 9.2, “Schema Object Names”

MICROSECOND()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

**MID()**
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

**MIN()**
Section 11.2.9, “2-Digit Years in Dates”
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 23.7.18, “C API Prepared Statement Problems”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.3.1, “How MySQL Uses Indexes”
Section B.4.7, “Known Issues in MySQL”
Section 11.1.1, “Numeric Data Type Syntax”
Section 13.2.10, “Optimizing Subqueries”
Section B.4.4.3, “Problems with NULL Values”
Section 1.3.2, “The Main Features of MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 8.2.1.1, “WHERE Clause Optimization”

**MINUTE()**
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

**MLineFromText()**
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

**MLineFromWKB()**
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

**MOD()**
Section 12.5.1, “Arithmetic Operators”
Section 3.3.4.5, “Date Calculations”
Section 12.5.2, “Mathematical Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 5.1.10, “Server SQL Modes”

**MONTH()**
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

**MONTHNAME()**
Section 12.6, “Date and Time Functions”
Section 10.16, “MySQL Server Locale Support”
Section 5.1.7, “Server System Variables”

**MPointFromText()**
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”
MPointFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

MPolyFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

MPolyFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

MultiLineString()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”

MultiLineStringFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

MultiLineStringFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

MultiPoint()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”

MultiPointFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

MultiPointFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

MultiPolygon()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”

MultiPolygonFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

MultiPolygonFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

my_open()
Section 5.1.9, “Server Status Variables”

N
[index top]

NAME_CONST()
Section 12.18, “Miscellaneous Functions”
Section 20.7, “Stored Program Binary Logging”

NOW()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
NULLIF()
Section 12.4, “Control Flow Functions”

NumGeometries()
Section 12.16.7.5, “GeometryCollection Property Functions”

NumInteriorRings()
Section 12.16.7.4, “Polygon and MultiPolygon Property Functions”

NumPoints()
Section 12.16.7.3, “LineString and MultiLineString Property Functions”

O

[ index top ]

OCT()
Section 12.7, “String Functions and Operators”

OCTET_LENGTH()
Section 12.7, “String Functions and Operators”

OLD_PASSWORD()
Section B.4.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Statement”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 5.1.7, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Statement”

ORD()
Section 12.7, “String Functions and Operators”

Overlaps()
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

P

[ index top ]
PASSWORD()
Section 6.2.5, “Access Control, Stage 1: Connection Verification”
Section 6.2.9, “Assigning Account Passwords”
Section 13.7.1.1, “CREATE USER Statement”
Section 12.13, “Encryption and Compression Functions”
Section B.4.2.15, “Ignoring user”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 19.2.5, “KEY Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 5.1.7, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Statement”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

PERIOD_ADD()
Section 12.6, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

PERIOD_DIFF()
Section 12.6, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

PI()
Section 9.2.5, “Function Name Parsing and Resolution”
Section 12.5.2, “Mathematical Functions”

Point()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”
Section 11.4.3, “Supported Spatial Data Formats”

PointFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

PointFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

PointN()
Section 12.16.7.3, “LineString and MultiLineString Property Functions”
Section 12.16.8, “Spatial Operator Functions”

PolyFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

PolyFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

Polygon()
Section 12.16.5, “MySQL-Specific Functions That Create Geometry Values”
PolygonFromText()
Section 12.16.3, “Functions That Create Geometry Values from WKT Values”

PolygonFromWKB()
Section 12.16.4, “Functions That Create Geometry Values from WKB Values”

POSITION()
Section 12.7, “String Functions and Operators”

POW()
Section 8.2.1.14, “Function Call Optimization”
Section 19.2.4, “HASH Partitioning”
Section 12.5.2, “Mathematical Functions”

POWER()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.5.2, “Mathematical Functions”

pthread_mutex()
Section 1.8.1, “Contributors to MySQL”

Q
[index top]

QUARTER()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

QUOTE()
Section 23.7.6.53, “mysql_real_escape_string()”
Section 12.7, “String Functions and Operators”
Section 9.1.1, “String Literals”

R
[index top]

RADIANS()
Section 12.5.2, “Mathematical Functions”

RAND()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.2.1.14, “Function Call Optimization”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.5.2, “Mathematical Functions”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.7, “Server System Variables”
RELEASE_ALL_LOCKS()
Section 8.10.3.1, “How the Query Cache Operates”

RELEASE_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 13.2.3, “DO Statement”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.11.1, “Internal Locking Methods”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 12.14, “Locking Functions”
Section 17.4.1.14, “Replication and System Functions”

REPEAT()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

REPLACE()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

replace()
Section 16.2.3.1, “Basic memcached Operations”

REVERSE()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

RIGHT()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

ROUND()
Section 12.5.2, “Mathematical Functions”
Section 12.19, “Precision Math”
Section 12.19.5, “Precision Math Examples”
Section 12.19.4, “Rounding Behavior”

ROW_COUNT()
Section 13.2.1, “CALL Statement”
Section 13.2.2, “DELETE Statement”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.15, “Information Functions”
Section 13.2.5, “INSERT Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 23.7.6.1, “mysql_affected_rows()”
Section 17.4.1.14, “Replication and System Functions”

RPAD()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”
RTRIM()
Section 12.7.3, “Character Set and Collation of Function Results"
Section 12.7, “String Functions and Operators”

S

SCHEMA()
Section 12.15, “Information Functions”

SEC_TO_TIME()
Section 12.6, “Date and Time Functions”

SECOND()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

SESSION_USER()
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.15, “Information Functions”
Section 10.2.2, “UTF-8 for Metadata”

set()
Section 16.2.3.1, “Basic memcached Operations”

setrlimit()
Section 5.1.7, “Server System Variables”

SHA()
Section 12.13, “Encryption and Compression Functions”

SHA1()
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”

SHA2()
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 6.1.1, “Security Guidelines”

SIGN()
Section 12.5.2, “Mathematical Functions”

SIN()
Section 24.4.2, “Adding a User-Defined Function”
Section 12.5.2, “Mathematical Functions”

SLEEP()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.14.2, “General Thread States”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.18, “Miscellaneous Functions”
Section 17.4.1, “Replication Features and Issues”
Section 21.31.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”

**SOUNDEX()**
Section 24.4, “Adding Functions to MySQL”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

**SPACE()**
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

**SQRT()**
Section 12.5.2, “Mathematical Functions”

**SRID()**
Section 12.16.7.1, “General Geometry Property Functions”

**StartPoint()**
Section 12.16.7.3, “LineString and MultiLineString Property Functions”
Section 12.16.8, “Spatial Operator Functions”

**STD()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 1.3.2, “The Main Features of MySQL”

**STDDEV()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”

**STDDEV_POP()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”

**STDDEV_SAMP()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”

**STR_TO_DATE()**
Section 11.2, “Date and Time Data Types”
Section 12.6, “Date and Time Functions”
Section 10.16, “MySQL Server Locale Support”

**STRCMP()**
Section B.4.4.2, “Problems Using DATE Columns”
Section 12.7.1, “String Comparison Functions and Operators”

**SUBDATE()**
Section 12.6, “Date and Time Functions”
SUBSTR()
Section 12.7, “String Functions and Operators”

SUBSTRING()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

SUBSTRING_INDEX()
Section 6.2.14, “SQL-Based Account Activity Auditing”
Section 12.7, “String Functions and Operators”

SUBTIME()
Section 12.6, “Date and Time Functions”

SUM()
Section 24.4.2, “Adding a User-Defined Function”
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 11.2.1, “Date and Time Data Type Syntax”
Section 8.2.1.11, “GROUP BY Optimization”
Section B.4.4.3, “Problems with NULL Values”
Section 11.3.5, “The ENUM Type”
Section 1.3.2, “The Main Features of MySQL”
Section 11.3.6, “The SET Type”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”

SYSDATE()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

SYSTEM_USER()
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.15, “Information Functions”
Section 10.2.2, “UTF-8 for Metadata”

T

[T index top]

TAN()
Section 12.5.2, “Mathematical Functions”

thr_setconcurrency()
Section 5.1.7, “Server System Variables”

TIME()
Section 12.6, “Date and Time Functions”
TIME_FORMAT()
Section 12.10, “Cast Functions and Operators”
Section 12.6, “Date and Time Functions”

TIME_TO_SEC()
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

TIMEDIFF()
Section 12.6, “Date and Time Functions”

TIMESTAMP()
Section 12.6, “Date and Time Functions”

TIMESTAMPADD()
Section 12.6, “Date and Time Functions”
Section 1.4, “What Is New in MySQL 5.5”

TIMESTAMPDIFF()
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”

TO_DAYS()
Section 12.6, “Date and Time Functions”
Section 19.2.4, “HASH Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.4, “Partition Pruning”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

TO_SECONDS()
Section 12.6, “Date and Time Functions”
Section 19.4, “Partition Pruning”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”
Section 1.4, “What Is New in MySQL 5.5”

Touches()
Section 12.16.9.1, “Spatial Relation Functions That Use Object Shapes”

TRIM()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 10.7, “Column Character Set Conversion”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.7, “String Functions and Operators”

TRUNCATE()
Section 12.5.2, “Mathematical Functions”

U

[index top]
UCASE()
Section 12.7.3, “Character Set and Collation of Function Results”
Section 12.7, “String Functions and Operators”

UNCOMPRESS()
Section 12.13, “Encryption and Compression Functions”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.7, “Server System Variables”

UNCOMPRESSED_LENGTH()
Section 12.13, “Encryption and Compression Functions”

UNHEX()
Section 12.13, “Encryption and Compression Functions”
Section 12.7, “String Functions and Operators”

UNIX_TIMESTAMP()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.3.9, “Indexed Lookups from TIMESTAMP Columns”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2.1, “RANGE Partitioning”
Section 5.1.7, “Server System Variables”
Section B.4.3.7, “Time Zone Problems”

UpdateXML()
Section 12.11, “XML Functions”

UPPER()
Section 12.10, “Cast Functions and Operators”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 10.2.1, “Character Set Repertoire”
Section 12.7, “String Functions and Operators”
Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”

USER()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 10.8.4, “Collation Coercibility in Expressions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Implementing Proxy User Support in Authentication Plugins
Section 12.15, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 6.2.11, “Proxy Users”
Section 17.4.1.14, “Replication and System Functions”
Section 6.2.14, “SQL-Based Account Activity Auditing”
Section 10.2.2, “UTF-8 for Metadata”
Writing the Server-Side Authentication Plugin

UTC_DATE
Section 12.6, “Date and Time Functions”
UTC_DATE()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

UTC_TIME
Section 12.6, “Date and Time Functions”

UTC_TIME()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

UTC_TIMESTAMP
Section 12.6, “Date and Time Functions”

UTC_TIMESTAMP()
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 5.1.12, “MySQL Server Time Zone Support”

UUID()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.2.1.14, “Function Call Optimization”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.18, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 20.7, “Stored Program Binary Logging”

UUID_SHORT()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.18, “Miscellaneous Functions”

V

[index top]

VALUES()
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 12.18, “Miscellaneous Functions”

VAR_POP()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”

VAR_SAMP()
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
**VARIANCE()**
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”

**VERSION()**
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 6.4.2.3, “Audit Log File Formats”
Section B.4.4.1, “Case Sensitivity in String Searches”
Section 10.8.4, “Collation Coercibility in Expressions”
Section 12.15, “Information Functions”
Section 17.4.1.14, “Replication and System Functions”
Section 10.2.2, “UTF-8 for Metadata”

**W**

[ index top ]

**WEEK()**
Section 12.6, “Date and Time Functions”
Section 5.1.7, “Server System Variables”

**WEEKDAY()**
Section 12.6, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

**WEEKOFYEAR()**
Section 12.6, “Date and Time Functions”

**Within()**
Section 12.16.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

**X**

[ index top ]

**X()**
Section 12.16.7.2, “Point Property Functions”
Section 11.4.3, “Supported Spatial Data Formats”

**Y**

[ index top ]

**Y()**
Section 12.16.7.2, “Point Property Functions”

**YEAR()**
Section 12.6, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.2.4, “HASH Partitioning”
INNODB_CMPMEM_RESET
Section 14.18.1, “InnoDB INFORMATION_SCHEMA Tables about Compression”
Section 14.18.1.2, “INNODB_CMPMEM and INNODB_CMPMEM_RESET”
Section 21.29.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”

INNODB_LOCK_WAITS
Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.29.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”

INNODB_LOCKS
Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.29.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.29.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”

INNODB_METRICS
MySQL Glossary

INNODB_TRX
Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.29.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

KEY_COLUMN_USAGE
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.11, “The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table”

N

NDB_TRANSID_MYSQL_CONNECTION_MAP
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”

ndb_transid_mysql_connection_map
Section 21.30, “INFORMATION_SCHEMA NDB Cluster Tables”
MySQL Server Options for NDB Cluster
Section 21.30.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”

P

[INDEX TOP]

PARAMETERS
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Statement”
Section 21.12, “The INFORMATION_SCHEMA PARAMETERS Table”
Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”

PARTITIONS
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 19.3.4, “Obtaining Information About Partitions”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Chapter 19, Partitioning
Section 13.7.5.37, “SHOW TABLE STATUS Statement”
Section 21.13, “The INFORMATION_SCHEMA PARTITIONS Table”
Section 21.22, “The INFORMATION_SCHEMA TABLES Table”

PLUGINS
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.2, “Obtaining Server Plugin Information”
Section 21.14, “The INFORMATION_SCHEMA PLUGINS Table”

PROCESSLIST
Section 8.14, “Examining Thread Information”
Section 13.7.6.4, “KILL Statement”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

PROFILING
Section 13.7.5.31, “SHOW PROFILE Statement”
Section 21.16, “The INFORMATION_SCHEMA PROFILING Table”

R

[INDEX TOP]

REFERENTIAL_CONSTRAINTS
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.17, “The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table”

ROUTINES
Section 21.1, “Introduction”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Statement”

3484
Section 20.2.3, “Stored Routine Metadata”
Section 21.18, “The INFORMATION_SCHEMA ROUTINES Table”

S

SCHEMA_PRIVILEGES
Section 21.20, “The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table”

SCHEMATA
Section 6.2.3, “Grant Tables”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.1.7, “Server System Variables”
Section 13.7.5.15, “SHOW DATABASES Statement”
Section 21.19, “The INFORMATION_SCHEMA SCHEMATA Table”

SESSION_STATUS
Section 18.5, “Management of NDB Cluster”
Section 18.5.16, “NDB API Statistics Counters and Variables”
Section 18.6, “NDB Cluster Replication”
Section 13.7.5.36, “SHOW STATUS Statement”
Section 21.9, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

SESSION_VARIABLES
Section 13.7.5.40, “SHOW VARIABLES Statement”
Section 21.10, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

STATISTICS
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.23, “SHOW INDEX Statement”
Section 21.21, “The INFORMATION_SCHEMA STATISTICS Table”

T

TABLE_CONSTRAINTS
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.17, “The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table”

TABLE_PRIVILEGES
Section 21.25, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”

TABLES
Section 21.1, “Introduction”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.37, “SHOW TABLE STATUS Statement”
TABLESPACES
Section 21.23, “The INFORMATION_SCHEMA TABLESPACES Table”

TP_THREAD_GROUP_STATE
Section 21.31, “INFORMATION_SCHEMA Thread Pool Tables”
Section 21.31.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 5.5.3.1, “Thread Pool Components”

TP_THREAD_GROUP_STATS
Section 21.31, “INFORMATION_SCHEMA Thread Pool Tables”
Section 21.31.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”
Section 21.31.3, “The INFORMATION_SCHEMA TP_THREAD_STATE Table”
Section 5.5.3.1, “Thread Pool Components”

TP_THREAD_STATE
Section 21.31, “INFORMATION_SCHEMA Thread Pool Tables”
Section 21.31.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 21.31.3, “The INFORMATION_SCHEMA TP_THREAD_STATE Table”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.2, “Thread Pool Installation”

TRIGGERS
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.13, “SHOW CREATE TRIGGER Statement”
Section 13.7.5.39, “SHOW TRIGGERS Statement”
Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 20.3.2, “Trigger Metadata”

U
[index top]

USER_PRIVILEGES
Section 21.27, “The INFORMATION_SCHEMA USER_PRIVILEGES Table”

V
[index top]

VIEWS
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.5, “View Metadata”

Join Types Index
A | C | E | F | I | R | S | U
Section 13.2.10.10, “Optimizing Subqueries”
Section 8.2.2, “Subquery Optimization”

R

[index top]

range
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.2.1.3, “Index Merge Optimization”
Section 8.2.1.5, “Nested-Loop Join Algorithms”
Section 8.2.1.2, “Range Optimization”

ref
Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 15.8.1, “MERGE Table Advantages and Disadvantages”
NDB Cluster System Variables
Section 8.2.2, “Subquery Optimization”

ref_or_null
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.9, “IS NULL Optimization”
Section 8.2.2, “Subquery Optimization”

S

[index top]

system
Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.2.1.2, “Range Optimization”
Section 13.2.9, “SELECT Statement”

U

[index top]

unique_subquery
Section 8.8.2, “EXPLAIN Output Format”
Section 13.2.10.10, “Optimizing Subqueries”
Section 8.2.2, “Subquery Optimization”

Operator Index

Symbols

Symbols

[3488]
- Section 12.5.1, "Arithmetic Operators"
Section 12.10, "Cast Functions and Operators"
Section 9.5, "Expressions"
Section 11.1.1, "Numeric Data Type Syntax"
Section 19.5, "Restrictions and Limitations on Partitioning"

! Section 9.5, "Expressions"
Section 12.3.3, "Logical Operators"
Section 12.3.1, "Operator Precedence"

!= Section 12.3.2, "Comparison Functions and Operators"
Section 12.3.1, "Operator Precedence"
Section 8.2.1.2, "Range Optimization"

% Section 12.5.1, "Arithmetic Operators"

& Section 12.12, "Bit Functions and Operators"
Section 13.1.17, "CREATE TABLE Statement"
Section 19.5, "Restrictions and Limitations on Partitioning"

&& Section 12.3.3, "Logical Operators"
Section 1.7.1, "MySQL Extensions to Standard SQL"

> Section 12.3.2, "Comparison Functions and Operators"
Section 8.3.8, "Comparison of B-Tree and Hash Indexes"
Section 8.8.2, "EXPLAIN Output Format"
Section 1.7.1, "MySQL Extensions to Standard SQL"
Section 12.3.1, "Operator Precedence"
Section 8.2.1.2, "Range Optimization"

>> Section 12.12, "Bit Functions and Operators"
Section 1.7.1, "MySQL Extensions to Standard SQL"
Section 19.5, "Restrictions and Limitations on Partitioning"

>= Section 12.3.2, "Comparison Functions and Operators"
Section 8.3.8, "Comparison of B-Tree and Hash Indexes"
Section 8.8.2, "EXPLAIN Output Format"
Section 1.7.1, "MySQL Extensions to Standard SQL"
Section 12.3.1, "Operator Precedence"
Section 8.2.1.2, "Range Optimization"

< Section 12.3.2, "Comparison Functions and Operators"
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 8.2.1.2, “Range Optimization”
Section 13.2.10.12, “Restrictions on Subqueries”
Section 8.2.1.15, “Row Constructor Expression Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 3.3.4.2, “Selecting Particular Rows”
Section 12.7.1, “String Comparison Functions and Operators”
Section 8.2.2, “Subquery Optimization”
Section 20.5.2, “View Processing Algorithms”

B

BETWEEN
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.2, “Range Optimization”
Section 12.2, “Type Conversion in Expression Evaluation”

BINARY
Section 12.10, “Cast Functions and Operators”
Section 8.4.2.2, “Optimizing for Character and String Types”
Section 3.3.4.7, “Pattern Matching”
Section 3.3.4.4, “Sorting Rows”

C

CASE
Section 13.6.5.1, “CASE Statement”
Section 12.4, “Control Flow Functions”
Section 9.5, “Expressions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

CASE value WHEN END
Section 12.4, “Control Flow Functions”

CASE WHEN END
Section 12.4, “Control Flow Functions”

CASE WHEN expr1 = expr2 THEN NULL ELSE expr1 END
Section 12.4, “Control Flow Functions”

D

DIV
Section 12.5.1, “Arithmetic Operators”
Section 19.5, “Restrictions and Limitations on Partitioning”

E

[in index top]

`expr BETWEEN min AND max`
Section 12.3.2, “Comparison Functions and Operators”

`expr IN ()`
Section 12.3.2, “Comparison Functions and Operators”

`expr LIKE pat`
Section 12.7.1, “String Comparison Functions and Operators”

`expr NOT BETWEEN min AND max`
Section 12.3.2, “Comparison Functions and Operators”

`expr NOT IN ()`
Section 12.3.2, “Comparison Functions and Operators”

`expr NOT LIKE pat`
Section 12.7.1, “String Comparison Functions and Operators”

`expr NOT REGEXP pat`
Section 12.7.2, “Regular Expressions”

`expr NOT RLIKE pat`
Section 12.7.2, “Regular Expressions”

`expr REGEXP pat`
Section 12.7.2, “Regular Expressions”

`expr RLIKE pat`
Section 12.7.2, “Regular Expressions”

`expr1 SOUNDS LIKE expr2`
Section 12.7, “String Functions and Operators”

I

[in index top]

`IN()`
Section 8.8.2, “EXPLAIN Output Format”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 13.2.10.12, “Restrictions on Subqueries”
Section 12.2, “Type Conversion in Expression Evaluation”
LIKE ' _A%'
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

LIKE 'pattern'
Section 8.2.1.2, “Range Optimization”
Section 13.7.5, “SHOW Statements”

LIKE ... ESCAPE
Section B.4.7, “Known Issues in MySQL”

N
[index top]

N % M
Section 12.5.1, “Arithmetic Operators”
Section 12.5.2, “Mathematical Functions”

N MOD M
Section 12.5.1, “Arithmetic Operators”
Section 12.5.2, “Mathematical Functions”

NOT
Section 12.3.3, “Logical Operators”
Section 5.1.10, “Server SQL Modes”

NOT LIKE
Section 3.3.4.7, “Pattern Matching”
Section 12.7.1, “String Comparison Functions and Operators”

NOT REGEXP
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 3.3.4.7, “Pattern Matching”
Section 12.7.1, “String Comparison Functions and Operators”

NOT RLIKE
Section 3.3.4.7, “Pattern Matching”
Section 12.7.1, “String Comparison Functions and Operators”

O

OR

Section 9.5, “Expressions”
Section 13.7.1.3, “GRANT Statement”
Section 8.2.1.3, “Index Merge Optimization”
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 8.2.1.15, “Row Constructor Expression Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 3.3.4.2, “Selecting Particular Rows”
Section 5.1.10, “Server SQL Modes”
Section 12.7.1, “String Comparison Functions and Operators”
Section 8.2.2, “Subquery Optimization”

R

REGEXP

Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 3.3.4.7, “Pattern Matching”
Section 12.7.2, “Regular Expressions”
Section 10.11, “Restrictions on Character Sets”

RLIKE

Section 3.3.4.7, “Pattern Matching”
Section 12.7.2, “Regular Expressions”
Section 10.11, “Restrictions on Character Sets”

X

XOR

Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.3.3, “Logical Operators”

Option Index

Symbols | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

Symbols

[index top]
Section 1.7.2.4, “--” as the Start of a Comment
Section 4.8.2, “replace — A String-Replacement Utility”

-#
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.6, “mysqlimport — A Data Import Program”
Section 4.5.7, “mysqlshow — Display Database, Table, and Column Information”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 5.1.6, “Server Command Options”
Section 24.5.3, “The DBUG Package”

/opt/mysql/server-5.5

Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/passive
Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/quiet
Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/uninstall
Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/x
Section 2.3.4.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

-1
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

-?
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlexport — A Data Import Program”
Section 4.5.6, “mysqlimport — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 4.8.1, “perror — Display MySQL Error Message Information”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 5.1.6, “Server Command Options”
Section 1.3.2, “The Main Features of MySQL”
Section 4.2.2.1, “Using Options on the Command Line”

A

[A]

Section 4.5.1.1, “mysql Client Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.6.3.4, “Other myisamchk Options”

-a

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 16.2.2.1, “memcached Command-Line Options”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.5.3, “mysqlexport — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 4.6.3.4, “Other myisamchk Options”

--abort-on-error
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--abort-slave-event-count
Section 17.1.3.3, “Replication Slave Options and Variables”

--add-drop-database
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”
--add-drop-table
Section 4.5.4, "mysqldump — A Database Backup Program"

--add-drop-trigger
Section 4.5.4, "mysqldump — A Database Backup Program"

--add-locks
Section 4.5.4, "mysqldump — A Database Backup Program"

--addtodest
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"

--all
Section 1.4, “What Is New in MySQL 5.5”

--all-databases
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 9.2.4, “Mapping of Identifiers to File Names”
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, "mysqlcheck — A Table Maintenance Program”
Section 4.5.4, "mysqldump — A Database Backup Program”
Section 18.5.10, "ndbinfo: The NDB Cluster Information Database”
Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”

--all-in-1
Section 4.5.3, "mysqlcheck — A Table Maintenance Program”

--all-tablespaces
Section 4.5.4, "mysqldump — A Database Backup Program”

--allow-keywords
Section 4.5.4, "mysqldump — A Database Backup Program”

--allow-suspicious-udfs
Section 24.4.2, “Adding a User-Defined Function”
Section 5.1.6, “Server Command Options”

--allowold
Section 4.6.9, "mysqlhotcopy — A Database Backup Program”

--analyze
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.1, "myisamchk General Options”
Section 4.5.3, "mysqlcheck — A Table Maintenance Program”
Section 4.6.3.4, "Other myisamchk Options”

--ansi
Section 1.7, “MySQL Standards Compliance”
Section 5.1.6, “Server Command Options”

antiono
Section 6.4.1.4, “PAM Pluggable Authentication”

--append
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--apply-slave-statements
Section 4.5.4, “mysqldump — A Database Backup Program”

--audit-log
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 6.4.2.1, “Installing MySQL Enterprise Audit”

--auto-generate-sql
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-add-autoincrement
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-execute-number
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-guid-primary
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-load-type
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-secondary-indexes
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-unique-query-number
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-unique-write-number
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-generate-sql-write-number
Section 4.5.7, “mysqlslap — Load Emulation Client”

--auto-rehash
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”

--auto-repair
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
--auto-vertical-output
Section 4.5.1.1, "mysql Client Options"

--autocommit
Section 5.1.7, “Server System Variables”

B

[index top]

-B
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.3.3, "myisamchk Repair Options"
Section 4.5.1.1, "mysql Client Options"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.5.4,"mysqldump — A Database Backup Program"

-b
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"
Section 4.5.1.1, "mysql Client Options"
Section 4.4.4, "mysql_plugin — Configure MySQL Server Plugins"
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 18.4.10, "ndb_desc — Describe NDB Tables"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Section 4.6.3.4, "Other myisamchk Options"
Section 5.1.6, “Server Command Options”

--back_log
Section 2.7, “Installing MySQL on Solaris”

--backup
Section 4.6.3.3, "myisamchk Repair Options"
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"

--backup-path
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

backup-path
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--backupid
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

--base64-output
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 4.6.7.2, "mysqlbinlog Row Event Display"
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
--binlog-do-db
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.4, “The Binary Log”

--binlog-format
Section 5.4.4.1, “Binary Logging Formats”
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 18.1.7.6, “Unsupported or Missing Features in NDB Cluster”

--binlog-ignore-db
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.4, “The Binary Log”

--binlog-row-event-max-size
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4.4.2, “Setting The Binary Log Format”

--binlog_format
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--blob-info
Section 18.4.10, “ndb_desc — Describe NDB Tables”

--block-search
Section 4.6.3.4, “Other myisamchk Options”

--bootstrap
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

--brief
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--builddir
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

C
Section 4.4.1, "comp_err — Compile MySQL Error Message File"
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.3.2, "myisamchk Check Options"
Section 4.5.1.1, "mysql Client Options"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"
Section 4.5.7, "mysqlslap — Load Emulation Client"

Section 4.6.1, "innochecksum — Offline InnoDB File Checksum Utility"
Section 18.2.2.1, "Installing NDB Cluster on Windows from a Binary Release"
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.7.3, "my_print_defaults — Display Options from Option Files"
Section 4.6.2, "myisam_ftdump — Display Full-Text Index Information"
Section 4.6.3.2, "myisamchk Check Options"
Section 4.6.4, "myisamlog — Display MyISAM Log File Contents"
Section 4.5.1.1, "mysql Client Options"
Section A.10, "MySQL FAQ: MySQL 5.5 and NDB Cluster"
Section 2.3.5.13, "MySQL Server Instance Config Wizard: Creating an Instance from the Command Line"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 4.5.7, "mysqlslap — Load Emulation Client"
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs"

Restoring to Fewer Nodes Than the Original

Section 2.9.8, "Dealing with Problems Compiling MySQL"
Section 4.7.2, "mysql_config — Display Options for Compiling Clients"

Section A.11, "MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets"
Section 5.1.6, "Server Command Options"
Section 10.10.7.1, "The cp932 Character Set"

Section 10.15, "Character Set Configuration"
Section 10.5, "Configuring Application Character Set and Collation"
Section A.11, "MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets"
Section 10.3.2, "Server Character Set and Collation"

Section B.4.2.17, "Can't initialize character set"
Section 10.15, "Character Set Configuration"
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--character_set_server
Section 2.9.7, “MySQL Source-Configuration Options”

--charset
Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--check
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--check-only-changed
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--check-orphans
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

--check-upgrade
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--checkpoint
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--chroot
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 5.1.6, “Server Command Options”

CMAKE_BUILD_TYPE
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_C_FLAGS
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_C_FLAGS_build_type
Section 2.9.7, “MySQL Source-Configuration Options”
CMAKE_C_FLAGS_RELWITHDEBINFO
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 2.9.8, “Dealing with Problems Compiling MySQL”
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS_build_type
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS_RELWITHDEBINFO
Section 2.9.7, “MySQL Source-Configuration Options”

CMAKE_INSTALL_PREFIX
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 2.9.5, “Installing MySQL Using a Development Source Tree”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.7, “Server System Variables”

--collation-server
Section 10.15, “Character Set Configuration”
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.3.2, “Server Character Set and Collation”

--collation_server
Section 2.9.7, “MySQL Source-Configuration Options”

--column-names
Section 4.5.1.1, “mysql Client Options”
Section 4.2.2.4, “Program Option Modifiers”

--column-type-info
Section 8.2.1.13, “LIMIT Query Optimization”
Section 4.5.1.1, “mysql Client Options”

--columns
Section 4.5.5, “mysqlimport — A Data Import Program”

--comments
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysqldump — A Database Backup Program”

--commit
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.7, “mysqlslap — Load Emulation Client”

--comp
Section 4.2.2, “Specifying Program Options”
--compact
Section 4.5.4, “mysqldump — A Database Backup Program”

--compatible
Section 4.5.4, “mysqldump — A Database Backup Program”

COMPILATION_COMMENT
Section 5.1.7, “Server System Variables”

--complete-insert
Section 4.5.4, “mysqldump — A Database Backup Program”

--compr
Section 4.2.2, “Specifying Program Options”

--compress
Section 4.2.5, “Connection Compression Control”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.2.2, “Specifying Program Options”

--concurrency
Section 4.5.7, “mysqlslap — Load Emulation Client”

--config-cache
Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--config-dir
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--config-file
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.3.4, “mysqlld_multi — Manage Multiple MySQL Servers”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 1.4, “What Is New in MySQL 5.5”

--config-from-node
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
--config_from_node
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"

--configdir
Section 18.3.3, "NDB Cluster Configuration Files"
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"

--configinfo
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"

--connect
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--connect-delay
Section 18.4.1, "ndbd — The NDB Cluster Data Node Daemon"

--connect-retries
Section 18.4.1, "ndbd — The NDB Cluster Data Node Daemon"

--connect-string
Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs"

--connect-timeout
Section 4.5.1.1, "mysql Client Options"

--connection-timeout
Section 18.4.13, "ndb_error_reporter — NDB Error-Reporting Utility"

--connections
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"

--console
Section 14.20.2, "Enabling InnoDB Monitors"
Section 5.4.2.1, "Error Logging on Windows"
Section 18.2.2.3, "Initial Startup of NDB Cluster on Windows"
Section 14.23, "InnoDB Troubleshooting"
Resetting the Root Password: Windows Systems
Section 5.1.6, "Server Command Options"
Section 2.3.6.5, "Starting MySQL from the Windows Command Line"
Section 2.3.6.4, "Starting the Server for the First Time"

--copy
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"

--core-file
Section 24.5.1.4, "Debugging mysqld under gdb"
Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs"
Section 5.1.6, "Server Command Options"
core-file
Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

--core-file-size
Section 4.3.2, “mysql_safe — MySQL Server Startup Script”
Section 5.1.6, “Server Command Options”

--correct-checksum
Section 4.6.3.3, “myisamchk Repair Options”

--count
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--create
Section 4.5.7, “mysqlslap — Load Emulation Client”

--create-options
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 1.4, “What Is New in MySQL 5.5”

--create-schema
Section 4.5.7, “mysqlslap — Load Emulation Client”

--cross-bootstrap
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

--csv
Section 4.5.7, “mysqlslap — Load Emulation Client”

D

[D]

-D
Section 10.13, “Adding a Character Set”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section B.4.2.17, “Can't initialize character set”
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 23.6.1, “Compiling Programs with libmysqld”
Section 2.9.6, “Configuring SSL Library Support”
Section 24.5.2, “Debugging a MySQL Client”
Section 2.9.4, “Installing MySQL Using a Standard Source Distribution”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Client Options”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 2.9.7, “MySQL Server-Configuration Options”
Section 24.1.1, “MySQL Source-Configuration Options”
3509
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Chapter 19, Partitioning
Section 22.2, “Performance Schema Build Configuration”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 15.10, “The EXAMPLE Storage Engine”
Section 15.9, “The FEDERATED Storage Engine”
Section 5.8, “Tracing mysqld Using DTrace”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”
Section 2.1.1, “Which MySQL Version and Distribution to Install”

-d
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index Information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.6, “mysqldaccess — Client for Checking Access Privileges”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.11, “ndb_drop_index — Drop Index from an NDB Table”
Section 18.4.12, “ndb_drop_table — Drop an NDB Table”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.23, “ndb_select_count — Print Row Counts for NDB Tables”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”
Section 4.6.3.4, “Other myisamchk Options”
Section 5.1.7, “Server System Variables”

--daemon
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--data-file-length
Section 4.6.3.3, “myisamchk Repair Options”

--database
Section 4.5.1.1, “mysql Client Options”
--debug-check

Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqldadmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqslap — Load Emulation Client”

--debug-info

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqldadmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqslap — Load Emulation Client”

--debug-sync-timeout

Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
--default-auth
Section 23.7.13, “C API Client Plugin Functions”
Client Plugin Descriptors
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 6.4.1.1, “Native Pluggable Authentication”
Section 6.4.1.2, “Old Native Pluggable Authentication”
Section 6.2.10, “Pluggable Authentication”
Using the Authentication Plugins

--default-character-set
Section 6.2.1, “Account User Names and Passwords”
Section 10.15, “Character Set Configuration”
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.4, “Connection Character Sets and Collations”
Section 4.5.1.5, “Executing SQL Statements from a Text File”
Section 13.2.6, “LOAD DATA Statement”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 5.1.7, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

--default-collation
Section 1.4, “What Is New in MySQL 5.5”

--default-table-type
Section 1.4, “What Is New in MySQL 5.5”

--default-time-zone
Section 5.1.12, “MySQL Server Time Zone Support”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

--default.key_buffer_size
Section 5.1.8.3, “Structured System Variables”

DEFAULT_CHARSET
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.3.2, “Server Character Set and Collation”
DEFAULT_COLLATION
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.3.2, “Server Character Set and Collation”

--defaults-extra-file
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqldcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.6, “Server Command Options”
Section 4.2.2.2, “Using Option Files”
Section 1.4, “What Is New in MySQL 5.5”

--defaults-file
Section 2.11.3, “Changes in MySQL 5.5”
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 14.11.1, “InnoDB Startup Configuration”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqldcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 23.6.3, “Options with the Embedded Server”
Resetting the Root Password: Unix and Unix-Like Systems
Resetting the Root Password: Windows Systems
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.6, “Server Command Options”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 5.7.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section 2.3.5.1, “Starting the MySQL Server Instance Configuration Wizard”

--defaults-group-suffix
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 4.9, “Environment Variables”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.1.6, “Server Command Options”

--delay
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”

--delay-key-write
Section 8.11.5, “External Locking”

--delay-key-write-for-all-tables
Section 1.4, “What Is New in MySQL 5.5”

--delay_key_write
Section 5.1.7, “Server System Variables”
Section 5.1.8, “Using System Variables”

delay_key_write
Section 15.3.1, “MyISAM Startup Options”

--delayed-insert
Section 4.5.4, “mysqldump — A Database Backup Program”

--delete
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--delete-master-logs
Section 4.5.4, “mysqldump — A Database Backup Program”

--delete-orphans
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
--delimiter
Section 4.5.1.1, “mysql Client Options”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--demangle
Section 24.5.1.5, “Using a Stack Trace”

--des-key-file
Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Statement”
Section 5.1.6, “Server Command Options”

--descending
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--description
Section 4.6.3.4, “Other myisamchk Options”

--detach
Section 4.5.7, “mysqlslap — Load Emulation Client”

--disable
Section 4.2.2.4, “Program Option Modifiers”

--disable-auto-rehash
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 4.5.1.1, “mysql Client Options”

--disable-indexes
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to More Nodes Than the Original

--disable-keys
Section 4.5.4, “mysqldump — A Database Backup Program”

--disable-log-bin
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--disable-named-commands
Section 4.5.1.1, “mysql Client Options”

--disable-plugin_name
Section 5.5.1, “Installing and Uninstalling Plugins”

--disable-ssl
Section 4.2.3, “Command Options for Connecting to the Server”
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
--disconnect-slave-event-count
Section 17.1.3.3, “Replication Slave Options and Variables”

--disk
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--diskscan
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”

--dont-ignore-systab-0
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--drop-source
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--dry-scp
Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

--dryrun
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--dump
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--dump-date
Section 4.5.4, “mysqldump — A Database Backup Program”

--dump-file
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

--dump-slave
Section 4.5.4, “mysqldump — A Database Backup Program”

E

[index top]

-E
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”

-e
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 13.2.7, “LOAD XML Statement”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
--enable-threads
Section 16.2.1, “Installing memcached”

ENABLE_DEBUG_SYNC
Section 2.9.7, “MySQL Source-Configuration Options”

ENABLED_LOCAL_INFILE
Section 2.9.7, “MySQL Source-Configuration Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--engine
Section 4.5.7, “mysqslap — Load Emulation Client”

--engine-condition-pushdown
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--env
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--error-insert
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--event-scheduler
Section 20.4.2, “Event Scheduler Configuration”

event-scheduler
Section 20.4.2, “Event Scheduler Configuration”

--events
Section 7.4.5.3, “Dumping Stored Programs”
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”

--example
Section 4.3.4, “mysql_multi — Manage Multiple MySQL Servers”

--exclude-*
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-databases
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-intermediate-sql-tables
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-missing-columns
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-missing-tables
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-tables
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--excludedbs
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--excludetables
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--execute
Section 4.5.1.3, “mysql Client Logging”
Section 4.5.1.1, “mysql Client Options”
Section 18.4.5, “ndb_mgm — The NDB Cluster Management Client”
Section 4.2.2.1, “Using Options on the Command Line”
Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”

--exit-info
Section 5.1.6, “Server Command Options”

--extend-check
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.3, “myisamchk Repair Options”

--extended
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--extended-insert
Section 4.5.4, “mysqldump — A Database Backup Program”

--external-locking
Section 8.11.5, “External Locking”
Section 15.3.1, “MyISAM Startup Options”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 8.12.1, “System Factors”
Section 1.4, “What Is New in MySQL 5.5”

--extra-file
Section 4.7.3, “my_print_defaults — Display Options from Option Files”

--extra-node-info
Section 18.4.10, “ndb_desc — Describe NDB Tables”

--extra-partition-info
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”

F

(index top)

-F

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.2, “mysqld Client Commands”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”

-f

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysqld Client Options”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 24.5.1.5, “Using a Stack Trace”

--fast

Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--federated

Section 15.9, “The FEDERATED Storage Engine”

--fields

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--fields-enclosed-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--fields-escaped-by
Section 7.4.3, "Dumping Data in Delimited-Text Format with mysqldump"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--fields-optionally-enclosed-by
Section 7.4.3, "Dumping Data in Delimited-Text Format with mysqldump"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--fields-terminated-by
Section 7.4.3, "Dumping Data in Delimited-Text Format with mysqldump"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--fields-xxx
Section 4.5.4, "mysqldump — A Database Backup Program"

--first-slave
Section 1.4, "What Is New in MySQL 5.5"

--fix-db-names
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"

--fix-table-names
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"

--flush
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section B.4.3.3, "What to Do If MySQL Keeps Crashing"

--flush-logs
Section 7.3.1, "Establishing a Backup Policy"
Section 5.4, "MySQL Server Logs"
Section 4.5.4, "mysqldump — A Database Backup Program"

--flush-privileges
Section 4.5.4, "mysqldump — A Database Backup Program"

--flush_time
Section 24.1.1, "MySQL Threads"

--flushlog
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"
--force
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqldadmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 24.1.2, “The MySQL Test Suite”
Section 3.5, “Using mysql in Batch Mode”

--force-if-open
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--force-read
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--foreground
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--format
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--fs
Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

G
[index top]

-G
Section 4.5.1.1, “mysql Client Options”

-g
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”

--gci
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--gci64
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--gdb
Section 24.5.1.4, “Debugging mysqld under gdb”
Section 5.1.6, “Server Command Options”
Section 4.10, “Unix Signal Handling in MySQL”

---general-log
Section 4.2.2.1, “Using Options on the Command Line”
Section 5.1.8, “Using System Variables”

---general_log
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.4.3, “The General Query Log”
Section 4.2.2.1, “Using Options on the Command Line”
Section 5.1.8, “Using System Variables”

---general_log_file
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.1.7, “Server System Variables”
Section 5.4.3, “The General Query Log”

H
[index top]

-H
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges”
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files”

-h
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.2.1, “Invoking MySQL Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 5.1.6, “Server Command Options”
Section 1.2, “Typographical and Syntax Conventions”
Section 4.2.2.1, “Using Options on the Command Line”
-l
Section 23.7.3.1, “Building C API Client Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.5, “memcached FAQ”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.8.1, “perror — Display MySQL Error Message Information”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”

-i
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”

--i-am-a-dummy
Section 4.5.1.1, “mysql Client Options”
Section 4.5.1.6, “mysql Client Tips”

--id
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--ignore
Section 4.5.5, “mysqlimport — A Data Import Program”

--ignore-lines
Section 4.5.5, “mysqlimport — A Data Import Program”

--ignore-spaces
Section 4.5.1.1, “mysql Client Options”

--ignore-table
Section 4.5.4, “mysqldump — A Database Backup Program”

--in-file
Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--include
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Restoring to Fewer Nodes Than the Original
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”
Section 18.5.1, “Summary of NDB Cluster Start Phases”

--initial-start
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--innodb
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.1.6, “Turning Off InnoDB”

--innodb-checksums
Section 14.17, “InnoDB Startup Options and System Variables”

--innodb-file-per-table
Section 5.1.6, “Server Command Options”

innodb-file-per-table
Section 5.1.6, “Server Command Options”

--innodb-rollback-on-timeout
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”

--innodb-status-file
Section 14.20.2, “Enabling InnoDB Monitors”
Section 14.17, “InnoDB Startup Options and System Variables”

--innodb-xxx
Section 5.1.6, “Server Command Options”

--innodb_file_per_table
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”

innodb_file_per_table
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

--innodb_support_xa
Section 5.4.4, “The Binary Log”

--insert-ignore
Section 4.5.4, “mysqldump — A Database Backup Program”

--install
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 5.1.6, “Server Command Options”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
--install-manual
Section 5.1.6, “Server Command Options”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

INSTALL_LAYOUT
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.7, “Server System Variables”

INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.7, “Server System Variables”

INSTALL_SECURE_FILE_PRIVDIR
Section 5.1.7, “Server System Variables”

--interactive
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--iterations
Section 4.5.7, “mysqlslap — Load Emulation Client”

J

-[index top]

-J
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--join
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

K

-[index top]

-K
Section 4.5.4, “mysqldump — A Database Backup Program”

-k
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--keep_files_on_create
Section 13.1.17, “CREATE TABLE Statement”

--keepold
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
--key_buffer_size
Section 5.1.6, “Server Command Options”

--keys
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--keys-used
Section 4.6.3.3, “myisamchk Repair Options”

L

[ index top ]

-L
Section 23.7.3.1, “Building C API Client Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 2.13.3, “Problems Using the Perl DBI/DBD Interface”

-l
Section 23.7.3.1, “Building C API Client Programs”
Section 23.7.12, “C API Embedded Server Function Descriptions”
Section 23.7.5, “C API Function Overview”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.3, “myisamchk Repair Options”
Section 23.7.6.39, “mysql_library_end()”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqlslap — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.23, “ndb_select_count — Print Row Counts for NDB Tables”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”
Section 5.1.6, “Server Command Options”
Section 5.1.6, “Server Command Options”
Section 5.4.3, “The General Query Log”

--language
Section 2.11.3, “Changes in MySQL 5.5”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

--large-pages
Section 8.12.4.2, “Enabling Large Page Support”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
--lc-messages
Section 5.1.6, “Server Command Options”

--lc-messages-dir
Section 5.1.6, “Server Command Options”

--ldata
Section 4.4.3, "mysql_install_db — Initialize MySQL Data Directory"

--ledir
Section 4.3.2, "mysqld_safe — MySQL Server Startup Script"

--length
Section 4.6.2, "myisam_ftdump — Display Full-Text Index information"

--libmysqld-libs
Section 4.7.2, "mysql_config — Display Options for Compiling Clients"

--libs
Section 4.7.2, "mysql_config — Display Options for Compiling Clients"

--libs_r
Section 4.7.2, "mysql_config — Display Options for Compiling Clients"

--line-numbers
Section 4.5.1.1, “mysql Client Options”

--lines-terminated-by
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--loadqueries
Section 18.4.25, "ndb_size.pl — NDBCLUSTER Size Requirement Estimator"

--local
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--local-infile
Section 13.2.7, “LOAD XML Statement”
Section 4.5.1.1, “mysql Client Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--local-load
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files”

--local-service
Section 5.1.6, “Server Command Options”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
--log-isam
Section 4.6.4, "myisamlog — Display MyISAM Log File Contents"
Section 5.1.6, "Server Command Options"

--log-long-format
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 1.4, "What Is New in MySQL 5.5"

--log-name
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"

--log-short-format
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 5.4.5, "The Slow Query Log"

--log-slave-updates
Section 17.4.5, "How to Report Replication Bugs or Problems"
Section 5.4.4, "The Binary Log"

--log-slow-admin-statements
Section 5.1.6, "Server Command Options"
Section 5.4.5, "The Slow Query Log"

--log-slow-slave-statements
Section 17.1.3.3, "Replication Slave Options and Variables"
Section 5.4.5, "The Slow Query Log"

--log-tc
Section 5.1.6, "Server Command Options"

--log-tc-size
Section 5.1.6, "Server Command Options"
Section 5.1.9, "Server Status Variables"

--log-update
Section 1.4, "What Is New in MySQL 5.5"

--log-warnings
Section B.4.2.11, "Communication Errors and Aborted Connections"
Section 5.4.2.4, "Error Log Filtering"
Section 5.4.4.3, "Mixed Binary Logging Format"
Section B.4.2.9, "MySQL server has gone away"
Section 17.1.3.3, "Replication Slave Options and Variables"
Section 5.1.6, "Server Command Options"
Section 1.4, “What Is New in MySQL 5.5”

--log_output
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”

--loops
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”

--loose
Section 4.2.2.4, “Program Option Modifiers”

--loose-opt_name
Section 4.2.2.2, “Using Option Files”

--lossy-conversions
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--low-priority
Section 4.5.5, “mysqlimport — A Data Import Program”

--low-priority-updates
Section 8.11.3, “Concurrent Inserts”
Section 13.2.5, “INSERT Statement”
Section 8.11.2, “Table Locking Issues”

--lower-case-table-names
Section 9.2.3, “Identifier Case Sensitivity”

M

-M
Section 16.2.2.1, “memcached Command-Line Options”

-m
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--malloc-lib
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--master-connect-retry
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
--master-data
Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 7.3.1, “Establishing a Backup Policy”
Section 5.4, “MySQL Server Logs”
Section 4.5.4, “mysqldump — A Database Backup Program”

--master-host
Section 1.4, “What Is New in MySQL 5.5”

--master-info-file
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.2, “Slave Status Logs”

--master-password
Section 1.4, “What Is New in MySQL 5.5”

--master-port
Section 1.4, “What Is New in MySQL 5.5”

--master-retry-count
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 17.1.3.3, “Replication Slave Options and Variables”

--master-ssl
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-ca
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-capath
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-cert
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-cipher
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-key
Section 1.4, “What Is New in MySQL 5.5”

--master-user
Section 1.4, “What Is New in MySQL 5.5”

--master-xxx
Section 1.4, “What Is New in MySQL 5.5”

--max
Section 4.2.2.5, “Using Options to Set Program Variables”
--max-allowed-packet
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysql dump — A Database Backup Program”

--max-binlog-dump-events
Section 17.1.3.4, “Binary Log Options and Variables”

--max-binlog-size
Section 17.1.3.3, “Replication Slave Options and Variables”

--max-join-size
Section 4.5.1.1, “mysql Client Options”
Section 4.5.1.6, “mysql Client Tips”

--max-record-length
Section 4.6.3.3, “myisamchk Repair Options”
Section 13.7.2.5, “REPAIR TABLE Statement”

--max-relay-log-size
Section 17.1.3.3, “Replication Slave Options and Variables”

--max-seeks-for-key
Section 8.2.1.16, “Avoiding Full Table Scans”
Section B.4.5, “Optimizer-Related Issues”

--max_a
Section 4.2.2.5, “Using Options to Set Program Variables”

--maximum
Section 4.2.2.4, “Program Option Modifiers”

--maximum-back_log
Section 4.2.2.4, “Program Option Modifiers”

--maximum-innodb-log-file-size
Section 5.1.8, “Using System Variables”

--maximum-max_heap_table_size
Section 4.2.2.4, “Program Option Modifiers”

--maximum-query_cache_size
Section 8.10.3.3, “Query Cache Configuration”

--maximum-var_name
Section 5.1.6, “Server Command Options”
Section 5.1.8, “Using System Variables”

--medium-check
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--memlock
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 14.9.3.1, “The System Tablespace”

--method
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--mount
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--my-plugin
Section 5.5.1, “Installing and Uninstalling Plugins”

--my-print-defaults
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

--my_plugin
Section 5.5.1, “Installing and Uninstalling Plugins”

--mycnf
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--myisam-block-size
Section 8.10.2.5, “Key Cache Block Size”
Section 5.1.6, “Server Command Options”

--myisam_sort_buffer_size
Section 4.6.3.6, “myisamchk Memory Usage”

MYSQL_ALLOW_EMPTY_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_DATABASE
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_LOG_CONSOLE
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_MAINTAINER_MODE
Section 2.9.8, “Dealing with Problems Compiling MySQL”

MYSQL_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_RANDOM_ROOT_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
MYSQL_ROOT_HOST
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_ROOT_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_TCP_PORT
Section 2.9.5, “Installing MySQL Using a Development Source Tree”
Section 2.9.7, “MySQL Source-Configuration Options”

MYSQL_UNIX_ADDR
Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 2.9.5, “Installing MySQL Using a Development Source Tree”
Section 2.9.7, “MySQL Source-Configuration Options”

MYSQL_USER
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--mysqladmin
Section 4.3.4, “mysqladmin — Manage Multiple MySQL Servers”

--mysqld
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--mysqld-version
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

N
[show top index]

-N
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysqldump — A Database Backup Program”

-n
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 4.7.4, "resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols"

--name
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

--name-file
Section 4.4.1, "comp_err — Compile MySQL Error Message File"

--named-commands
Section 4.5.1.1, “mysql Client Options”

--ndb
Section 4.8.1, "perror — Display MySQL Error Message Information"

--ndb-batch-size
MySQL Server Options for NDB Cluster

--ndb-blob-read-batch-bytes
MySQL Server Options for NDB Cluster

--ndb-blob-write-batch-bytes
MySQL Server Options for NDB Cluster

--ndb-cluster
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”

--ndb-cluster-connection-pool
MySQL Server Options for NDB Cluster

--ndb-connectstring
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original

--ndb-deferred-constraints
MySQL Server Options for NDB Cluster

--ndb-distribution
MySQL Server Options for NDB Cluster
--ndb-force-send
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--ndb-index-stat-enable
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--ndb-log-apply-status
MySQL Server Options for NDB Cluster
NDB Cluster System Variables

--ndb-log-empty-epochs
MySQL Server Options for NDB Cluster
Section 18.6.4, “NDB Cluster Replication Schema and Tables”

--ndb-log-empty-update
MySQL Server Options for NDB Cluster

--ndb-log-orig
MySQL Server Options for NDB Cluster
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
NDB Cluster System Variables

--ndb-log-transaction-id
Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Server Options for NDB Cluster
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster System Variables

--ndb-log-update-as-write
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 5.4.4, “The Binary Log”

--ndb-log-updated-only
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

--ndb-mgmd-host
MySQL Server Options for NDB Cluster
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--ndb-nodegroup-map
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--ndb-nodeid
MySQL Server Options for NDB Cluster
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
--network
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--nice
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--no-auto-rehash
Section 4.5.1.1, “mysql Client Options”

--no-autocommit
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-beep
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--no-binlog
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--no-contact
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--no-create-db
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-create-info
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-data
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-defaults
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysql_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
--no-drop
Section 4.5.7, "mysqlslap — Load Emulation Client"

--no-log
Section 4.3.4, "mysqld_multi — Manage Multiple MySQL Servers"

--no-named-commands
Section 1.4, "What Is New in MySQL 5.5"

--no-nodeid-checks
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"

--no-pager
Section 1.4, "What Is New in MySQL 5.5"

--no-restore-disk-objects
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--no-set-names
Section 4.5.4, "mysqldump — A Database Backup Program"

--no-symlinks
Section 4.6.3.3, “myisamchk Repair Options”

--no-tablespaces
Section 4.5.4, "mysqldump — A Database Backup Program"

--no-tee
Section 1.4, "What Is New in MySQL 5.5"

--no-upgrade
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--nodaemon
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"
Section 18.4.1, "ndbd — The NDB Cluster Data Node Daemon"

--nodata
Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table"

--nodeid
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original
--nodes
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--noindices
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--nostart
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--not-started
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--nowait-nodes
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--number-char-cols
Section 4.5.7, “mysqlslap — Load Emulation Client”

--number-int-cols
Section 4.5.7, “mysqlslap — Load Emulation Client”

--number-of-queries
Section 4.5.7, “mysqlslap — Load Emulation Client”

--numeric-dump-file
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”

O
[index top]

-O
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 1.4, “What Is New in MySQL 5.5”

-o
Section 23.6.1, “Compiling Programs with libmysqld”
Section 4.6.3.3, “mysamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 8.12.2, “Optimizing Disk I/O”
--offset
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"

--old-style-user-limits
Section 5.1.6, “Server Command Options”
Section 6.2.12, “Setting Account Resource Limits”

--old_server
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"

ON
Section 3.3.4.9, “Using More Than one Table”

--one-database
Section 4.5.1.1, “mysql Client Options”

--one-thread
Section 5.1.6, “Server Command Options”

--only-print
Section 4.5.7, "mysqlslap — Load Emulation Client"

--open-files-limit
Section B.4.2.18, “File Not Found and Similar Errors”
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.3.2, "mysql_safe — MySQL Server Startup Script”
Section 5.1.7, “Server System Variables”

--opt
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 4.5.4, "mysqldump — A Database Backup Program”

--opt_name
Section 4.2.2.2, “Using Option Files”

--optimize
Section 4.5.3, "mysqlcheck — A Table Maintenance Program”

--order
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--order-by-primary
Section 4.5.4, "mysqldump — A Database Backup Program”

--out-dir
Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--out-file
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.2.1, “Invoking MySQL Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqlldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 5.1.6, “Server Command Options”

Section 6.2.1, “Account User Names and Passwords”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 2.12, “Downgrading MySQL”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 4.2.1, “Invoking MySQL Programs”
Section 19.2.5, “KEY Partitioning”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “mysqamchk Repair Options”
Section 4.6.4, “mysamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqlldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table"
Section 18.4.23, "ndb_select_count — Print Row Counts for NDB Tables"
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"
Section 18.4.2, "ndbinfo_select_all — Select From ndbinfo Tables"
Section B.4.2.5, "Password Fails When Entered Interactively"
Section 2.10.4, "Securing the Initial MySQL Accounts"
Section 2.3.6.7, "Starting MySQL as a Windows Service"
Section 2.3.6.5, "Starting MySQL from the Windows Command Line"
Section 2.3.6.8, "Testing The MySQL Installation"
Section 2.10.3, "Testing the Server"
Section 18.5.10.4, "The ndbinfo cluster_operations Table"
Section 18.5.10.15, "The ndbinfo server_operations Table"
Section 6.2.13, "Troubleshooting Problems Connecting to MySQL"
Section 2.11, "Upgrading MySQL"
Section 2.11.5, "Upgrading MySQL on Windows"
Section 4.2.2.1, "Using Options on the Command Line"
Section 2.3.8, "Windows Postinstallation Procedures"

--pager
Section 4.5.1.2, "mysql Client Commands"
Section 4.5.1.1, "mysql Client Options"

--parallel-recover
Section 4.6.3.3, "myisamchk Repair Options"

--parallelism
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table"
Section 18.4.23, "ndb_select_count — Print Row Counts for NDB Tables"
Section 18.4.2, "ndbinfo_select_all — Select From ndbinfo Tables"

parallelism
Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table"

--parsable
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"

--partition
Section 5.1.6, "Server Command Options"

--password
Section 6.2.1, "Account User Names and Passwords"
Section 4.2.3, "Command Options for Connecting to the Server"
Section 4.2.4, "Connecting to the MySQL Server Using Command Options"
Section 6.1.2.1, "End-User Guidelines for Password Security"
Section 7.3, "Example Backup and Recovery Strategy"
Section 4.2.1, "Invoking MySQL Programs"
Section 4.5.1.1, "mysql Client Options"
Section 4.6.10, "mysql_convert_table_format — Convert Tables to Use a Given Storage Engine"
Section 4.6.13, "mysql_setpermission — Interactively Set Permissions in Grant Tables"
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables"
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
--performance_schema_max_mutex_classes
Section 22.7, “Performance Schema Status Monitoring”

--performance_schema_max_mutex_instances
Section 22.7, “Performance Schema Status Monitoring”

--pid-file
Section 5.4.2.1, “Error Logging on Windows”
Section 4.3.4, “mysql_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.1.6, “Server Command Options”
Section 5.4.4, “The Binary Log”

pid-file
Section 4.3.3, “mysql.server — MySQL Server Startup Script”

--pipe
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysql_multi — Manage Multiple MySQL Servers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”
Section B.4.2.5, “Password Fails When Entered Interactively”
Section 6.4.1.7, “Test Pluggable Authentication”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 4.2.2.1, “Using Options on the Command Line”

--plan
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--plugin
Section 5.1.6, “Server Command Options”

--plugin-dir
Section 23.7.13, “C API Client Plugin Functions”
Client Plugin Descriptors
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 6.2.10, “Pluggable Authentication”

Using the Authentication Plugins

--plugin-ini
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

--plugin-innodb-file-per-table
Section 5.1.6, “Server Command Options”

--plugin-load
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.4.2.1, “Installing MySQL Enterprise Audit”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 6.4.1.4, “PAM Pluggable Authentication”
Section 24.2.3, “Plugin API Components”
Section 24.2.4.2, “Plugin Data Structures”
Section 5.1.6, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 6.4.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.4.1.7, “Test Pluggable Authentication”
Section 24.2, “The MySQL Plugin API”
Section 5.5.3.2, “Thread Pool Installation”
Using the Authentication Plugins
Section 6.4.1.5, “Windows Pluggable Authentication”

--plugin-sql-mode
Section 5.1.6, “Server Command Options”

--plugin-xxx
Section 5.1.6, “Server Command Options”

--plugin_dir
Section 2.9.7, “MySQL Source-Configuration Options”
Section 24.2.3, “Plugin API Components”

--plugin_name
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

```markdown
--plugindir
```

Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

```markdown
--port
```

Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.5.1.1, “mysql Client Options”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqldadmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”

```markdown
--port-open-timeout
```

Section 5.1.6, “Server Command Options”

```markdown
--position
```

Section 1.4, “What Is New in MySQL 5.5”

```markdown
--post-query
```

Section 4.5.7, “mysqlslap — Load Emulation Client”

```markdown
--post-system
```

Section 4.5.7, “mysqlslap — Load Emulation Client”

```markdown
--pre-query
```

Section 4.5.7, “mysqlslap — Load Emulation Client”

```markdown
--pre-system
```

Section 4.5.7, “mysqlslap — Load Emulation Client”

PREFIX

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
---prefix
Section 16.2.1, “Installing memcached”

---preserve-trailing-spaces
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---preview
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

---print
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---print-data
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---print-defaults
Section 4.2.2.3, “Command-Line Options that Affect Option-File Handling”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqldadmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.6, “Server Command Options”
Section 2.11.6, “Upgrade Troubleshooting”

---print-full-config
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

---print-log
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---print-meta
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---print_*
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---progress-frequency
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

---promote-attributes
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--prompt
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”

--protocol
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 2.3.6.4, “Starting the Server for the First Time”
Section 2.3.6.8, “Testing The MySQL Installation”
Section 1.3.2, “The Main Features of MySQL”
Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”

Q

[index top]

-Q
Section 4.5.4, “mysqldump — A Database Backup Program”

-q
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”

--query
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--query-all
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--query-cache-size
Section 8.11.5, “External Locking”
--quick
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.1, “mysql — The MySQL Command-Line Client”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section B.4.2.8, “Out of memory”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 4.2.2.2, “Using Option Files”

--quiet
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--quote-names
Section 4.5.4, “mysqldump — A Database Backup Program”

R
[index top]

-R
Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.4.1, “memcached General Statistics”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.3.4, “Other myisamchk Options”

-r
Section 24.4.2, “Adding a User-Defined Function”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 5.1.6, “Server Command Options”

--raw
Section 4.5.1.1, “mysql Client Options”
--read-from-remote-server
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"

--read-only
Section 4.6.3.2, "myisamchk Check Options"

--real_table_name
Section 18.4.25, "ndb_size.pl — NDBCLUSTER Size Requirement Estimator"

--rebuild-indexes
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--reconnect
Section 4.5.1.1, “mysql Client Options”

--record_log_pos
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"

--recover
Section 4.6.3.2, "myisamchk Check Options"
Section 4.6.3.1, "myisamchk General Options"
Section 4.6.3.6, "myisamchk Memory Usage"
Section 4.6.3.3, "myisamchk Repair Options"

--regexp
Section 4.6.11, "mysql_find_rows — Extract SQL Statements from Files"
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"

--relative
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"

--relay-log-purge
Section 17.1.3.3, “Replication Slave Options and Variables”

--relay-log-recovery
Section 17.1.3.3, “Replication Slave Options and Variables”

--relay-log-space-limit
Section 17.1.3.3, “Replication Slave Options and Variables”

--relnotes
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"

--reload
Section 18.5.14.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.1.7.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
--remove
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 5.1.6, “Server Command Options”
Section 5.7.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.6.7, “Starting MySQL as a Windows Service”

--remove
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--repair
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--replace
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”

--replicate-*
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”

--replicate-*-db
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 20.8, “Restrictions on Stored Programs”

--replicate-*-table
Section 17.2.3.3, “Replication Rule Application”

--replicate-do-*
Section 18.6.3, “Known Issues in NDB Cluster Replication”

--replicate-do-db
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 5.4.4, “The Binary Log”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-do-table
Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-ignore-*
Section 18.6.3, “Known Issues in NDB Cluster Replication”

--replicate-ignore-db
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.14, “Replication and System Functions”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 5.4.4, “The Binary Log”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-ignore-table
Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-rewrite-db
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-same-server-id
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 17.1.3.3, “Replication Slave Options and Variables”

--replicate-wild-do-table
Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
replication-ignore-table
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

replication-rewrite-db
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--report-host
Section 17.1.4.1, “Checking Replication Status”
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--report-password
Section 17.1.3.2, “Replication Master Options and Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--report-port
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--report-user
Section 17.1.3.2, “Replication Master Options and Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--resetmaster
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--resetslave
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--restore-data
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

--restore-epoch
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”

--restore-meta
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to More Nodes Than the Original
--restore-privilege-tables
Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--result-file
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”

--retries
Section 18.4.10, “ndb_desc — Describe NDB Tables”

--rewrite-database
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--rhost
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--rollback
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--routines
Section 7.4.5.3, “Dumping Stored Programs”
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”

--rowid
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--rows
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--rpm
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

S

[S]

-S
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.2.1, “Invoking MySQL Programs”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlslap — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.6.3.4, “Other myisamchk Options”

-S
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.8.1, “perror — Display MySQL Error Message Information”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”

--safe-mode
Section 5.1.6, “Server Command Options”

--safe-recover
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”

--safe-show-database
Section 1.4, “What Is New in MySQL 5.5”

--safe-updates
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.1.6, “mysql Client Tips”
Section 5.1.7, “Server System Variables”

--safe-user-create
Section 5.1.6, “Server Command Options”
--savequeries
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--secure-auth
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.5.1.1, “mysql Client Options”
Section 6.1.2.4, “Password Hashing in MySQL”

--select-limit
Section 4.5.1.1, “mysql Client Options”
Section 4.5.1.6, “mysql Client Tips”

--server-id
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--server-id-bits
MySQL Server Options for NDB Cluster
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
NDB Cluster System Variables

service-startup-timeout
Section 4.3.3, “mysql.server — MySQL Server Startup Script”

--set-auto-increment
Section 4.6.3.4, “Other myisamchk Options”

--set-charset
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”

--set-collation
Section 4.6.3.3, “myisamchk Repair Options”

--set-variable
Section 1.4, “What Is New in MySQL 5.5”

--shared-memory-base-name
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”
--short-form
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"

--show-slave-auth-info
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Statement”

--show-table-type
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"

--show-temp-status
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"

--show-warnings
Section 4.5.1.1, "mysql Client Options"

--sigint-ignore
Section 4.5.1.1, "mysql Client Options"
Section 4.10, “Unix Signal Handling in MySQL”

--silent
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.8.1, “perror — Display MySQL Error Message Information”
Section 4.8.3, “resolvectl — Resolve Host name to IP Address or Vice Versa”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”

--single-transaction
Section 7.2, “Database Backup Methods”
Section 7.3.1, “Establishing a Backup Policy”
Section 14.21.1, “InnoDB Backup”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 14.11.9, “Purge Configuration”

--single-user
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--skip
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.2.2.4, “Program Option Modifiers”
Section 5.1.6, “Server Command Options”

--skip-add-drop-table
Section 4.5.4, “mysqldump — A Database Backup Program”
--skip-add-locks
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-auto-rehash
Section 4.5.1.1, "mysql Client Options"
Section 14.23.3, "Troubleshooting InnoDB Data Dictionary Operations"

--skip-broken-objects
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"

--skip-character-set-client-handshake
Section A.11, "MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 10.10.7.1, "The cp932 Character Set"

--skip-column-names
Section 4.5.1.1, "mysql Client Options"

--skip-comments
Section 4.5.1.1, "mysql Client Options"
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-compact
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-config-cache
Section 18.4.4, "ndb_mgmd — The NDB Cluster Management Server Daemon"

--skip-disable-keys
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-dump-date
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-engine_name
Section 13.7.5.17, "SHOW ENGINES Statement"
Section 21.7, "The INFORMATION_SCHEMA ENGINES Table"

--skip-events
Section 7.4.5.3, "Dumping Stored Programs"

--skip-extended-insert
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-external-locking
Section 8.11.5, "External Locking"
Section 8.14.2, "General Thread States"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 8.12.1, “System Factors”
Section 1.4, “What Is New in MySQL 5.5”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

--skip-grant-tables
Section 24.4.2, “Adding a User-Defined Function”
Section 2.11.3, “Changes in MySQL 5.5”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”
Section 20.4.2, “Event Scheduler Configuration”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 5.6.1, “Installing and Uninstalling User-Defined Functions”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 6.2.10, “Pluggable Authentication”
Resetting the Root Password: Generic Instructions
Section 5.1.6, “Server Command Options”
Section 5.3, “The mysql System Database”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 4.2.2.1, “Using Options on the Command Line”
Section 6.2.8, “When Privilege Changes Take Effect”

--skip-host-cache
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 5.1.6, “Server Command Options”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

--skip-innodb
Section 14.1.3, “Checking InnoDB Availability”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 14.1.6, “Turning Off InnoDB”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”

--skip-innodb-adaptive-hash-index
Section 14.17, “InnoDB Startup Options and System Variables”

--skip-innodb-checksums
Section 14.17, “InnoDB Startup Options and System Variables”

--skip-innodb-doublewrite
Section 14.17, “InnoDB Startup Options and System Variables”

--skip-kill-mysqld
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--skip-line-numbers
Section 4.5.1.1, “mysql Client Options”
--skip-lock-tables
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip-locking
Section 1.4, “What Is New in MySQL 5.5”

--skip-name-resolve
Section 4.4.3, "mysql_install_db — Initialize MySQL Data Directory”

--skip-named-commands
Section 4.5.1.1, “mysql Client Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-ndbcluster
MySQL Server Options for NDB Cluster
Section 18.3.2.5, “NDB Cluster mysqld Option and Variable Reference”
NDB Cluster System Variables

--skip-new
Section 24.5.1, “Debugging a MySQL Server”
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

--skip-nodegroup
Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

--skip-opt
Section 4.5.4, "mysqldump — A Database Backup Program”

--skip-pager
Section 4.5.1.1, “mysql Client Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-partition
Chapter 19, Partitioning
Section 5.1.6, “Server Command Options”

--skip-password
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, "mysqldump — A Database Backup Program”
Section 4.5.5, "mysqlimport — A Data Import Program”
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, "mysqlslap — Load Emulation Client”
--skip-xxx
Section 4.5.4, "mysqldump — A Database Backup Program"

--skip_grant_tables
Section 4.2.2.1, “Using Options on the Command Line”

--slave-skip-errors
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.4.1.28, “Slave Errors During Replication”

--slave_compressed_protocol
Section 17.1.3.3, “Replication Slave Options and Variables”

--sleep
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--slow-start-timeout
Section 5.1.6, “Server Command Options”

--slow_query_log
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.4.5, “The Slow Query Log”

--slow_query_log_file
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.4.5, “The Slow Query Log”

--socket
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section B.4.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.5.1.1, “mysql Client Options”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.2, “mysql_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqslap — Load Emulation Client”
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.7.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.6, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 2.3.6.8, “Testing The MySQL Installation”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 5.7.4, “Using Client Programs in a Multiple-Server Environment”

--sort-index
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.4, “Other myisamchk Options”

--sort-records
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.4, “Other myisamchk Options”

--sort-recover
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”

--spassword
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--sporadic-binlog-dump-fail
Section 17.1.3.4, “Binary Log Options and Variables”

--sql-bin-update-same
Section 1.4, “What Is New in MySQL 5.5”

--sql-mode
Chapter 12, Functions and Operators
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.6, “Server Command Options”
Section 5.1.10, “Server SQL Modes”

sql-mode
Section 5.1.10, “Server SQL Modes”

--srcdir
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

--ssl
Section 4.2.3, “Command Options for Connecting to the Server”
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"
Section 4.5.7, "mysqlslap — Load Emulation Client"
Section 5.1.6, "Server Command Options"

--ssl*
Section 4.5.1.1, "mysql Client Options"
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.5, "mysqlimport — A Data Import Program"
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"
Section 4.5.7, "mysqlslap — Load Emulation Client"
Section 5.1.6, "Server Command Options"

--ssl-ca
Section 4.2.3, "Command Options for Connecting to the Server"
Section 6.3.1, "Configuring MySQL to Use Encrypted Connections"
Section 6.3.3, "Creating SSL Certificates and Keys Using openssl"
Section 13.7.1.3, "GRANT Statement"
Section 17.3.7, "Setting Up Replication to Use Encrypted Connections"
Section 6.3.4, "SSL Library-Dependent Capabilities"

--ssl-capath
Section 4.2.3, "Command Options for Connecting to the Server"
Section 6.3.1, "Configuring MySQL to Use Encrypted Connections"
Section 13.7.1.3, "GRANT Statement"
Section 17.3.7, "Setting Up Replication to Use Encrypted Connections"
Section 6.3.4, "SSL Library-Dependent Capabilities"

--ssl-cert
Section 4.2.3, "Command Options for Connecting to the Server"
Section 6.3.1, "Configuring MySQL to Use Encrypted Connections"
Section 6.3.3, "Creating SSL Certificates and Keys Using openssl"
Section 13.7.1.3, "GRANT Statement"
Section 17.3.7, "Setting Up Replication to Use Encrypted Connections"

--ssl-cipher
Section 4.2.3, "Command Options for Connecting to the Server"
Section 6.3.2, "Encrypted Connection TLS Protocols and Ciphers"
Section 6.3.4, "SSL Library-Dependent Capabilities"

--ssl-key
Section 4.2.3, "Command Options for Connecting to the Server"
Section 6.3.1, "Configuring MySQL to Use Encrypted Connections"
Section 6.3.3, "Creating SSL Certificates and Keys Using openssl"
Section 13.7.1.3, "GRANT Statement"
Section 17.3.7, "Setting Up Replication to Use Encrypted Connections"

--ssl-mode
Section 23.7.14, "C API Encrypted Connection Support"
--ssl-verify-server-cert
Section 4.2.3, “Command Options for Connecting to the Server”
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--ssl-xxx
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 2.9.6, “Configuring SSL Library Support”
Section 5.1.7, “Server System Variables”

--staging-tries
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--standalone
Section 24.5.1.2, “Creating Trace Files”
Section 5.1.6, “Server Command Options”
Section 2.3.6.5, “Starting MySQL from the Windows Command Line”

--start-datetime
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.1, “Point-in-Time Recovery Using Event Times”

--start-position
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.2, “Point-in-Time Recovery Using Event Positions”
Section 1.4, “What Is New in MySQL 5.5”

--start_row
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”

--state-file
Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--stats
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”

--status
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--stop-datetime
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.1, “Point-in-Time Recovery Using Event Times”

--stop-position
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.2, “Point-in-Time Recovery Using Event Positions”

--suffix
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--super-large-pages
Section 8.12.4.2, “Enabling Large Page Support”
Section 5.1.6, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--superuser
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--symbolic-links
Section 5.1.6, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--symbols-file
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”

--sys-*
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-check
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-create
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-create-if-not-exist
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

sys-create-if-not-exist
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-create-if-not-valid
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-drop
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-skip-events
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-skip-tables
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

SYSCONFDIR
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.2.2.2, “Using Option Files”
--sysdate-is-now
Section 17.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication"
Section 12.6, "Date and Time Functions"
Section 17.4.1.14, "Replication and System Functions"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"

--syslog
Section 5.4.2.3, "Error Logging to the System Log"
Section 4.3.2, "mysqld_safe — MySQL Server Startup Script"

--syslog-tag
Section 4.3.2, "mysqld_safe — MySQL Server Startup Script"

--system
Section 18.4.7, "ndb_config — Extract NDB Cluster Configuration Information"

T

[index top]

-T
Section 4.4.1, "comp_err — Compile MySQL Error Message File"
Section 4.6.3.2, "myisamchk Check Options"
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"
Section 4.5.1.1, "mysql Client Options"
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.5.7, "mysqlslap — Load Emulation Client"
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup"
Section 5.1.6, "Server Command Options"

-t
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.3.3, "myisamchk Repair Options"
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"
Section 4.5.1.1, "mysql Client Options"
Section 2.3.5.13, "MySQL Server Instance Config Wizard: Creating an Instance from the Command Line"
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables"
Section 4.6.15, "mysql_zap — Kill Processes That Match a Pattern"
Section 4.6.6, "mysqlexec — Client for Checking Access Privileges"
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.6.8, "mysqldumpslow — Summarize Slow Query Log Files"
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"
Section 18.4.9, "ndb_delete_all — Delete All Rows from an NDB Table"
Section 18.4.10, "ndb_desc — Describe NDB Tables"
Section 18.4.5, "ndb_mgm — The NDB Cluster Management Client"
Section 18.4.20, "ndb_redo_log_reader — Check and Print Content of Cluster Redo Log"
Section 18.4.22, "ndb_select_all — Print Rows from an NDB Table"
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"
Section 18.4.26, "ndb_waiter — Wait for NDB Cluster to Reach a Given Status"
Section 5.1.6, “Server Command Options”

--tab
Section 7.1, “Backup and Recovery Types”
Section 7.2, “Database Backup Methods”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, "mysqldump — A Database Backup Program”
Section 18.4.21, "ndb_restore — Restore an NDB Cluster Backup”
Section 7.4, "Using mysqldump for Backups”

--table
Section 4.5.1.1, “mysql Client Options”
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges”
Section 18.4.10, "ndb_desc — Describe NDB Tables”

--tables
Section 4.5.3, "mysqlcheck — A Table Maintenance Program”
Section 4.5.4, "mysqldump — A Database Backup Program”

--tc-heuristic-recover
Section 5.1.6, “Server Command Options”

--tcp-ip
Section 4.3.4, "mysqld_multi — Manage Multiple MySQL Servers”

--tee
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”

--temp-pool
Section 5.1.6, “Server Command Options”

--test
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables”

Text
Section 1.2, “Typographical and Syntax Conventions”

--thread_cache_size
Section 24.5.1.4, “Debugging mysqld under gdb”

--thread_handling
Section 5.1.6, “Server Command Options”

--timeout
Section 18.4.26, "ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--timezone
Section 5.1.12, “MySQL Server Time Zone Support”
Section 4.3.2, "mysqld_safe — MySQL Server Startup Script”
Section 17.4.1.33, “Replication and Time Zones”
Section 5.1.7, “Server System Variables"
Section B.4.3.7, “Time Zone Problems”

--tmpdir
Section B.4.2.13, “Can't create/write to file”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 5.1.6, “Server Command Options”
Section 2.3.6.7, “Starting MySQL as a Windows Service”
Section B.4.3.5, “Where MySQL Stores Temporary Files”

tmpdir
Section 2.3, “Installing MySQL on Microsoft Windows”

--to-last-log
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--transaction-isolation
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Statement”
Section 14.10.2.1, “Transaction Isolation Levels”

--transactional
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”

--triggers
Section 7.4.5.3, “Dumping Stored Programs”
Section 4.5.4, “mysqldump — A Database Backup Program”

--try-reconnect
Section 18.4.5, “ndb_mgm — The NDB Cluster Management Client”

--tupscan
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--type
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

--tz-utc
Section 4.5.4, “mysqldump — A Database Backup Program”

U

[index top]
Section 2.5.1, "Installing MySQL on Linux Using RPM Packages"
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.3.2, "myisamchk Check Options"
Section 4.5.1.1, "mysql Client Options"
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"

Section 6.2.1, "Account User Names and Passwords"
Section 4.2.3, "Command Options for Connecting to the Server"
Section 2.12, "Downgrading MySQL"
Section 4.2.1, "Invoking MySQL Programs"
Section 16.2.2.1, "memcached Command-Line Options"
Section 4.6.3.3, "myisamchk Repair Options"
Section 4.6.4, "mysqllog — Display MyISAM Log File Contents"
Section 4.5.1.1, "mysql Client Options"
Section 4.4.7, "mysql_upgrade — Check and Upgrade MySQL Tables"
Section 4.6.6, "mysqlaccess — Client for Checking Access Privileges"
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"
Section 4.5.3, "mysqlcheck — A Table Maintenance Program"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 4.6.9, "mysqlhotcopy — A Database Backup Program"
Section 4.5.5, "mysqldump — A Data Import Program"
Section 4.5.6, "mysqlshow — Display Database, Table, and Column Information"
Section 4.5.7, "mysqslap — Load Emulation Client"
Section 18.4.10, "ndb_desc — Describe NDB Tables"
Section 18.4.11, "ndb_recover — Reverse an NDB Cluster Backup"
Section 18.4.14, "ndb_index_stat — NDB Index Statistics Utility"
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"
Section 5.1.6, "Server Command Options"
Section 2.3.8, "Windows Postinstallation Procedures"

--unbuffered
Section 4.5.1.1, "mysql Client Options"

--unpack
Section 15.3.3, "MyISAM Table Storage Formats"
Section 4.6.3.3, "myisamchk Repair Options"
Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables"

--unqualified
Section 18.4.10, "ndb_desc — Describe NDB Tables"
Section 18.4.24, "ndb_show_tables — Display List of NDB Tables"

--update
Section 18.4.14, "ndb_index_stat — NDB Index Statistics Utility"

--update-state
Section 7.6.3, "How to Repair MyISAM Tables"
Section 4.6.3.2, “myisamchk Check Options”
Section 15.3, “The MyISAM Storage Engine”

**--upgrade**
Section 2.3.3.4, “MySQL Installer Product Catalog and Dashboard”

**--upgrade-system-tables**
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”

**--usage**
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

**--use-frm**
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

**--use-symbolic-links**
Section 5.1.6, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

**--use-threads**
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 23.7.3.2, “Writing C API Threaded Client Programs”

**--useHexFormat**
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

**--user**
Section 6.2.1, “Account User Names and Passwords”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 7.3, “Example Backup and Recovery Strategy”
Section B.4.2.18, “File Not Found and Similar Errors”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section 2.10.1, “Initializing the Data Directory”
Section 4.2.1, “Invoking MySQL Programs”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.1, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqslap — Load Emulation Client”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 4.6.3.1, “my_print_defaults — Display Options from Option Files”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 5.1.6, “Server Command Options”
Section 4.2.2.1, “Using Options on the Command Line”

--var_name
Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 5.1.6, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--variable
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

--verbose
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 4.5.1.5, “Executing SQL Statements from a Text File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.1.6, “Server Command Options”

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--wait
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--wait-nodes
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--warnings
Section 5.1.6, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--where
Section 4.5.4, “mysqldump — A Database Backup Program”

--windows
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

--with-libevent
Section 16.2.1, “Installing memcached”

--with-pstack
Section 1.4, “What Is New in MySQL 5.5”

WITH_BUNDLED_MEMCACHED
Section 2.9.7, “MySQL Source-Configuration Options”
WITH_CLASSPATH
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_DEBUG
Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.5.1.1, “mysql Client Options”
Section 2.9.7, “MySQL Source-Configuration Options”

WITH_NDB_JAVA
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_NDBCLUSTER
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_NDBCLUSTER_STORAGE_ENGINE
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 2.9.7, “MySQL Source-Configuration Options”

WITH_PERFSHEMA_STORAGE_ENGINE
Section 22.2, “Performance Schema Build Configuration”

WITH_SSL
Section 2.9.6, “Configuring SSL Library Support”
Section 2.9.2, “Source Installation Prerequisites”

WITH_ZLIB
Section 2.9.7, “MySQL Source-Configuration Options”

--write-binlog
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

-X
Section 4.5.1.2, “mysql Client Commands”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysqldump — A Database Backup Program”

-X
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--xml
Section 13.2.7, “LOAD XML Statement”
Section 4.5.1.1, “mysql Client Options”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 12.11, “XML Functions”

Y

[ index top ]

-Y
Section 4.5.4, “mysqldump — A Database Backup Program”

-Z
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

Privileges Index

A | C | D | E | F | G | I | L | P | R | S | T | U

A

[ index top ]

ALL
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

ALL PRIVILEGES
Section 6.2.2, “Privileges Provided by MySQL”

ALTER
Section 13.1.1, “ALTER DATABASE Statement”
Section 13.1.7, “ALTER TABLE Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Statement”

ALTER ROUTINE
Section 13.1.3, “ALTER FUNCTION Statement”
Section 13.1.5, “ALTER PROCEDURE Statement”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.1.7, “Server System Variables”
Section 20.7, “Stored Program Binary Logging”
Section 20.2.2, “Stored Routines and MySQL Privileges”

CREATE
Section 13.1.7, “ALTER TABLE Statement”
Section 13.1.10, “CREATE DATABASE Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Statement”

CREATE ROUTINE
Section 17.1.3.4, “Binary Log Options and Variables”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.7.1.3, “GRANT Statement”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 6.2.2, “Privileges Provided by MySQL”
Section 20.7, “Stored Program Binary Logging”
Section 20.2.2, “Stored Routines and MySQL Privileges”

CREATE TABLESPACE
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

CREATE TEMPORARY TABLES
Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

CREATE USER
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 6.2.9, “Assigning Account Passwords”
Section 13.7.1.1, “CREATE USER Statement”
Section 13.7.1.2, “DROP USER Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Statement”
Section 13.7.1.5, “REVOKE Statement”

CREATE VIEW
Section 13.1.9, “ALTER VIEW Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 13.7.1.3, “GRANT Statement”
EXECUTE
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.1.7, “Server System Variables”
Section 20.6, “Stored Object Access Control”
Section 20.2.2, “Stored Routines and MySQL Privileges”

FILE
Section 13.1.17, “CREATE TABLE Statement”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 13.2.6, “LOAD DATA Statement”
Section 13.2.7, “LOAD XML Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 5.1.7, “Server System Variables”
Section 12.7, “String Functions and Operators”
Section 11.3.4, “The BLOB and TEXT Types”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

INDEX
Section 13.1.7, “ALTER TABLE Statement”
Section 13.7.1.3, “GRANT Statement”

3586
Section 6.2.2, “Privileges Provided by MySQL”

INSERT
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 24.4.2, “Adding a User-Defined Function”
Section 13.1.7, “ALTER TABLE Statement”
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 6.2.9, “Assigning Account Passwords”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.7.1.1, “CREATE USER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 13.7.1.3, “GRANT Statement”
Section 13.2.5, “INSERT Statement”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 5.6.1, “Installing and Uninstalling User-Defined Functions”
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Statement”
Section 13.7.2.5, “REPAIR TABLE Statement”
Section 13.2.8, “REPLACE Statement”
Section 5.1.6, “Server Command Options”
Section 20.6, “Stored Object Access Control”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

L

[INDEX TOP]

LOCK TABLES
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”

P

[INDEX TOP]

PROCESS
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 20.4.2, “Event Scheduler Configuration”
Section 8.14, “Examining Thread Information”
Section 13.7.1.3, “GRANT Statement”
Section 8.12.5.1, “How MySQL Handles Client Connections”
Section 21.1, “Introduction”
Section 13.7.6.4, “KILL Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.5.16, “SHOW ENGINE Statement”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 21.29.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”
Section 21.29.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”
Section 21.29.3, “The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table”
Section 21.29.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 21.29.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 21.29.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.29.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 22.10.6.2, “The threads Table”
Section B.4.2.7, “Too many connections”

PROXY
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Implementing Proxy User Support in Authentication Plugins
Section 6.4.1.4, “PAM Pluggable Authentication”
Section 6.2.2, “Privileges Provided by MySQL”
Section 6.2.11, “Proxy Users”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 6.4.1.5, “Windows Pluggable Authentication”

PROXY ... WITH GRANT OPTION
Section 6.2.11, “Proxy Users”

R

[index top]

REFERENCES
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

RELOAD
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 23.7.6.55, “mysql_refresh()”
Section 23.7.6.56, “mysql_reload()”
Section 4.5.4, “mysql_dump — A Database Backup Program”
Section 4.6.9, “mysql_hotcopy — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.6.6, “RESET Statement”
Section 5.4.7, “Server Log Maintenance”
REPLICATION CLIENT
Section 13.7.1.3, “GRANT Statement"
Section 6.2.2, “Privileges Provided by MySQL"
Section 13.7.5.2, “SHOW BINARY LOGS Statement”
Section 13.7.5.24, “SHOW MASTER STATUS Statement”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”

REPLICATION SLAVE
Section 17.1.1.3, “Creating a User for Replication”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

S

[ index top ]

SELECT
Section 6.2, “Access Control and Account Management”
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 13.7.2.3, “CHECKSUM TABLE Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.17.4, “CREATE TABLE ... LIKE Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 13.2.2, “DELETE Statement”
Section 13.8.2, “EXPLAIN Statement”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 13.7.1.3, “GRANT Statement”
Section 13.2.5, “INSERT Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 22.9, “Performance Schema General Table Characteristics”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.2.5, “REPAIR TABLE Statement”
Section 20.9, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 13.7.5.22, “SHOW GRANTS Statement”
Section 20.6, “Stored Object Access Control”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 15.8, “The MERGE Storage Engine”
Section 20.3.1, “Trigger Syntax and Examples”
Section 13.2.11, “UPDATE Statement”

SHOW DATABASES
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.6, “SET PASSWORD Statement”
Section 13.3.6, “SET TRANSACTION Statement”
Section 13.7.5.2, “SHOW BINARY LOGS Statement”
Section 13.7.5.22, “SHOW GRANTS Statement”
Section 13.7.5.24, “SHOW MASTER STATUS Statement”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 13.4.2.5, “START SLAVE Statement”
Section 13.4.2.6, “STOP SLAVE Statement”
Section 20.6, “Stored Object Access Control”
Section 20.7, “Stored Program Binary Logging”
Section 5.1.8.1, “System Variable Privileges”
Section B.4.2.7, “Too many connections”

T

[index top]

TRIGGER
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.30, “DROP TRIGGER Statement”
Section 13.7.1.3, “GRANT Statement”
Section 4.5.4, “mysql — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.5.13, “SHOW CREATE TRIGGER Statement”
Section 13.7.5.39, “SHOW TRIGGERS Statement”
Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”

U

[index top]

UPDATE
Section 6.2.9, “Assigning Account Passwords”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 13.7.1.3, “GRANT Statement”
Section 13.2.5, “INSERT Statement”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 22.9, “Performance Schema General Table Characteristics”
Section 22.4, “Performance Schema Runtime Configuration”
Section 22.10.2, “Performance Schema Setup Tables”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Statement”
Section 13.7.1.5, “REVOKE Statement”
Section 20.6, “Stored Object Access Control”
Section 15.8, “The MERGE Storage Engine”
Section 20.3.1, “Trigger Syntax and Examples”
Section 13.2.11, “UPDATE Statement”

USAGE
Section 13.7.1.3, “GRANT Statement”
SQL Modes Index

A | D | E | H | I | M | N | O | P | R | S | T

A

[index top]

ALLOW_INVALID_DATES
Section 11.2, “Date and Time Data Types”
Section 12.6, “Date and Time Functions”
Section B.4.4.2, “Problems Using DATE Columns”
Section 5.1.10, “Server SQL Modes”
Section 11.2.2, “The DATE, DATETIME, and TIMESTAMP Types”

ANSI
Section 9.2.5, “Function Name Parsing and Resolution”
Section 5.1.10, “Server SQL Modes”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”

ANSI_QUOTES
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 4.5.1.6, “mysql Client Tips”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 9.2, “Schema Object Names”
Section 5.1.10, “Server SQL Modes”
Section 9.1.1, “String Literals”

D

[index top]

DB2
Section 5.1.10, “Server SQL Modes”

E

[index top]

ERROR_FOR_DIVISION_BY_ZERO
Section 12.19.3, “Expression Handling”
Section 12.19.5, “Precision Math Examples”
Section 5.1.10, “Server SQL Modes”

H

[index top]
HIGH_NOT_PRECEDENCE
Section 9.5, “Expressions”
Section 12.3.1, “Operator Precedence”
Section 5.1.10, “Server SQL Modes”

IGNORE_SPACE
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 9.2.5, “Function Name Parsing and Resolution”
Section 4.5.1.1, “mysql Client Options”
Section 5.1.10, “Server SQL Modes”

MAXDB
Section 11.2.1, “Date and Time Data Type Syntax”
Section 5.1.10, “Server SQL Modes”
Section 11.2.2, “The DATE, DATETIME, and TIMESTAMP Types”

MSSQL
Section 5.1.10, “Server SQL Modes”

MYSQL323
Section 5.1.10, “Server SQL Modes”

MYSQL40
Section 5.1.10, “Server SQL Modes”

NO_AUTO_CREATE_USER
Section 13.7.1.3, “GRANT Statement”
Section 5.1.10, “Server SQL Modes”

NO_AUTO_VALUE_ON_ZERO
Section 13.1.17, “CREATE TABLE Statement”
Section 11.1.6, “Numeric Type Attributes”
Section 5.1.10, “Server SQL Modes”
Section 3.6.9, “Using AUTO_INCREMENT”

NO_BACKSLASH_ESCAPES
Section 5.1.10, “Server SQL Modes”
Section 12.7.1, “String Comparison Functions and Operators”
Section 9.1.1, “String Literals”
NO_DIR_IN_CREATE
Section 13.1.17, "CREATE TABLE Statement"
Section 17.4.1.10, "Replication and DIRECTORY Table Options"
Section 17.4.1.37, "Replication and Variables"
Section 5.1.10, "Server SQL Modes"
Section 19.2.6, "Subpartitioning"
Section 5.4.4, "The Binary Log"

NO_ENGINE_SUBSTITUTION
Section 13.1.7, "ALTER TABLE Statement"
Section 13.1.17, "CREATE TABLE Statement"
Section 5.5.1, "Installing and Uninstalling Plugins"
Section 5.1.10, "Server SQL Modes"
Section 15.1, "Setting the Storage Engine"
Section 17.3.2, "Using Replication with Different Master and Slave Storage Engines"

NO_FIELD_OPTIONS
Section 5.1.10, "Server SQL Modes"

NO_KEY_OPTIONS
Section 5.1.10, "Server SQL Modes"

NO_TABLE_OPTIONS
Section 5.1.10, "Server SQL Modes"

NO_UNSIGNED_SUBTRACTION
Section 12.5.1, "Arithmetic Operators"
Section 12.10, "Cast Functions and Operators"
Section 11.1.1, "Numeric Data Type Syntax"
Section 11.1.7, "Out-of-Range and Overflow Handling"
Section 19.5, "Restrictions and Limitations on Partitioning"
Section 5.1.10, "Server SQL Modes"

NO_ZERO_DATE
Section 11.2.6, "Automatic Initialization and Updating for TIMESTAMP"
Section 12.10, "Cast Functions and Operators"
Section 11.2, "Date and Time Data Types"
Section 12.6, "Date and Time Functions"
Section B.4.4.2, "Problems Using DATE Columns"
Section 5.1.10, "Server SQL Modes"
Section 11.2.2, "The DATE, DATETIME, and TIMESTAMP Types"

NO_ZERO_IN_DATE
Section 13.1.17, "CREATE TABLE Statement"
Section 11.2, "Date and Time Data Types"
Section 12.6, "Date and Time Functions"
Section B.4.4.2, "Problems Using DATE Columns"
Section 5.1.10, "Server SQL Modes"
ONLY_FULL_GROUP_BY
Section 3.3.4.8, “Counting Rows”
Section 12.17.2, “GROUP BY Modifiers”
Section 12.17.3, “MySQL Handling of GROUP BY”
Section 5.1.10, “Server SQL Modes”

ORACLE
Section 5.1.10, “Server SQL Modes”

P

P

PAD_CHAR_TO_FULL_LENGTH
Section 5.1.10, “Server SQL Modes”
Section 11.3.1, “String Data Type Syntax”
Section 11.3.2, “The CHAR and VARCHAR Types”

PIES_AS_CONCAT
Section 9.5, “Expressions”
Section 12.3.3, “Logical Operators”
Section 12.3.1, “Operator Precedence”
Section 5.1.10, “Server SQL Modes”

POSTGRESQL
Section 5.1.10, “Server SQL Modes”

R

REAL_AS_FLOAT
Section 11.1.1, “Numeric Data Type Syntax”
Section 11.1, “Numeric Data Types”
Section 5.1.10, “Server SQL Modes”

S

STRICT_ALL_TABLES
Section 1.7.3.3, “Constraints on Invalid Data”
Section 12.19.3, “Expression Handling”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.10, “Server SQL Modes”

STRICT_TRANS_TABLES
Section 1.7.3.3, “Constraints on Invalid Data”
Section 12.19.3, “Expression Handling”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.10, “Server SQL Modes”

T

[ index top ]

TRADITIONAL
Section 11.2.6, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.19.3, “Expression Handling”
Section 13.2.6, “LOAD DATA Statement”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.10, “Server SQL Modes”

Statement/Syntax Index

A | B | C | D | E | F | G | H | I | K | L | O | P | R | S | T | U | W | X

A

[ index top ]

ALTER DATABASE
Section 13.1.1, “ALTER DATABASE Statement”
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.3.3, “Database Character Set and Collation”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 17.1.3.3, “Replication Slave Options and Variables”

ALTER EVENT
Section 13.1.2, “ALTER EVENT Statement”
Section 13.1.11, “CREATE EVENT Statement”
Section 20.4.4, “Event Metadata”
Section 20.4.1, “Event Scheduler Overview”
Section 20.4.3, “Event Syntax”
Section 12.15, “Information Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section 20.8, “Restrictions on Stored Programs”
Section 13.7.5.19, “SHOW EVENTS Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.7, “Stored Program Binary Logging”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”

ALTER EVENT event_name ENABLE
Section 17.4.1.15, “Replication of Invoked Features”

ALTER FUNCTION
Section 13.1.3, “ALTER FUNCTION Statement”
ALTER LOGFILE GROUP
Section 13.1.4, “ALTER LOGFILE GROUP Statement”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”

ALTER ONLINE TABLE
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”

ALTER ONLINE TABLE ... REORGANIZE PARTITION
Section 18.5.14.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.5.14.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.2.7, “Upgrading and Downgrading NDB Cluster”

ALTER PROCEDURE
Section 13.1.5, “ALTER PROCEDURE Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.7, “Stored Program Binary Logging”
Section 20.2.1, “Stored Routine Syntax”

ALTER SCHEMA
Section 13.1.1, “ALTER DATABASE Statement”

ALTER SERVER
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.5, “Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER”
Section 13.3.3, “Statements That Cause an Implicit Commit”

ALTER TABLE
Section 11.2.5, “2-Digit YEAR(2) Limitations and Migrating to 4-Digit YEAR”
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 13.1.7.2, “ALTER TABLE Examples”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Statement”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 2.11.3, “Changes in MySQL 5.5”
Section 13.7.2.2, “CHECK TABLE Statement”
Section 10.3.5, “Column Character Set and Collation”
Section 10.7, “Column Character Set Conversion”
Section 8.3.4, “Column Indexes”
Section 14.16.4, “Concurrency Considerations for Fast Index Creation”
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 10.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
ALTER TABLE ... ADD PARTITION
Section 19.3.1, “Management of RANGE and LIST Partitions”

ALTER TABLE ... CHANGE
Section 14.16.6, “Limitations of Fast Index Creation”

ALTER TABLE ... DISABLE KEYS
Section 13.2.6, “LOAD DATA Statement”

ALTER TABLE ... DISCARD TABLESPACE
MySQL Glossary

ALTER TABLE ... DROP PARTITION
Section 17.4.1.23, “Replication and Partitioning”

ALTER TABLE ... ENABLE KEYS
Section 13.2.6, “LOAD DATA Statement”

ALTER TABLE ... ENGINE = MEMORY
Section 17.4.1.20, “Replication and MEMORY Tables”

ALTER TABLE ... ENGINE = NDB
Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”

ALTER TABLE ... IMPORT TABLESPACE
Section 13.1.7, “ALTER TABLE Statement”
MySQL Glossary

ALTER TABLE ... OPTIMIZE PARTITION
Section 19.3.3, “Maintenance of Partitions”
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”

ALTER TABLE ... PARTITION BY
Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”

ALTER TABLE ... PARTITION BY ...
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 19.5, “Restrictions and Limitations on Partitioning”

ALTER TABLE ... PARTITION BY ALGORITHM=1 KEY ()
Section 2.12.3, “Downgrade Notes”

ALTER TABLE ... PARTITION BY ALGORITHM=2 KEY ()
Section 2.11.3, “Changes in MySQL 5.5”
ALTER TABLE ... RENAME
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

ALTER TABLE ... REORGANIZE PARTITION
Section 18.5.14.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”

ALTER TABLE ... REPAIR PARTITION
Section 19.3.3, “Maintenance of Partitions”

ALTER TABLE ... TRUNCATE PARTITION
Section 19.3.3, “Maintenance of Partitions”
Section 19.3, “Partition Management”
Section 1.4, “What Is New in MySQL 5.5”

ALTER TABLE mysql.ndb_apply_status ENGINE=MyISAM
Section 18.6.3, “Known Issues in NDB Cluster Replication”

ALTER TABLE t3 DROP PARTITION p2
Section 5.4.6, “The DDL Log”

ALTER TABLE table_name REORGANIZE PARTITION
Section 18.5.14.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”

ALTER TABLE tbl_name TABLESPACE tablespace_name
MySQL Glossary

ALTER TABLESPACE
Section 13.1.8, “ALTER TABLESPACE Statement”
Section 13.1.18, “CREATE TABLESPACE Statement”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”

ALTER VIEW
Section 13.1.9, “ALTER VIEW Statement”
Section 12.15, “Information Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 20.8, “Restrictions on Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”

ANALYZE TABLE
Section 13.1.7, “ALTER TABLE Statement”
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 14.11.10.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Statement”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 8.14.2, “General Thread States”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 14.17, “InnoDB Startup Options and System Variables”
Section B.4.7, “Known Issues in MySQL”
Section 19.3.3, “Maintenance of Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3.1, “myisamchk General Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 8.8.1, “Optimizing MyISAM Queries”
Section 8.2.1, “Optimizing Queries with EXPLAIN”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.7.5.23, “SHOW INDEX Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 21.21, “The INFORMATION_SCHEMA STATISTICS Table”
Section 5.4.5, “The Slow Query Log”

B

BEGIN

Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 13.6.1, “BEGIN ... END Compound Statement”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 17.4.1.34, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 20.8, “Restrictions on Stored Programs”
Section 5.1.7, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.7, “Stored Program Binary Logging”

BEGIN ... END

Section 13.6.1, “BEGIN ... END Compound Statement”
Section 13.6.5.1, “CASE Statement”
Section 13.6, “Compound-Statements”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.6.6.1, “Cursor CLOSE Statement”
Section 13.6.6.3, “Cursor FETCH Statement”
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.3, “DECLARE Statements”
Section 20.1, “Defining Stored Programs”
Section 20.4.1, “Event Scheduler Overview”
Section 13.6.4.1, “Local Variable DECLARE Statement”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section 20.8, “Restrictions on Stored Programs”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 13.5.2, “Statement Labels”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.3.1, “Trigger Syntax and Examples”

**BINLOG**
Section 13.7.6.1, “BINLOG Statement”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 6.2.2, “Privileges Provided by MySQL”

**C**

[INDEX TOP]

**CACHE INDEX**
Section 13.7.6.2, “CACHE INDEX Statement”
Section 8.10.2.4, “Index Preloading”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Statement”
Section 8.10.2.2, “Multiple Key Caches”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 1.4, “What Is New in MySQL 5.5”

**CALL**
Section 23.7.4, “C API Data Structures”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 23.7.17, “C API Prepared CALL Statement Support”
Section 23.7.18, “C API Prepared Statement Problems”
Section 13.2.1, “CALL Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.37, “mysql_insert_id()”
Section 23.7.6.45, “mysql_more_results()”
Section 23.7.6.46, “mysql_next_result()”
Section 23.7.6.52, “mysql_real_connect()”
Section 23.7.6.64, “mysql_set_server_option()”
Section 23.7.10.17, “mysql_stmt_next_result()”
Section 13.5, “Prepared Statements”
Section 20.6, “Stored Object Access Control”
Chapter 20, Stored Objects
Section 20.7, “Stored Program Binary Logging”
Section 20.2.1, “Stored Routine Syntax”
Section 20.3.1, “Trigger Syntax and Examples”

**CALL p()**
Section 13.6.7.3, “RESIGNAL Statement”

3603
CALL stored_procedure()
Section 19.5.4, “Partitioning and Table-Level Locking”

CASE
Section 13.6.5.1, “CASE Statement”
Section 12.4, “Control Flow Functions”
Section 13.6.5, “Flow Control Statements”

CHANGE MASTER TO
Section 6.2.9, “Assigning Account Passwords”
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 17.1.4.1, “Checking Replication Status”
Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”
Section 13.7.1.3, “GRANT Statement”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.27, “Replication and Master or Slave Shutdowns”
Section 17.1, “Replication Configuration”
Section 8.14.8, “Replication Slave Connection Thread States”
Section 8.14.6, “Replication Slave I/O Thread States”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.4.2.3, “RESET SLAVE Statement”
Section 5.1.9, “Server Status Variables”
Section 17.1.1.10, “Setting the Master Configuration on the Slave”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section 17.1.1.7, “Setting Up Replication with New Master and Slaves”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 17.2.2.2, “Slave Status Logs”
Section 17.3.6, “Switching Masters During Failover”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 1.4, “What Is New in MySQL 5.5”

CHECK TABLE
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 2.11.3, “Changes in MySQL 5.5”
Section 13.7.2.2, “CHECK TABLE Statement”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.20, “CREATE VIEW Statement”
Section 8.11.5, “External Locking”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 14.21.2, “InnoDB Recovery”
Section 14.23, “InnoDB Troubleshooting”
Section 19.3.3, “Maintenance of Partitions”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”
Section A.6, “MySQL 5.5 FAQ: Views”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section B.4.2.9, “MySQL server has gone away”
Section 23.7.6.69, “mysql_store_result()”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 23.7.6.71, “mysql_use_result()”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”
Section 15.5.1, “Repairing and Checking CSV Tables”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.6.6.5, “Restrictions on Server-Side Cursors”
Section 20.8, “Restrictions on Stored Programs”
Section 20.9, “Restrictions on Views”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.6, “Server Command Options”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.8, “The MERGE Storage Engine”
Section 5.4.5, “The Slow Query Log”

CHECK TABLE ... EXTENDED
Section 13.7.2.2, “CHECK TABLE Statement”

CHECK TABLE ... FOR UPGRADE
Section 13.7.2.5, “REPAIR TABLE Statement”

CHECK TABLE QUICK
Section 13.7.2.2, “CHECK TABLE Statement”

CHECKSUM TABLE
Section 13.7.2.3, “CHECKSUM TABLE Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 17.4.1.4, “Replication and CHECKSUM TABLE”

COMMIT
Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 14.5, “InnoDB and the ACID Model”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 4.5.4, “mysqldump — A Database Backup Program”
NDB Cluster System Variables
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 17.4.1.34, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements”
CREATE DATABASE
Section 7.1, “Backup and Recovery Types”
Section 23.7.5, “C API Function Overview”
Section 10.5, “Configuring Application Character Set and Collation”
Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 13.1.10, “CREATE DATABASE Statement”
Section 10.3.3, “Database Character Set and Collation”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 9.2.3, “Identifier Case Sensitivity”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.7.6.8, “mysql_create_db()”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 10.3.2, “Server Character Set and Collation”
Section B.3.1, “Server Error Message Reference”
Section 13.7.5.8, “SHOW CREATE DATABASE Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”

CREATE DATABASE dbx
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”

CREATE DATABASE IF NOT EXISTS
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE EVENT
Section 13.1.2, “ALTER EVENT Statement”
Section 13.1.11, “CREATE EVENT Statement”
Section 20.4.4, “Event Metadata”
Section 20.4.3, “Event Syntax”
Section 9.5, “Expressions”
Section 12.15, “Information Functions”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section 20.8, “Restrictions on Stored Programs”
Section 13.7.5.9, “SHOW CREATE EVENT Statement”
Section 13.7.5.19, “SHOW EVENTS Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Chapter 20, Stored Objects
CREATE EVENT IF NOT EXISTS

CREATE FUNCTION

CREATE INDEX
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 7.1, “Backup and Recovery Types”
Section 14.1.2, “Best Practices for InnoDB Tables”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 2.11.3, “Changes in MySQL 5.5”
Section 10.3.5, “Column Character Set and Collation”
Section 8.3.4, “Column Indexes”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.13, “CREATE INDEX Statement”
Section 13.1.16, “CREATE SERVER Statement”
Section 13.1.17.4, “CREATE TABLE ... LIKE Statement”
Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 3.3.2, “Creating a Table”
Section 14.9.1.1, “Creating InnoDB Tables”
Section 11.4.4, “Creating Spatial Columns”
Section 11.4.8, “Creating Spatial Indexes”
Section 7.2, “Database Backup Methods”
Section 10.3.3, “Database Character Set and Collation”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.20.2, “Enabling InnoDB Monitors”
Section B.2, “Error Information Interfaces”
Section 1.7.3.2, “FOREIGN KEY Constraints”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 12.9, “Full-Text Search Functions”
Section 3.4, “Getting Information About Databases and Tables”
Section 19.2.4, “HASH Partitioning”
Section 13.8.3, “HELP Statement”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 9.2.3, “Identifier Case Sensitivity”
Section 12.15, “Information Functions”
Section 18.2.3, “Initial Configuration of NDB Cluster”
Section 14.22, “InnoDB and MySQL Replication”
Section 14.14, “InnoDB Row Formats”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.23, “InnoDB Troubleshooting”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 14.1, “Introduction to InnoDB”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 19.2.5, “KEY Partitioning”
Section 18.1.7.5, “Limits Associated with Database Objects in NDB Cluster”
Section 8.4.6, “Limits on Table Size”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 19.2.2, “LIST Partitioning”
Section 13.2.7, “LOAD XML Statement”
Section 3.3.3, “Loading Data into a Table”
CREATE TABLE IF NOT EXISTS ... LIKE
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE TABLE IF NOT EXISTS ... SELECT
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE TABLE tbl_name ... TABLESPACE tablespace_name
MySQL Glossary

CREATE TABLE...AS SELECT
Section 8.2.1, “Optimizing SELECT Statements”

CREATE TABLESPACE
Section 13.1.8, “ALTER TABLESPACE Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.18, “CREATE TABLESPACE Statement”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 13.1.29, “DROP TABLESPACE Statement”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
MySQL Glossary
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.30.1, “The INFORMATION_SCHEMA FILES Table”

CREATE TEMPORARY TABLE
Section 13.7.1.3, “GRANT Statement”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section B.4.6.2, “TEMPORARY Table Problems”

CREATE TRIGGER
Section 13.1.19, “CREATE TRIGGER Statement”
Section 12.15, “Information Functions”
Section A.5, “MySQL 5.5 FAQ: Triggers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section 20.8, “Restrictions on Stored Programs”
Section 13.7.5.13, “SHOW CREATE TRIGGER Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Chapter 20, Stored Objects
Section 20.7, “Stored Program Binary Logging”
Section 8.2.2, “Subquery Optimization”
CREATE UNDO TABLESPACE
MySQL Glossary

CREATE USER
Section 6.2, “Access Control and Account Management”
Section 6.2.1, “Account User Names and Passwords”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 6.2.9, “Assigning Account Passwords”
Section 5.1.11.3, “Connecting Using the IPv6 Local Host Address”
Section 13.7.1.1, “CREATE USER Statement”
Section 17.1.1.3, “Creating a User for Replication”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Implementing Proxy User Support in Authentication Plugins
Section 5.1.11, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.4.1.4, “PAM Pluggable Authentication”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 6.2.2, “Privileges Provided by MySQL”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 6.2.11, “Proxy Users”
Section 5.1.7, “Server System Variables”
Section 6.2.4, “Specifying Account Names”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section 6.4.1.5, “Windows Pluggable Authentication”

CREATE VIEW
Section 13.1.9, “ALTER VIEW Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 8.14.2, “General Thread States”
Section 9.2.1, “Identifier Length Limits”
Section 12.15, “Information Functions”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 20.9, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Chapter 20, Stored Objects
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”

D

[ index top ]

DEALLOCATE PREPARE
Section 13.5.3, “DEALLOCATE PREPARE Statement”
Section 13.5.1, “PREPARE Statement”
Section 13.5, “Prepared Statements”
Section 20.8, “Restrictions on Stored Programs”
Section 5.1.9, “Server Status Variables”

DECLARE
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.6.3, “DECLARE Statements”
Section 13.6.7.4, “SIGNAL Statement”
Section 13.6.4, “Variables in Stored Programs”

DECLARE ... CONDITION
Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Statement”
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.7.4, “SIGNAL Statement”

DECLARE ... HANDLER
Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Statement”
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.7.4, “SIGNAL Statement”

DELETE
Section 6.2, “Access Control and Account Management”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.7.5, “C API Function Overview”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 14.8.2, “Change Buffer”
Section 2.11.3, “Changes in MySQL 5.5”
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 13.2.2, “DELETE Statement”
Section B.4.4.6, “Deleting Rows from Related Tables”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 13.1.17.6, “FOREIGN KEY Constraints”

3614
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.4, “The MEMORY Storage Engine”
Section 15.8, “The MERGE Storage Engine”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 20.3.1, “Trigger Syntax and Examples”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 13.1.33, “TRUNCATE TABLE Statement”
Section 14.9.7, “Undo Logs”
Section 20.5.3, “Updatable and Insertable Views”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”

DELETE FROM ... WHERE ...
Section 23.7.20.2, “What Results You Can Get from a Query”
Section 6.2.8, “When Privilege Changes Take Effect”
Section 8.2.1.1, “WHERE Clause Optimization”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

DELETE FROM a.t
Section 17.1.3.3, “Replication Slave Options and Variables”

DELETE FROM t1,t2
Section 5.8.1.12, “Statement Probes”

DESCRIBE
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 3.3.2, “Creating a Table”
Section 13.8.1, “DESCRIBE Statement”
Section 13.8.2, “EXPLAIN Statement”
Section 21.32, “Extensions to SHOW Statements”
Section 3.4, “Getting Information About Databases and Tables”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 23.7.10.28, “mysql_stmt_store_result()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 13.7.5.6, “SHOW COLUMNS Statement”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 3.6.6, “Using Foreign Keys”
Section 10.2.2, “UTF-8 for Metadata”

DO
Section 13.1.2, “ALTER EVENT Statement”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.2.3, “DO Statement”
DROP DATABASE
Section 23.7.5, “C API Function Overview”
Section 13.1.21, “DROP DATABASE Statement”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 8.10.3.1, “How the Query Cache Operates”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.7.6.11, “mysql_drop_db()”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 2.3.9, “Windows Platform Restrictions”

DROP DATABASE IF EXISTS
Section 17.4.1.11, “Replication of DROP ... IF EXISTS Statements”

DROP EVENT
Section 20.4.3, “Event Syntax”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.7, “Stored Program Binary Logging”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

DROP FUNCTION
Section 24.4.2, “Adding a User-Defined Function”
Section 24.4, “Adding Functions to MySQL”
Section 13.1.3, “ALTER FUNCTION Statement”
Section 1.8.1, “Contributors to MySQL”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.1.23, “DROP FUNCTION Statement”
Section 13.7.3.2, “DROP FUNCTION Statement”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”
Section 9.2.5, “Function Name Parsing and Resolution”
Section 5.6.1, “Installing and Uninstalling User-Defined Functions”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.7, “Stored Program Binary Logging”
Section 20.2.1, “Stored Routine Syntax”
Section 2.11.6, “Upgrade Troubleshooting”

DROP INDEX
Section 13.1.7, “ALTER TABLE Statement”
MySQL Glossary
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 18.4.11, "ndb_drop_index — Drop Index from an NDB Table"
Section 18.4.12, "ndb_drop_table — Drop an NDB Table"
Section 8.5.6, "Optimizing InnoDB DDL Operations"
Section 18.6.9.2, "Point-In-Time Recovery Using NDB Cluster Replication"
Section 20.9, "Restrictions on Views"
Section 5.4.1, "Selecting General Query Log and Slow Query Log Output Destinations"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 5.4.4.2, "Setting The Binary Log Format"
Section 13.7.5.35, "SHOW SLAVE STATUS Statement"
Section 13.6.7.4, "SIGNAL Statement"
Section 13.4.2.5, "START SLAVE Statement"
Section 13.3.3, "Statements That Cause an Implicit Commit"
Section 5.4.6, "The DDL Log"
Section 15.4, "The MEMORY Storage Engine"
Section 15.8, "The MERGE Storage Engine"
Section 14.23.3, "Troubleshooting InnoDB Data Dictionary Operations"
Section 13.1.33, "TRUNCATE TABLE Statement"
Section 24.2.1, "Types of Plugins"
Section 13.7.3.4, "UNINSTALL PLUGIN Statement"

**DROP TABLE IF EXISTS**
Section 17.4.1.11, "Replication of DROP ... IF EXISTS Statements"

```sql
DROP TABLE IF EXISTS mysql.user mysql.db mysql.tables_priv
mysql.columns_priv mysqlprocs_priv
```
Section 18.5.15, "Distributed Privileges Using Shared Grant Tables"

**DROP TABLESPACE**
Section 13.1.29, "DROP TABLESPACE Statement"
Section 18.1.7.8, "Issues Exclusive to NDB Cluster"

**DROP TEMPORARY TABLE IF EXISTS**
Section 17.1.2.2, "Usage of Row-Based Logging and Replication"

**DROP TRIGGER**
Section 13.1.30, "DROP TRIGGER Statement"
Section A.5, "MySQL 5.5 FAQ: Triggers"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 17.4.1.15, "Replication of Invoked Features"
Section 13.3.3, "Statements That Cause an Implicit Commit"
Section 20.3.1, "Trigger Syntax and Examples"

**DROP USER**
Section 6.2.1, "Account User Names and Passwords"
Section 6.2.7, "Adding Accounts, Assigning Privileges, and Dropping Accounts"
Section 13.7.1.2, "DROP USER Statement"
Section 13.7.6.3, "FLUSH Statement"
Section 13.7.1.3, "GRANT Statement"
Section 8.12.4.1, "How MySQL Uses Memory"
Section 12.15, “Information Functions”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.7.1.5, “REVOKE Statement”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

DROP USER 'x'@'localhost'
Using the Authentication Plugins

DROP VIEW
Section 13.1.31, “DROP VIEW Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 20.9, “Restrictions on Views”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.5.1, “View Syntax”

DROP VIEW IF EXISTS
Section 17.4.1.11, “Replication of DROP ... IF EXISTS Statements”

E

[index top]

EXECUTE
Section 23.7.17, “C API Prepared CALL Statement Support”
Section 13.2.1, “CALL Statement”
Section 13.5.2, “EXECUTE Statement”
Section 13.5.1, “PREPARE Statement”
Section 13.5, “Prepared Statements”
Section 20.9, “Restrictions on Stored Programs”
Section 20.8, “Restrictions on Views”
Section 20.9, “Restrictions on Views”
Section 5.1.9, “Server Status Variables”

EXPLAIN
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.2.10.8, “Derived Tables”
Section 13.8.1, “DESCRIBE Statement”
Section 8.2.1.12, “DISTINCT Optimization”
Section 8.2.1.14, “Engine Condition Pushdown Optimization”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Statement”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.9.3, “Index Hints”
EXPLAIN SELECT
Section 13.2.10.8, “Derived Tables”
Section 8.8.2, “EXPLAIN Output Format”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 1.6, “How to Report Bugs or Problems”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.3.4, “Obtaining Information About Partitions”

EXPLAIN tbl_name
Section 8.8.1, “Optimizing Queries with EXPLAIN”

F

[index top]

FETCH
Section 13.6.6.2, “Cursor DECLARE Statement”
Section 13.6.6.3, “Cursor FETCH Statement”
Section 20.8, “Restrictions on Stored Programs”

FETCH ... INTO var_list
Section 13.6.4, “Variables in Stored Programs”

FLUSH
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 13.7.6.6, “RESET Statement”
Section 20.8, “Restrictions on Stored Programs”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 4.10, “Unix Signal Handling in MySQL”

FLUSH BINARY LOGS
Section 13.7.6.3, “FLUSH Statement”
Section 5.4.7, “Server Log Maintenance”

FLUSH DES_KEY_FILE
Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Statement”

FLUSH ENGINE LOGS
Section 13.7.6.3, “FLUSH Statement”

FLUSH ERROR LOGS
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 13.7.6.3, “FLUSH Statement”
FLUSH GENERAL LOGS
Section 13.7.6.3, “FLUSH Statement”

FLUSH HOSTS
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 13.7.6.3, “FLUSH Statement”
Section B.4.2.6, “Host ‘host_name’ is blocked”
Section 23.7.6.55, “mysql_refresh()”
Section 5.1.7, “Server System Variables”

FLUSH LOGS
Section 7.3.3, “Backup Strategy Summary”
Section 2.11.3, “Changes in MySQL 5.5”
Section 7.2, “Database Backup Methods”
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Statement”
Section 5.4, “MySQL Server Logs”
Section 23.7.6.55, “mysql_refresh()”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.9, “Server Status Variables”
Section 17.2.2.1, “The Slave Relay Log”

FLUSH MASTER
Section 13.7.6.3, “FLUSH Statement”
Section 17.4.1.13, “Replication and FLUSH”

FLUSH PRIVILEGES
Section 18.5.15, “Distributed Privileges Using Shared Grant Tables”
Section 13.7.6.3, “FLUSH Statement”
Section 6.2.3, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 23.7.6.55, “mysql_refresh()”
Section 23.7.6.56, “mysql_reload()”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.1.6, “Server Command Options”
Section 6.2.12, “Setting Account Resource Limits”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 1.2, “Typographical and Syntax Conventions”
Section 6.2.8, “When Privilege Changes Take Effect”

FLUSH QUERY CACHE
Section 13.7.6.3, “FLUSH Statement”
Section 8.10.3.4, “Query Cache Status and Maintenance”

FLUSH RELAY LOGS
Section 13.7.6.3, “FLUSH Statement”
FLUSH SLAVE
Section 13.7.6.3, “FLUSH Statement”
Section 17.4.1.13, “Replication and FLUSH”

FLUSH SLOW LOGS
Section 13.7.6.3, “FLUSH Statement”

FLUSH STATUS
Section 13.7.6.3, “FLUSH Statement”
Section 23.7.6.55, “mysql_refresh()”
Section 5.1.9, “Server Status Variables”

FLUSH TABLE
Section 13.7.6.3, “FLUSH Statement”

FLUSH TABLES
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 2.11.3, “Changes in MySQL 5.5”
Section 13.7.6.3, “FLUSH Statement”
Section 8.14.2, “General Thread States”
Section 13.2.4, “HANDLER Statement”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 15.8.2, “MERGE Table Problems”
Section 4.6.3, “mysamchk — MyISAM Table-Maintenance Utility”
Section 23.7.6.55, “mysql_refresh()”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.1.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

FLUSH TABLES ... FOR EXPORT
MySQL Glossary

FLUSH TABLES tbl_list WITH READ LOCK
Section 2.11.3, “Changes in MySQL 5.5”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

FLUSH TABLES tbl_name ...
Section 13.7.6.3, “FLUSH Statement”

FLUSH TABLES tbl_name ... WITH READ LOCK
Section 13.7.6.3, “FLUSH Statement”

FLUSH TABLES tbl_name WITH READ LOCK
Section 13.2.4, “HANDLER Statement”
FLUSH TABLES WITH READ LOCK
Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 7.2, “Database Backup Methods”
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Statement”
Section 8.14.2, “General Thread States”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
MySQL Glossary
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 17.4.1.13, “Replication and FLUSH”
Section 13.3.7.3, “Restrictions on XA Transactions”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.7, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 13.3.3, “Statements That Cause an Implicit Commit”

FLUSH USER _RESOURCES
Section 13.7.6.3, “FLUSH Statement”
Section 6.2.12, “Setting Account Resource Limits”

G

[link top]

GRANT
Section 6.2, “Access Control and Account Management”
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 6.2.1, “Account User Names and Passwords”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 6.2.9, “Assigning Account Passwords”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.11.3, “Connecting Using the IPv6 Local Host Address”
Section 13.7.1.1, “CREATE USER Statement”
Section 17.1.3.3, “Creating a User for Replication”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Implementing Proxy User Support in Authentication Plugins
Section 12.15, “Information Functions”
Section 5.1.11, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.14, “MySQL 5.5 FAQ: Replication”
MySQL Glossary
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 8.2.5, “Optimizing Database Privileges”
Section 6.4.1.4, “PAM Pluggable Authentication”

3625
GRANT ALL
Section 13.7.1.3, "GRANT Statement"

GRANT EVENT
Section 20.4.6, "The Event Scheduler and MySQL Privileges"

GRANT USAGE
Section 6.2.9, "Assigning Account Passwords"
Section 13.7.1.3, "GRANT Statement"
Section 6.2.12, "Setting Account Resource Limits"

H
[index top]

HANDLER
Section 23.7.19, "C API Automatic Reconnection Control"
Section 15.9.3, "FEDERATED Storage Engine Notes and Tips"
Section 13.7.6.3, "FLUSH Statement"
Section A.4, "MySQL 5.5 FAQ: Stored Procedures and Functions"
Section 1.7, "MySQL Standards Compliance"
Section 23.7.6.3, "mysql_change_user()"
Section 19.5, "Restrictions and Limitations on Partitioning"
Section 5.1.7, "Server System Variables"

HANDLER ... CLOSE
Section 13.7.5.25, "SHOW OPEN TABLES Statement"
HANDLER ... OPEN
Section 13.7.5.25, “SHOW OPEN TABLES Statement”

HANDLER ... READ
Section 20.8, “Restrictions on Stored Programs”

HANDLER OPEN
Section 13.2.4, “HANDLER Statement”
Section 13.1.33, “TRUNCATE TABLE Statement”

HELP
Section 13.8.3, “HELP Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 5.1.13, “Server-Side Help Support”

IF
Section 12.4, “Control Flow Functions”
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.2, “IF Statement”

INSERT
Section 6.2, “Access Control and Account Management”
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 7.1, “Backup and Recovery Types”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 14.8.2, “Change Buffer”
Section 2.11.3, “Changes in MySQL 5.5”
Section 10.7, “Column Character Set Conversion”
Section 8.11.3, “Concurrent Inserts”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.13, “CREATE INDEX Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 18.5.16, “NDB API Statistics Counters and Variables”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 8.2.4, “Optimizing Data Change Statements”
Section 8.2.4.1, “Optimizing INSERT Statements”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 11.1.7, “Out-of-Range and Overflow Handling”
Section 19.4, “Partition Pruning”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 11.4.5, “Populating Spatial Columns”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 6.2.2, “Privileges Provided by MySQL”
Section 14.11.9, “Purge Configuration”
Section 8.14.4, “Query Cache Thread States”
Section 19.2.1, “RANGE Partitioning”
Section 13.2.8, “REPLACE Statement”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.29, “Replication and Server SQL Mode”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.37, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.2.3.3, “Replication Rule Application”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 20.8, “Restrictions on Stored Programs”
Section 5.8.1.7, “Row-Level Probes”
Section 5.4.1.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section B.3.1, “Server Error Message Reference”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 13.7.5.28, “SHOW PROCEDURE CODE Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”
Section 17.4.1.28, “Slave Errors During Replication”
Section 5.8.1.12, “Statement Probes”
Section 20.7, “Stored Program Binary Logging”
Section 13.2.10, “Subqueries”
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 10.8.5, “The binary Collation Compared to _bin Collations”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.8, “The MERGE Storage Engine”
Section 15.3, “The MyISAM Storage Engine”
Section 8.10.3, “The MySQL Query Cache”
Section 5.1.14, “The Server Shutdown Process”
Section 20.3.1, “Trigger Syntax and Examples”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 14.9.7, “Undo Logs”
Section 20.5.3, “Updatable and Insertable Views”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”
Section 20.3, “Using Triggers”
Section 23.7.20.2, “What Results You Can Get from a Query”
Section 6.2.8, “When Privilege Changes Take Effect”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”

**INSERT ... ()**
Section 5.8.1.12, “Statement Probes”

**INSERT ... ON DUPLICATE KEY UPDATE**
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 17.1.2.3, “ Determination of Safe and Unsafe Statements in Binary Logging”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 12.15, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 14.10, “MERGE Table Problems”
Section 12.18, “Miscellaneous Functions”
MySQL Glossary
Section 23.7.6.1, “mysql_affected_rows()”
Section 23.7.6.37, “mysql_insert_id()”
Section 19.5.4, “Partitioning and Table-Level Locking”

**INSERT ... SELECT**
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 2.11.3, “Changes in MySQL 5.5”
Section 8.11.3, “Concurrent Inserts”
Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.1, “INSERT ... SELECT Statement”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 8.4.7, “Known Issues in MySQL”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 23.7.6.37, “mysql_insert_id()”
NDB Cluster System Variables
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 17.4.1.16, “Replication and LIMIT”
Section 5.1.7, “Server System Variables”
Section 5.8.1.12, “Statement Probes”
Section 5.4.4, “The Binary Log”

**INSERT ... SELECT ON DUPLICATE KEY UPDATE**
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.1, “INSERT ... SELECT Statement”

**INSERT ... SET**
Section 13.2.5, “INSERT Statement”
INSERT ... VALUES
Section 13.2.5, “INSERT Statement”
Section 23.7.6.35, “mysql_info()”

INSERT DELAYED
Section 13.1.7, “ALTER TABLE Statement”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.14.3, “Delayed-Insert Thread States”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 13.7.6.4, “KILL Statement”
Section B.4.7, “Known Issues in MySQL”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 15.5.2, “MERGE Table Problems”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 24.1.1, “MySQL Threads”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 20.8, “Restrictions on Stored Programs”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.4, “The MEMORY Storage Engine”
Section 20.5.3, “Updatable and Insertable Views”

INSERT IGNORE
Section 2.11.3, “Changes in MySQL 5.5”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”
Section 1.7.3.4, “ENUM and SET Constraints”
Section 12.15, “Information Functions”
Section 13.2.5, “INSERT Statement”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 5.1.10, “Server SQL Modes”

INSERT IGNORE ... SELECT
Section 13.2.5.1, “INSERT ... SELECT Statement”

INSERT INTO ... SELECT
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.2.5, “INSERT Statement”
Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 15.4, “The MEMORY Storage Engine”
INSERT INTO ... SELECT ...
Section 23.7.20.2, “What Results You Can Get from a Query”

INSERT INTO ... SELECT FROM memory_table
Section 17.4.1.20, “Replication and MEMORY Tables”

INSERT INTO...SELECT
Section 8.2.1, “Optimizing SELECT Statements”

INSTALL PLUGIN
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 13.7.6.3, “FLUSH Statement”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.4.2.1, “Installing MySQL Enterprise Audit”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 5.5.2, “Obtaining Server Plugin Information”
Section 6.4.1.4, “PAM Pluggable Authentication”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Section 24.2.4.2, “Plugin Data Structures”
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.6, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 5.1.7, “Server System Variables”
Section 13.7.5.26, “SHOW PLUGINS Statement”
Section 6.4.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.4.1.7, “Test Pluggable Authentication”
Section 21.14, “The INFORMATION_SCHEMA PLUGINS Table”
Section 24.2, “The MySQL Plugin API”
Section 13.7.3.4, “UNINSTALL PLUGIN Statement”
Section 6.4.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

ITERATE
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Statement”
Section 13.6.2, “Statement Labels”

K

[index top]
KILL
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Statement”
Section 13.7.6.4, “KILL Statement”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section B.4.2.9, “MySQL server has gone away”
Section 23.7.6.38, “mysql_kill()”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”

KILL CONNECTION
Section 13.7.6.4, “KILL Statement”
Section 13.4.2.6, “STOP SLAVE Statement”
Section 5.1.14, “The Server Shutdown Process”

KILL QUERY
Section 13.7.6.4, “KILL Statement”
Section 12.18, “Miscellaneous Functions”
Section 13.4.2.6, “STOP SLAVE Statement”
Section 5.1.14, “The Server Shutdown Process”

LEAVE
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.4, “LEAVE Statement”
Section 13.6.5.5, “LOOP Statement”
Section 20.8, “Restrictions on Stored Programs”
Section 13.6.5.7, “RETURN Statement”
Section 13.6.2, “Statement Labels”

LOAD DATA
Section 6.4.2.3, “Audit Log File Formats”
Section 6.4.2.8, “Audit Log Restrictions”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.11.3, “Concurrent Inserts”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 7.2, “Database Backup Methods”
Section 10.3.3, “Database Character Set and Collation”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section B.4.3.4, “How MySQL Handles a Full Disk”
Section 12.15, “Information Functions”
Section B.4.7, “Known Issues in MySQL”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
LOAD DATA ... REPLACE
Section 13.2.8, “REPLACE Statement”

LOAD DATA LOCAL
Section 23.7.5, “C API Function Overview”
LOAD INDEX INTO CACHE
Section 13.7.6.2, “CACHE INDEX Statement”
Section 8.10.2.4, “Index Preloading”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Statement”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 1.4, “What Is New in MySQL 5.5”

LOAD INDEX INTO CACHE ... IGNORE LEAVES
Section 13.7.6.5, “LOAD INDEX INTO CACHE Statement”

LOAD XML
Section 13.2.7, “LOAD XML Statement”
Section 1.4, “What Is New in MySQL 5.5”

LOAD XML LOCAL
Section 13.2.7, “LOAD XML Statement”

LOCK TABLE
Section 8.11.3, “Concurrent Inserts”
Section 8.14.2, “General Thread States”
Section B.4.6.1, “Problems with ALTER TABLE”

LOCK TABLES
Section 14.1.2, “Best Practices for InnoDB Tables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 13.1.10, “CREATE DATABASE Statement”
Section 13.1.17.4, “CREATE TABLE ... LIKE Statement”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 14.10.5.2, “Deadlock Detection and Rollback”
Section 14.10.5, “Deadlocks in InnoDB”
Section 13.7.6.3, “FLUSH Statement”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Statement”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 8.11.1, “Internal Locking Methods”
Section 18.1.7.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 15.8.2, “MERGE Table Problems”
Section 8.11.4, “Metadata Locking”
Section 4.6.3.1, “myisamchk General Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Server Options for NDB Cluster
Section 4.5.3, “mysqldump — A Database Backup Program”
Section 18.5.12.3, “NDB Cluster Disk Data Storage Requirements”
Section 18.5.13, “Online Operations with ALTER TABLE in NDB Cluster”
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.2.4.2, “Optimizing UPDATE Statements”
Section 8.2.6, “Other Optimization Tips”
Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 15.3.3.1, “Static (Fixed-Length) Table Characteristics”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.1.14, “The Server Shutdown Process”
Section 5.4.5, “The Slow Query Log”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

P

[INDEX TOP]

PREPARE
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 23.7.17, “C API Prepared CALL Statement Support”
Section 13.2.1, “CALL Statement”
Section 13.5.3, “DEALLOCATE PREPARE Statement”
Section 13.5.2, “EXECUTE Statement”
Section 9.2.3, “Identifier Case Sensitivity”
Section 8.11.4, “Metadata Locking”
Section 13.5.1, “PREPARE Statement”
Section 13.5, “Prepared Statements”
Section 20.8, “Restrictions on Stored Programs”
Section 20.9, “Restrictions on Views”
Section 5.1.9, “Server Status Variables”

PURGE BINARY LOGS
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.1.3, “GRANT Statement”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.4.1.1, “PURGE BINARY LOGS Statement”
Section 13.4.1.2, “RESET MASTER Statement”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.7, “Server System Variables”
Section 5.4.4, “The Binary Log”
RELEASE SAVEPOINT
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements”

RENAME TABLE
Section 13.1.7, “ALTER TABLE Statement”
Section 13.2.2, “DELETE Statement”
Section 8.14.2, “General Thread States”
Section 9.2.3, “Identifier Case Sensitivity”
Section 8.11.4, “Metadata Locking”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 13.1.32, “RENAME TABLE Statement”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

RENAME USER
Section 13.7.1.3, “GRANT Statement”
Section 12.15, “Information Functions”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Statement”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.2.8, “When Privilege Changes Take Effect”

REPAIR TABLE
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Statement”
Section 2.11.3, “Changes in MySQL 5.5”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 8.11.5, “External Locking”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 8.14.2, “General Thread States”
Section 16.1.3, “Handling MySQL Recovery with ZFS”
Section 8.4.3.4, “How MySQL Handles a Full Disk”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 13.7.6.4, “KILL Statement”
Section B.4.7, “Known Issues in MySQL”
Section 13.2.6, “LOAD DATA Statement”
Section 19.3.3, “Maintenance of Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 15.3.1, “MyISAM Startup Options”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”
Section 13.2.10, “Subqueries”
Section 15.6, “The ARCHIVE Storage Engine”
Section 1.3.2, “The Main Features of MySQL”

REPLACE ... SELECT
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section B.4.7, “Known Issues in MySQL”

RESET
Section 13.7.6.3, “FLUSH Statement”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 13.7.6.6, “RESET Statement”

RESET MASTER
Section 13.7.6.3, “FLUSH Statement”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 23.7.6.55, “mysql_refresh()”
Section 13.4.1.2, “RESET MASTER Statement”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 17.3.6, “Switching Masters During Failover”
Section 5.4.4, “The Binary Log”

RESET QUERY CACHE
Section 8.14.4, “Query Cache Thread States”

RESET SLAVE
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 13.7.6.3, “FLUSH Statement”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 23.7.6.55, “mysql_refresh()”
Section 13.4.1.2, “RESET MASTER Statement”
Section 13.4.2.3, “RESET SLAVE Statement”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”

RESET SLAVE ALL
Section 13.4.2.1, “CHANGE MASTER TO Statement”

RE SIGNAL
Section 13.6.7, “Condition Handling”
Section 13.6.7.5, “Condition Handling and OUT or INOUT Parameters”
Section 13.6.7.1, “DECLARE ... CONDITION Statement”
Section 13.6.7.2, “DECLARE ... HANDLER Statement”
Section 13.6.7.3, “RE SIGNAL Statement”
Section 13.6.7.6, “Restrictions on Condition Handling”
Section 20.8, “Restrictions on Stored Programs”
Section 13.6.7.4, “SIGNAL Statement”
Section 1.4, “What Is New in MySQL 5.5”

RETURN
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.5, “LOOP Statement”
Section 20.8, “Restrictions on Stored Programs”
Section 13.6.5.7, “RETURN Statement”
Section 13.6.7.4, “SIGNAL Statement”

REVOKE
Section 6.2, “Access Control and Account Management”
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 6.2.1, “Account User Names and Passwords”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 12.15, “Information Functions”
Section 5.1.11, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 1.7.2, “MySQL Differences from Standard SQL”
MySQL Glossary
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.2.2, “Privileges Provided by MySQL”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 6.2.11, “Proxy Users”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.21, “Replication of the mysql System Database”
Section 13.7.1.5, “REVOKE Statement”
Section 6.1.1, “Security Guidelines”
Section 5.1.7, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.2.8, “When Privilege Changes Take Effect”

REVOKE ALL PRIVILEGES
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”

ROLLBACK
Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 14.10.5.2, “Deadlock Detection and Rollback”
Section 12.15, “Information Functions”
Section 14.5, “InnoDB and the ACID Model”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 23.7.6.3, “mysql_change_user()”
Section 17.4.1.34, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section B.4.4.5, “Rollback Failure for Nontransactional Tables”
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements”
Section 5.1.7, “Server System Variables”
ROLLBACK TO SAVEPOINT
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements”

ROLLBACK to SAVEPOINT
Section 20.3.1, “Trigger Syntax and Examples”

SAVEPOINT
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Statements”

SELECT
Section 6.2, “Access Control and Account Management”
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 13.1.7, “ALTER TABLE Statement”
Section 13.1.9, “ALTER VIEW Statement”
Section 13.3.4, “Assignment Operators”
Section 6.4.2.3, “Audit Log File Formats”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 23.7.15, “C API Multiple Statement Execution Support”
Section 23.7.17, “C API Prepared CALL Statement Support”
Section 23.7.9, “C API Prepared Statement Function Overview”
Section 2.11.3, “Changes in MySQL 5.5”
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.11.3, “Concurrent Inserts”
Section 10.4, “Connection Character Sets and Collations”
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.13, “CREATE INDEX Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.17.5, “CREATE TABLE ... SELECT Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 3.3.1, “Creating and Selecting a Database”
Section 13.6.6.2, “Cursor DECLARE Statement”
Section 13.6.6.3, “Cursor FETCH Statement”
Section 14.10.5.2, “Deadlock Detection and Rollback”
Section 13.2.2, “DELETE Statement”
Section 13.2.10.8, “Derived Tables”
Section 8.4.3.2, “Disadvantages of Creating Many Tables in the Same Database”
Section 13.2.3, “DO Statement”
Section 3.2, “Entering Queries”
Section 20.4.2, “Event Scheduler Configuration”
Section 10.8.6, “Examples of the Effect of Collation”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Statement”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 8.2.1.14, “Function Call Optimization”
Chapter 12, Functions and Operators
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Statement”
Section 13.2.4, “HANDLER Statement”
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 8.10.3.1, “How the Query Cache Operates”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 1.6, “How to Report Bugs or Problems”
Section 8.9.3, “Index Hints”
Section 12.15, “Information Functions”
Section 2.10.1, “Initializing the Data Directory”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 13.2.5.1, “INSERT ... SELECT Statement”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 13.2.5, “INSERT Statement”
Section 8.11.1, “Internal Locking Methods”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 21.1, “Introduction”
Section 13.2.9.2, “JOIN Clause”
Section 9.3, “Keywords and Reserved Words”
Section 13.7.6.4, “KILL Statement”
Section B.4.7, “Known Issues in MySQL”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.2.7, “LOAD XML Statement”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 14.10.2.4, “Locking Reads”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 8.3.5, “Multiple-Column Indexes”
Section 7.6.4, “MyISAM Table Optimization”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 17.4.1.15, “Replication of Invoked Features”
Section 20.8, “Restrictions on Stored Programs”
Section 3.3.4, “Retrieving Information from a Table”
Section 3.6.7, “Searching on Two Keys”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 13.2.9.1, “SELECT … INTO Statement”
Section 13.2.9, “SELECT Statement”
Section 3.3.4.1, “Selecting All Data”
Section 3.3.4.2, “Selecting Particular Rows”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.3, “SHOW BINLOG EVENTS Statement”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Statement”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 13.7.5.18, “SHOW ERRORS Statement”
Section 13.7.5.28, “SHOW PROCEDURE CODE Statement”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 13.7.5.33, “SHOW RELAYLOG EVENTS Statement”
Section 13.7.5, “SHOW Statements”
Section 13.7.5.40, “SHOW VARIABLES Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”
Section B.4.4.7, “Solving Problems with No Matching Rows”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 5.8.1.12, “Statement Probes”
Section 20.7, “Stored Program Binary Logging”
Section 20.2.1, “Stored Routine Syntax”
Section 9.1.1, “String Literals”
Section 13.2.10, “Subqueries”
Section 13.2.10.6, “Subqueries with EXISTS or NOT EXISTS”
Section 13.2.10.9, “Subquery Errors”
Section 8.2.2, “Subquery Optimization”
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.4.4, “The Binary Log”
Section 11.3.5, “The ENUM Type”
Section 21.5, “The INFORMATION_SCHEMA COLUMNS Table”
Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”
Section 21.10, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”
Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 13.2.10.1, “The Subquery as Scalar Operand”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 20.3.1, “Trigger Syntax and Examples”
Section 12.2, “Type Conversion in Expression Evaluation”
Section 1.2, “Typographical and Syntax Conventions”
Section 13.2.9.3, “UNION Clause”
Section 13.2.11, “UPDATE Statement”
Section 9.4, “User-Defined Variables”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”
Section 4.2.2.1, “Using Options on the Command Line”
Section 8.4.2.4, “Using PROCEDURE ANALYSE”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 11.4.9, “Using Spatial Indexes”
Section 10.2.2, “UTF-8 for Metadata”
Section 20.5.1, “View Syntax”
Section 8.2.1.1, “WHERE Clause Optimization”
Section B.4.3.5, “Where MySQL Stores Temporary Files”
Section 24.2.4.8, “Writing Audit Plugins”

**SELECT ***
Section 11.3.4, “The BLOB and TEXT Types”

**SELECT * INTO OUTFILE 'file_name' FROM tbl_name**
Section 7.2, “Database Backup Methods”

**SELECT ... FOR UPDATE**
Section 14.10.5, “Deadlocks in InnoDB”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 14.10.1, “InnoDB Locking”
Section 14.10.2.4, “Locking Reads”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”

**SELECT ... FROM**
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”

**SELECT ... INTO**
Section 13.1.11, “CREATE EVENT Statement”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section 17.4.1.14, “Replication and System Functions”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 13.2.9, “SELECT Statement”

**SELECT ... INTO DUMPFILE**
Section 2.10.1, “Initializing the Data Directory”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.7, “Server System Variables”

**SELECT ... INTO OUTFILE**
Section 7.1, “Backup and Recovery Types”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 13.2.6, “LOAD DATA Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 9.1.7, “NULL Values”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 1.2, “Typographical and Syntax Conventions”
Section 2.3.9, “Windows Platform Restrictions”

SELECT ... INTO OUTFILE 'file_name'
Section 13.2.9.1, “SELECT ... INTO Statement”

SELECT ... INTO var_list
Section 20.8, “Restrictions on Stored Programs”
Section 13.6.4, “Variables in Stored Programs”

SELECT ... LOCK IN SHARE MODE
Section 14.10.1, “InnoDB Locking”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.10.2.4, “Locking Reads”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 14.10.2.1, “Transaction Isolation Levels”

SELECT DISTINCT
Section 8.14.2, “General Thread States”
Section 13.2.10.12, “Restrictions on Subqueries”

SET
Section 12.3.4, “Assignment Operators”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 10.4, “Connection Character Sets and Collations”
Section 20.1, “Defining Stored Programs”
Section 20.4.2, “Event Scheduler Configuration”
Section 12.1, “Function and Operator Reference”
Chapter 12, Functions and Operators
Section 12.15, “Information Functions”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.5.1.6, “mysql Client Tips”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 12.3, “Operators”
Section 8.10.3.3, “Query Cache Configuration”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.6, “Server Command Options”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 13.7.4, “SET Statements”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.40, “SHOW VARIABLES Statement”
Section 20.7, “Stored Program Binary Logging”
Section 13.2.10, “Subqueries”
Section 5.1.8.1, “System Variable Privileges”
Section 5.4.5, “The Slow Query Log”
Section 20.3.1, “Trigger Syntax and Examples”
Section 9.4, “User-Defined Variables”
Section 4.2.2.1, “Using Options on the Command Line”
SET autocommit
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 13.3, “Transactional and Locking Statements”

SET autocommit = 0
Section 17.3.8, “Semisynchronous Replication”

SET CHARACTER SET
Section 10.4, “Connection Character Sets and Collations”
Section 23.7.53, “mysql_real_escape_string()”
Section 13.7.4.2, “SET CHARACTER SET Statement”
Section 13.7.4, “SET Statements”
Section 10.9, “Unicode Support”

SET CHARACTER SET 'charset_name'
Section 10.4, “Connection Character Sets and Collations”

SET CHARACTER SET charset_name
Section 10.4, “Connection Character Sets and Collations”

SET GLOBAL
Section 14.8.2, “Change Buffer”
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
Section 14.11.7, “Configuring InnoDB I/O Capacity”
Section 14.11.8, “Configuring Spin Lock Polling”
Section 14.9.3.2, “File-Per-Table Tablespaces”
Section 13.7.1.3, “GRANT Statement”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”
Section 8.10.2.2, “Multiple Key Caches”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”

SET GLOBAL sql_slave_skip_counter
Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Statement”

SET NAMES
Section 23.7.19, “C API Automatic Reconnection Control”
Section 10.3.6, “Character String Literal Character Set and Collation”
Section 10.5, “Configuring Application Character Set and Collation”
Section 10.4, “Connection Character Sets and Collations”
Section 10.6, “Error Message Character Set”
Section 13.2.6, “LOAD DATA Statement”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 4.5.1.2, “mysql Client Commands”
Section 23.7.6.53, “mysql_real_escape_string()”
Section 23.7.6.61, “mysql_set_character_set()”
SET NAMES 'charset_name'
Section 10.4, “Connection Character Sets and Collations”

SET NAMES 'cp1251'
Section 10.4, “Connection Character Sets and Collations”

SET NAMES charset_name
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

SET NAMES default_character_set
Section 4.5.4, “mysqldump — A Database Backup Program”

SET PASSWORD
Section 6.2.9, “Assigning Account Passwords”
Section 8.4.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Statement”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 12.15, “Information Functions”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 17.4.1.37, “Replication and Variables”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Resetting the Root Password: Generic Instructions
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 17.4.1.26, “SET PASSWORD and Row-Based Replication”
Section 13.7.1.6, “SET PASSWORD Statement”
Section 13.7.4, “SET Statements”
Section 6.2.4, “Specifying Account Names”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 6.2.8, “When Privilege Changes Take Effect”

SET PASSWORD ... = PASSWORD()
Section 6.2.9, “Assigning Account Passwords”

SET SESSION
Section 5.1.8.1, “System Variable Privileges”

SET sql_log_bin = 0
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

SET sql_log_bin=OFF
Section 5.4.4, “The Binary Log”
SET sql_mode='modes'
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”

SET TIMESTAMP = value
Section 8.14, “Examining Thread Information”

SET TRANSACTION
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 14.10.2.1, “Transaction Isolation Levels”

SET TRANSACTION ISOLATION LEVEL
Section 13.7.4, “SET Statements”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”

SET var_name = value
Section 13.7.4, “SET Statements”

SHOW
Section 23.7.4, “C API Data Structures”
Section 23.7.5, “C API Function Overview”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 3.3, “Creating and Using a Database”
Section 13.6.6.2, “Cursor DECLARE Statement”
Section 21.32, “Extensions to SHOW Statements”
Section 21.1, “Introduction”
Section 9.2.4, “Mapping of Identifiers to File Names”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.7.10.28, “mysql_stmt_store_result()”
Section 23.7.6.69, “mysql_store_result()”
Section 23.7.6.71, “mysql_use_result()”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 22.1, “Performance Schema Quick Start”
Section 20.8, “Restrictions on Stored Programs”
Section 13.7.5.6, “SHOW COLUMNS Statement”
Section 13.7.5, “SHOW Statements”
Section 13.7.5.38, “SHOW TABLES Statement”
Section 13.4.1, “SQL Statements for Controlling Master Servers”
Section 5.4.4, “The Binary Log”
Section 1.3.2, “The Main Features of MySQL”
Section 10.2.2, “UTF-8 for Metadata”

SHOW AUTHORS
Section 13.7.5.1, “SHOW AUTHORS Statement”

SHOW BINARY LOGS
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.4.1.1, “PURGE BINARY LOGS Statement”
Section 13.7.5.2, “SHOW BINARY LOGS Statement”
SHOW BINLOG EVENTS
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 13.6.6.5, “Restrictions on Server-Side Cursors”
Section 13.7.5.3, “SHOW BINLOG EVENTS Statement”
Section 13.4.1, “SQL Statements for Controlling Master Servers”
Section 13.4.2.5, “START SLAVE Statement”

SHOW CHARACTER SET
Section 10.3.8, “Character Set Introducers”
Section 10.2, “Character Sets and Collations in MySQL”
Section 10.3.6, “Character String Literal Character Set and Collation”
Section 10.3.5, “Column Character Set and Collation”
Section 10.3.3, “Database Character Set and Collation”
Section 21.32, “Extensions to SHOW Statements”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 13.7.5.4, “SHOW CHARACTER SET Statement”
Section 10.10, “Supported Character Sets and Collations”
Section 10.3.4, “Table Character Set and Collation”
Section 21.2, “The INFORMATION_SCHEMA CHARACTER_SETS Table”

SHOW COLLATION
Section 10.15, “Character Set Configuration”
Section 10.14.2, “Choosing a Collation ID”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 13.7.5.5, “SHOW COLLATION Statement”
Section 21.4, “The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table”
Section 21.3, “The INFORMATION_SCHEMA COLLATIONS Table”

SHOW COLUMNS
Section 13.8.2, “EXPLAIN Statement”
Section 21.32, “Extensions to SHOW Statements”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 22.1, “Performance Schema Quick Start”
Section 13.7.5.6, “SHOW COLUMNS Statement”
Section 21.5, “The INFORMATION_SCHEMA COLUMNS Table”
Section 21.29.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”
Section 21.29.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”
Section 21.29.3, “The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table”
Section 21.29.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 21.29.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 21.29.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.29.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”

SHOW COLUMNS FROM tbl_name LIKE 'enum_col'
Section 11.3.5, “The ENUM Type”
SHOW CONTRIBUTORS
Section 13.7.5.7, “SHOW CONTRIBUTORS Statement”

SHOW COUNT()
Section 13.7.5.18, “SHOW ERRORS Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”

SHOW CREATE DATABASE
Section 5.1.7, “Server System Variables”
Section 13.7.5.8, “SHOW CREATE DATABASE Statement”

SHOW CREATE EVENT
Section 20.4.4, “Event Metadata”
Section 13.7.5.19, “SHOW EVENTS Statement”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

SHOW CREATE FUNCTION
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 1.6, “How to Report Bugs or Problems”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Statement”
Section 20.2.3, “Stored Routine Metadata”

SHOW CREATE PROCEDURE
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 1.6, “How to Report Bugs or Problems”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.10, “SHOW CREATE FUNCTION Statement”
Section 20.2.3, “Stored Routine Metadata”

SHOW CREATE SCHEMA
Section 13.7.5.8, “SHOW CREATE DATABASE Statement”

SHOW CREATE TABLE
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Statement”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 11.5, “Data Type Default Values”
Section 13.8.2, “EXPLAIN Statement”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 3.4, “Getting Information About Databases and Tables”
Section 15.9.2, “How to Create FEDERATED Tables”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 19.2.5, “KEY Partitioning”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.1.7.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 19.3.4, “Obtaining Information About Partitions”
Section 22.1, “Performance Schema Quick Start”
Section 2.11.7, “Rebuilding or Repairing Tables or Indexes”
SHOW CREATE TRIGGER
Section 13.7.5.13, “SHOW CREATE TRIGGER Statement”
Section 20.3.2, “Trigger Metadata”

SHOW CREATE VIEW
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 20.9, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.5, “View Metadata”

SHOW DATABASES
Section 13.1.10, “CREATE DATABASE Statement”
Section 3.3, “Creating and Using a Database”
Section 21.32, “Extensions to SHOW Statements”
Section 3.4, “Getting Information About Databases and Tables”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 9.2.3, “Identifier Case Sensitivity”
Section 21.1, “Introduction”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 22.2, “Performance Schema Build Configuration”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.7.5.15, “SHOW DATABASES Statement”
Section 21.19, “The INFORMATION_SCHEMA SCHEMATA Table”

SHOW ENGINE
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.5.16, “SHOW ENGINE Statement”

SHOW ENGINE INNODB MUTEX
Section 13.7.5.16, “SHOW ENGINE Statement”
Section 1.4, “What Is New in MySQL 5.5”

SHOW ENGINE INNODB STATUS
Section 14.8.3, “Adaptive Hash Index”
Section 14.8.1, “Buffer Pool”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 14.10.5, “Deadlocks in InnoDB”
Section 14.20.2, “Enabling InnoDB Monitors”
Section B.2, “Error Information Interfaces”
SHOW ENGINE NDB STATUS
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.5, “Management of NDB Cluster”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 13.7.5.16, “SHOW ENGINE Statement”

SHOW ENGINE NDBCLUSTER STATUS
MySQL Server Options for NDB Cluster
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”

SHOW ENGINE PERFORMANCE_SCHEMA STATUS
Section 22.7, “Performance Schema Status Monitoring”
Section 13.7.5.16, “SHOW ENGINE Statement”

SHOW ENGINES
Chapter 15, Alternative Storage Engines
Section 14.1.3, “Checking InnoDB Availability”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
NDB Cluster System Variables
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 22.2, “Performance Schema Build Configuration”
Section 22.1, “Performance Schema Quick Start”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 2.3.6.3, “Selecting a MySQL Server Type”
Section 5.1.7, “Server System Variables”
Section 13.7.5.17, “SHOW ENGINES Statement”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.7, “The INFORMATION_SCHEMA ENGINES Table”
Section 1.4, “What Is New in MySQL 5.5”

SHOW ERRORS
Section B.2, “Error Information Interfaces”
Section 13.6.7.3, “RESIGNAL Statement”
Section 5.1.7, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”
Section 13.6.7.4, “SIGNAL Statement”
SHOW EVENTS
Section 20.4.4, “Event Metadata”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.7.5.19, “SHOW EVENTS Statement”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.8, “The INFORMATION_SCHEMA EVENTS Table”

SHOW FULL COLUMNS
Section 13.1.17, “CREATE TABLE Statement”
Section 21.6, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”

SHOW FULL PROCESSLIST
Section 8.14, “Examining Thread Information”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

SHOW FULL TABLES
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

SHOW FUNCTION CODE
Section 13.7.5.28, “SHOW PROCEDURE CODE Statement”

SHOW FUNCTION STATUS
Section 13.7.5.29, “SHOW PROCEDURE STATUS Statement”
Section 20.2.3, “Stored Routine Metadata”

SHOW GLOBAL STATUS
NDB Cluster Status Variables
Section 5.1.7, “Server System Variables”
Section 21.9, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

SHOW GLOBAL VARIABLES
Section 21.10, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

SHOW GRANTS
Section 6.2, “Access Control and Account Management”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.3, “Grant Tables”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.5, “REVOKE Statement”
Section 6.1.1, “Security Guidelines”
Section 13.7.5.22, “SHOW GRANTS Statement”
Section 13.7.5.27, “SHOW PRIVILEGES Statement”

SHOW INDEX
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Statement”
Section 8.9.3, “Index Hints”
SHOW PRIVILEGES
Section 13.7.5.27, “SHOW PRIVILEGES Statement”

SHOW PROCEDURE CODE
Section 13.7.5.20, “SHOW FUNCTION CODE Statement”

SHOW PROCEDURE STATUS
Section 13.7.5.21, “SHOW FUNCTION STATUS Statement”
Section 20.2.3, “Stored Routine Metadata”

SHOW PROCESSLIST
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 17.1.4.1, “Checking Replication Status”
Section 5.8.1.2, “Command Probes”
Section 5.8.1.1, “Connection Probes”
Section 20.4.2, “Event Scheduler Configuration”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Statement”
Section 8.12.5.1, “How MySQL Handles Client Connections”
Section 12.15, “Information Functions”
Section 14.23.4, “InnoDB Error Handling”
Section 13.7.6.4, “KILL Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 23.7.6.43, “mysql_list_processes()”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 6.2.2, “Privileges Provided by MySQL”
Section 5.8.1.6, “Query Execution Probes”
Section 5.8.1.3, "Query Probes"
Section 17.2.1, “Replication Implementation Details”
Section 13.7.5.30, “SHOW PROCESSLIST Statement”
Section 13.7.5.31, “SHOW PROFILE Statement”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 17.3.6, “Switching Masters During Failover”
Section 21.30.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”
Section 21.15, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”
Section 22.10.6.2, “The threads Table”
Section B.4.2.7, “Too many connections”
Section 17.4.4, “Troubleshooting Replication”

SHOW PROFILE
Section 8.14, “Examining Thread Information”
Section 8.14.2, “General Thread States”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 5.1.7, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Statement”
Section 13.7.5.32, “SHOW PROFILES Statement”
Section 21.16, “The INFORMATION_SCHEMA PROFILING Table”
SHOW TABLE STATUS
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 14.9.1.1, “Creating InnoDB Tables”
Section 13.8.2, “EXPLAIN Statement”
Section 14.15.2, “File Space Management”
Section 14.25, “InnoDB Restrictions and Limitations”
Section 14.14, “InnoDB Row Formats”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 19.3.4, “Obtaining Information About Partitions”
Section 13.7.5.6, “SHOW COLUMNS Statement”
Section 13.7.5.37, “SHOW TABLE STATUS Statement”
Section 15.6, “The ARCHIVE Storage Engine”
Section 21.22, “The INFORMATION_SCHEMA TABLES Table”

SHOW TABLES
Section 3.3.2, “Creating a Table”
Section 21.32, “Extensions to SHOW Statements”
Section 9.2.3, “Identifier Case Sensitivity”
Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 21.1, “Introduction”
Section 9.2.4, “Mapping of Identifiers to File Names”
MySQL Glossary
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
SHOW TABLES FROM some_ndb_database
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”

SHOW TRIGGERS
Section A.5, “MySQL 5.5 FAQ: Triggers”
Section 13.7.39, “SHOW TRIGGERS Statement”
Section 21.26, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 20.3.2, “Trigger Metadata”

SHOW VARIABLES
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 20.4.2, “Event Scheduler Configuration”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Chapter 19, Partitioning
Section 24.2.2, “Plugin API Characteristics”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 5.7, “Running Multiple MySQL Instances on One Machine”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.6, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 5.1.7, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.40, “SHOW VARIABLES Statement”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 5.1.8, “Using System Variables”
Section 24.2.4, “Writing Plugins”

SHOW WARNINGS
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.7, “ALTER TABLE Statement”
Section 13.6.7, “Condition Handling”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Statements”
Section 13.1.28, “DROP TABLE Statement”
Section B.2, “Error Information Interfaces”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Statement”
Section 13.8.2, “Extended EXPLAIN Output Format”
Section 8.8.3, “Function Name Parsing and Resolution”
Section 13.2.6, “LOAD DATA Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 8.8.1, “Optimizing Queries with EXPLAIN”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 12.19.4, “Rounding Behavior”
Section B.3.1, “Server Error Message Reference”
START TRANSACTION READ ONLY
MySQL Glossary

START TRANSACTION WITH CONSISTENT SNAPSHOT
Section 14.10.2.3, "Consistent Nonlocking Reads"

STOP SLAVE
Section 3.4.2.1, "CHANGE MASTER TO Statement"
Section 17.1.4.1, "Checking Replication Status"
Section 17.1.4.9, "Introducing Additional Slaves to an Existing Replication Environment"
Section 4.5.4, "mysqldump — A Database Backup Program"
Section 17.1.4.2, "Pausing Replication on the Slave"
Section 13.4.1.2, "RESET MASTER Statement"
Section 13.4.2.3, "RESET SLAVE Statement"
Section 17.3.8.2, "Semisynchronous Replication Installation and Configuration"
Section 13.4.2.5, "START SLAVE Statement"
Section 13.4.2.6, "STOP SLAVE Statement"
Section 17.3.6, "Switching Masters During Failover"
Section 17.1.2.2, "Usage of Row-Based Logging and Replication"

STOP SLAVE SQL_THREAD
Section 17.1.2.2, "Usage of Row-Based Logging and Replication"

T

TRUNCATE TABLE
Section 18.5.14.1, "Adding NDB Cluster Data Nodes Online: General Issues"
Section 2.11.3, "Changes in MySQL 5.5"
Section 18.5.2, "Commands in the NDB Cluster Management Client"
Section 15.3.3.3, "Compressed Table Characteristics"
Section 14.9.1.3, "Converting Tables from MyISAM to InnoDB"
Section 13.1.19, "CREATE TRIGGER Statement"
Section 13.2.2, "DELETE Statement"
Section 22.4.3, "Event Pre-Filtering"
Section 15.9.3, "FEDERATED Storage Engine Notes and Tips"
Section 22.10.5.2, "File I/O Summary Tables"
Section 14.9.3.2, "File-Per-Table Tablespaces"
Section 13.2.4, "HANDLER Statement"
Section 8.10.3.1, "How the Query Cache Operates"
Section 18.1.7.2, "Limits and Differences of NDB Cluster from Standard MySQL Limits"
Section 18.1.7.3, "Limits Relating to Transaction Handling in NDB Cluster"
Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Statements"
Section 5.4.4.4, "Logging Format for Changes to mysql Database Tables"
Section 19.3.3, "Maintenance of Partitions"
Section 19.3.1, "Management of RANGE and LIST Partitions"
Section 15.8.2, "MERGE Table Problems"
MySQL Glossary
Section 4.5.4, "mysqldump — A Database Backup Program"
UNINSTALL PLUGIN

Section 13.7.6.3, “FLUSH Statement”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 4.4.4, "mysql_plugin — Configure MySQL Server Plugins"
Section 6.4.1.4, "PAM Pluggable Authentication"
Section 22.14, “Performance Schema and Plugins”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Server Plugin Library and Plugin Descriptors
Section 13.7.5.26, “SHOW PLUGINS Statement”
Section 6.4.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.4.1.7, “Test Pluggable Authentication”
Section 21.14, “The INFORMATION_SCHEMA PLUGINS Table”
Section 13.7.3.4, “UNINSTALL PLUGIN Statement”
Section 6.4.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

**UNION**
Section 23.7.4, “C API Data Structures”
Section 12.7.3, “Character Set and Collation of Function Results”
Section 13.1.17, “CREATE TABLE Statement”
Section 13.1.20, “CREATE VIEW Statement”
Section 8.8.2, “EXPLAIN Output Format”
Section 12.15, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Statement”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 11.1.6, “Numeric Type Attributes”
Section 8.2.1.2, “Range Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 13.2.9, “SELECT Statement”
Section 5.1.9, “Server Status Variables”
Section 13.2.10, “Subqueries”
Section 15.8, “The MERGE Storage Engine”
Section 13.2.9.3, “UNION Clause”
Section 20.5.3, “Updatable and Insertable Views”
Section 8.4.2.4, “Using PROCEDURE ANALYSE”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”
Section 12.11, “XML Functions”

**UNION ALL**
Section 12.15, “Information Functions”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 13.2.9.3, “UNION Clause”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”

**UNION DISTINCT**
Section 13.2.9.3, “UNION Clause”

**UNLOCK TABLES**
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 13.7.6.3, “FLUSH Statement”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 20.8, “Restrictions on Stored Programs”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 8.12.1, “System Factors”

**UPDATE**
Section 6.2, “Access Control and Account Management”
Section 6.2.6, “Access Control, Stage 2: Request Verification”
Section 6.2.7, “Adding Accounts, Assigning Privileges, and Dropping Accounts”
Section 20.5.3, “Updatable and Insertable Views”
Section 1.7.2.2, “UPDATE Differences”
Section 13.2.11, “UPDATE Statement”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 23.7.20.2, “What Results You Can Get from a Query”
Section 6.2.8, “When Privilege Changes Take Effect”
Section 8.2.1.1, “WHERE Clause Optimization”
Section 23.7.20.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”

**UPDATE ... ()**
Section 14.10.2.3, “Consistent Nonlocking Reads”

**UPDATE ... WHERE**
Section 14.10.5, “Deadlocks in InnoDB”

**UPDATE ... WHERE ...**
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”

**UPDATE IGNORE**
Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 5.1.10, “Server SQL Modes”
Section 13.2.11, “UPDATE Statement”

**UPDATE t1,t2 ...**
Section 5.8.1.12, “Statement Probes”

**USE**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 3.3.1, “Creating and Selecting a Database”
Section 3.3, “Creating and Using a Database”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 21.1, “Introduction”
Section 4.5.1.1, “mysql Client Options”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “myisqldump — A Database Backup Program”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 20.2.1, “Stored Routine Syntax”
Section 13.8.4, “USE Statement”

**USE db2**
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

**USE db_name**
Section 4.5.1.1, “mysql Client Options”
USE test
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"

WHILE
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Statement”
Section 13.6.5.4, “LEAVE Statement”
Section 13.6.2, "Statement Labels"
Section 13.6.5.8, "WHILE Statement"

XA COMMIT
Section 2.12.4, “Downgrading MySQL Binary and Package Installations on Unix/Linux”
Section 5.1.7, "Server System Variables"
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”
Section 13.3.7.2, “XA Transaction States”

XA END
Section 13.3.7.3, “Restrictions on XA Transactions”
Section 13.3.7.1, “XA Transaction SQL Statements”
Section 13.3.7.2, “XA Transaction States”

XA PREPARE
Section 13.3.7.2, “XA Transaction States”

XA RECOVER
Section 2.12.4, “Downgrading MySQL Binary and Package Installations on Unix/Linux”
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”
Section 13.3.7.1, “XA Transaction SQL Statements”
Section 13.3.7.2, “XA Transaction States”

XA ROLLBACK
Section 2.12.4, “Downgrading MySQL Binary and Package Installations on Unix/Linux”
Section 5.1.7, "Server System Variables"
Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”
Section 13.3.7.2, “XA Transaction States”

XA START
Section 13.3.7.3, “Restrictions on XA Transactions”
Section 13.3.7.1, “XA Transaction SQL Statements”
Section 13.3.7.2, “XA Transaction States”

XA START xid
Section 13.3.7.1, “XA Transaction SQL Statements”
Status Variable Index

A  | B  | C  | D  | F  | H  | I  | K  | L  | M  | N  | O  | P  | Q  | R  | S  | T  | U

A

[index top]

**Aborted_clients**
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section 5.1.9, “Server Status Variables”

**Aborted_connects**
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section 5.1.9, “Server Status Variables”

B

[index top]

**Binlog_cache_disk_use**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.9, “Server Status Variables”
Section 5.4.4, “The Binary Log”

**Binlog_cache_use**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.9, “Server Status Variables”
Section 5.4.4, “The Binary Log”

**Binlog_stmt_cache_disk_use**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.9, “Server Status Variables”

**Binlog_stmt_cache_use**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.9, “Server Status Variables”

**Bytes_received**
Section 5.1.9, “Server Status Variables”

**Bytes_sent**
Section 5.1.9, “Server Status Variables”

C

[index top]

**Com_flush**
Section 5.1.9, “Server Status Variables”
Com_stmt_reprepare
Section 13.5.4, “Automatic Prepared Statement Repreparation”

Compression
Section 5.1.9, “Server Status Variables”

Connections
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Created_tmp_disk_tables
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Created_tmp_files
Section 5.1.9, “Server Status Variables”

Created_tmp_tables
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 13.7.5.36, “SHOW STATUS Statement”

D

[ index top ]

Delayed_errors
Section 5.1.9, “Server Status Variables”

Delayed_insert_threads
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.9, “Server Status Variables”

Delayed_writes
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.9, “Server Status Variables”

F

[ index top ]

Flush_commands
Section 5.1.9, “Server Status Variables”

H

[ index top ]

Handler_commit
Section 5.1.9, “Server Status Variables”
Handler_delete
Section 5.1.9, “Server Status Variables”

Handler_discover
NDB Cluster Status Variables

Handler_prepare
Section 5.1.9, “Server Status Variables”

Handler_read_first
Section 5.1.9, “Server Status Variables”

Handler_read_key
Section 5.1.9, “Server Status Variables”

Handler_read_last
Section 5.1.9, “Server Status Variables”

Handler_read_next
Section 5.1.9, “Server Status Variables”

Handler_read_prev
Section 5.1.9, “Server Status Variables”

Handler_read_rnd
Section 5.1.9, “Server Status Variables”

Handler_read_rnd_next
Section 5.1.9, “Server Status Variables”

Handler_rollback
Section 5.1.9, “Server Status Variables”

Handler_savepoint
Section 5.1.9, “Server Status Variables”

Handler_savepoint_rollback
Section 5.1.9, “Server Status Variables”

Handler_update
Section 5.1.9, “Server Status Variables”

Handler_write
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_bytes_data
Section 5.1.9, “Server Status Variables”
Innodb_buffer_pool_bytes_dirty
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_data
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_dirty
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_flushed
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_free
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_latched
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_misc
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_pages_total
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_read_ahead
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.9, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_buffer_pool_read_ahead_evicted
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.9, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_buffer_pool_read_ahead_rnd
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_read_requests
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_reads
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_wait_free
Section 5.1.9, “Server Status Variables”

Innodb_buffer_pool_write_requests
Section 5.1.9, “Server Status Variables”
Innodb_data_fsyncs
Section 14.17, "InnoDB Startup Options and System Variables"
Section 5.1.9, “Server Status Variables”

Innodb_data_pending_fsyncs
Section 5.1.9, “Server Status Variables”

Innodb_data_pending_reads
Section 5.1.9, “Server Status Variables”

Innodb_data_pending_writes
Section 5.1.9, “Server Status Variables”

Innodb_data_read
Section 5.1.9, “Server Status Variables”

Innodb_data_reads
Section 5.1.9, “Server Status Variables”

Innodb_data_writes
Section 5.1.9, “Server Status Variables”

Innodb_data_written
Section 5.1.9, “Server Status Variables”

Innodb_dblwr_pages_written
Section 5.1.9, “Server Status Variables”

Innodb_dblwr_writes
Section 5.1.9, “Server Status Variables”

Innodb_have_atomic_builtins
Section 5.1.9, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_log_waits
Section 5.1.9, “Server Status Variables”

Innodb_log_write_requests
Section 5.1.9, “Server Status Variables”

Innodb_log_writes
Section 5.1.9, “Server Status Variables”

Innodb_os_log_fsyncs
Section 5.1.9, “Server Status Variables”

Innodb_os_log_pending_fsyncs
Section 5.1.9, “Server Status Variables”
Innodb_os_log_pending_writes
Section 5.1.9, "Server Status Variables"

Innodb_os_log_written
Section 5.1.9, "Server Status Variables"

Innodb_page_size
Section 5.1.9, "Server Status Variables"

Innodb_pages_created
Section 5.1.9, "Server Status Variables"

Innodb_pages_read
Section 5.1.9, "Server Status Variables"

Innodb_pages_written
Section 5.1.9, "Server Status Variables"

Innodb_row_lock_current_waits
Section 5.1.9, "Server Status Variables"

Innodb_row_lock_time
Section 5.1.9, "Server Status Variables"

Innodb_row_lock_time_avg
Section 5.1.9, "Server Status Variables"

Innodb_row_lock_time_max
Section 5.1.9, "Server Status Variables"

Innodb_row_lock_waits
Section 5.1.9, "Server Status Variables"

Innodb_rows_deleted
Section 5.1.9, "Server Status Variables"

Innodb_rows_inserted
Section 5.1.9, "Server Status Variables"

Innodb_rows_read
Section 5.1.9, "Server Status Variables"

Innodb_rows_updated
Section 5.1.9, "Server Status Variables"

Innodb_truncated_status_writes
Section 5.1.9, "Server Status Variables"

K

[index top]
Key_blocks_not_flushed
Section 5.1.9, “Server Status Variables”

Key_blocks_unused
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Key_blocks_used
Section 5.1.9, “Server Status Variables”

Key_read_requests
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Key_reads
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Key_write_requests
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Key_writes
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

L
[index top]

Last_query_cost
Section 5.1.9, “Server Status Variables”

M
[index top]

Max_used_connections
Section 13.7.6.3, “FLUSH Statement”
Section 5.1.9, “Server Status Variables”

N
[index top]

Ndb_api_bytes_received_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_received_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables
**Ndb_api_bytes_received_count_slave**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_bytes_sent_count**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_bytes_sent_count_session**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_bytes_sent_count_slave**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_bytes_count**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_bytes_count_injector**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_data_count**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_data_count_injector**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_nondata_count**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_event_nondata_count_injector**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_pk_op_count**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_pk_op_count_session**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables

**Ndb_api_pk_op_count_slave**  
Section 18.5.16, “NDB API Statistics Counters and Variables”  
NDB Cluster Status Variables
Ndb_api_pruned_scan_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pruned_scan_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pruned_scan_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_table_scan_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables
Ndb_api_table_scan_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_table_scan_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_local_read_row_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_local_read_row_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables
Ndb_api_trans_local_read_row_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_meta_request_count
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_meta_request_count_session
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_meta_request_count_slave
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables
NDB Cluster Status Variables

**Ndb_api_wait_nanos_count**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_api_wait_nanos_count_session**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_api_wait_nanos_count_slave**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_api_wait_scan_result_count**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_api_wait_scan_result_count_session**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_api_wait_scan_result_count_slave**
Section 18.5.16, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

**Ndb_cluster_node_id**
NDB Cluster Status Variables

**Ndb_config_from_host**
NDB Cluster Status Variables

**Ndb_config_from_port**
NDB Cluster Status Variables

**Ndb_conflict_fn_epoch**
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

**Ndb_conflict_fn_epoch_trans**
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster Status Variables

**Ndb_conflict_fn_max**
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

**Ndb_conflict_fn_old**
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

**Ndb_conflict_trans_conflict_commit_count**
NDB Cluster Status Variables
**Ndb_conflict_trans_row_conflict_count**
NDB Cluster Status Variables

**Ndb_conflict_trans_row_reject_count**
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

**Ndb_execute_count**
NDB Cluster Status Variables

**Ndb_number_of_data_nodes**
NDB Cluster Status Variables

**Ndb_pruned_scan_count**
NDB Cluster Status Variables

**Ndb_pushed_queries_defined**
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

**Ndb_pushed_queries_dropped**
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

**Ndb_pushed_queries_executed**
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

**Ndb_pushed_reads**
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

**Ndb_scan_count**
NDB Cluster Status Variables

**Not_flushed_delayed_rows**
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.9, “Server Status Variables”

**O**

[index top]

**Open_files**
Section 5.1.9, “Server Status Variables”

**Open_streams**
Section 5.1.9, “Server Status Variables”
Open_table_definitions
Section 5.1.9, “Server Status Variables”

Open_tables
Section 5.1.9, “Server Status Variables”

Opened_files
Section 5.1.9, “Server Status Variables”

Opened_table_definitions
Section 5.1.9, “Server Status Variables”

Opened_tables
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

P

[link to index top]

Performance_schema_cond_classes_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_cond_instances_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_file_classes_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_file_handles_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_file_instances_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_locker_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_mutex_classes_lost
Section 22.7, “Performance Schema Status Monitoring”
Section 22.13, “Performance Schema Status Variables”

Performance_schema_mutex_instances_lost
Section 22.7, “Performance Schema Status Monitoring”
Section 22.13, “Performance Schema Status Variables”

Performance_schema_rwlock_classes_lost
Section 22.13, “Performance Schema Status Variables”
Performance_schema_rwlock_instances_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_table_handles_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_table_instances_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_thread_classes_lost
Section 22.13, “Performance Schema Status Variables”

Performance_schema_thread_instances_lost
Section 22.13, “Performance Schema Status Variables”
Section 22.12, “Performance Schema System Variables”

Prepared_stmt_count
Section 5.1.9, “Server Status Variables”

Q

Qcache_free_blocks
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.9, “Server Status Variables”

Qcache_free_memory
Section 5.1.9, “Server Status Variables”

Qcache_hits
Section 8.10.3.1, “How the Query Cache Operates”
Section 5.1.9, “Server Status Variables”

Qcache_inserts
Section 5.1.9, “Server Status Variables”

Qcache_lowmem_prunes
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.9, “Server Status Variables”

Qcache_not_cached
Section 5.1.9, “Server Status Variables”

Qcache_queries_in_cache
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.9, “Server Status Variables”
Qcache_total_blocks
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.9, “Server Status Variables”

Queries
Section 5.1.9, “Server Status Variables”

Questions
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 5.1.9, “Server Status Variables”

R

Rpl_semi_sync_master_clients
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_net_avg_wait_time
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_net_wait_time
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_net_waits
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_no_times
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_no_tx
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_status
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_timefunc_failures
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_tx_avg_wait_time
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_tx_wait_time
Section 5.1.9, “Server Status Variables”
Rpl_semi_sync_master�名
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_wait_pos_backtraverse
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_wait_sessions
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_master_yes_tx
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.9, “Server Status Variables”

Rpl_semi_sync_slave_status
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.9, “Server Status Variables”

Rpl_status
Section 5.1.9, “Server Status Variables”

S

[ index top ]

Select_full_join
Section 5.1.9, “Server Status Variables”

Select_full_range_join
Section 5.1.9, “Server Status Variables”

Select_range
Section 5.1.9, “Server Status Variables”

Select_range_check
Section 5.1.9, “Server Status Variables”

Select_scan
Section 5.1.9, “Server Status Variables”

Slave_heartbeat_period
Section 5.1.9, “Server Status Variables”

Slave_last_heartbeat
Section 17.1.4.1, “Checking Replication Status”

Slave_open_temp_tables
Section 17.4.1.30, “Replication and Temporary Tables”
Slave_received_heartbeats
Section 5.1.9, “Server Status Variables”

Slave_retried_transactions
Section 5.1.9, “Server Status Variables”

Slave_running
Section 17.2.1, “Replication Implementation Details”
Section 5.1.9, “Server Status Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”

Slow_launch_threads
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Slow_queries
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Sort_merge_passes
Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

Sort_range
Section 5.1.9, “Server Status Variables”

Sort_rows
Section 5.1.9, “Server Status Variables”

Sort_scan
Section 5.1.9, “Server Status Variables”

Ssl_accept_renegotiates
Section 5.1.9, “Server Status Variables”

Ssl_accepts
Section 5.1.9, “Server Status Variables”

Ssl_callback_cache_hits
Section 5.1.9, “Server Status Variables”

Ssl_cipher
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”
Section 5.1.9, “Server Status Variables”

Ssl_cipher_list
Section 6.3.2, “Encrypted Connection TLS Protocols and Ciphers”
Section 5.1.9, “Server Status Variables”

Ssl_client_connects
Section 5.1.9, “Server Status Variables”

Ssl_connect_renegotiates
Section 5.1.9, “Server Status Variables”

Ssl_ctx_verify_depth
Section 5.1.9, “Server Status Variables”

Ssl_ctx_verify_mode
Section 5.1.9, “Server Status Variables”

Ssl_default_timeout
Section 5.1.9, “Server Status Variables”

Ssl_finished Accepts
Section 5.1.9, “Server Status Variables”

Ssl_finished_connects
Section 5.1.9, “Server Status Variables”

Ssl_sessions_reused
Section 5.1.9, “Server Status Variables”

Ssl_used_session_cache_entries
Section 5.1.9, “Server Status Variables”
Ssl_verify_mode
Section 5.1.9, "Server Status Variables"

Ssl_version
Section 6.3.2, "Encrypted Connection TLS Protocols and Ciphers"
Section 5.1.9, "Server Status Variables"

T

Table_locks_immediate
Section 8.11.1, "Internal Locking Methods"
Section 5.1.9, "Server Status Variables"

Table_locks_waited
Section 8.11.1, "Internal Locking Methods"
Section 5.1.9, "Server Status Variables"

Tc_log_max_pages_used
Section 5.1.9, "Server Status Variables"

Tc_log_page_size
Section 5.1.9, "Server Status Variables"

Tc_log_page_waits
Section 5.1.9, "Server Status Variables"

Threads_cached
Section 8.12.5.1, "How MySQL Handles Client Connections"
Section 5.1.9, "Server Status Variables"

Threads_connected
Section 5.1.9, "Server Status Variables"

Threads_created
Section 8.12.5.1, "How MySQL Handles Client Connections"
Section 5.1.9, "Server Status Variables"
Section 5.1.7, "Server System Variables"

Threads_running
Section A.15, "MySQL 5.5 FAQ: MySQL Enterprise Thread Pool"
Section 5.1.9, "Server Status Variables"

U

Uptime
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 5.1.9, “Server Status Variables”

Uptime_since_flush_status
Section 5.1.9, “Server Status Variables”

System Variable Index

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W

A

[ index top]

audit_log_buffer_size
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”

audit_log_file
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 6.4.2, “MySQL Enterprise Audit”
Section 6.4.2.2, “MySQL Enterprise Audit Security Considerations”

audit_log_flush
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”

audit_log_format
Section 6.4.2.3, “Audit Log File Formats”
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 6.4.2, “MySQL Enterprise Audit”

audit_log_policy
Section 6.4.2.5, “Audit Log Filtering”
Section 6.4.2.7, “Audit Log Options and System Variables”
Section 6.4.2, “MySQL Enterprise Audit”
Section 5.1.8, “Using System Variables”

audit_log_rotate_on_size
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”

audit_log_strategy
Section 6.4.2.4, “Audit Log Logging Control”
Section 6.4.2.7, “Audit Log Options and System Variables”

authentication_windows_log_level
Section 5.1.7, “Server System Variables”
Section 6.4.1.5, “Windows Pluggable Authentication”
authentication_windows_use_principal_name
Section 5.1.7, “Server System Variables”
Section 6.4.1.5, “Windows Pluggable Authentication”

auto_increment_increment
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.1, “MySQL 5.5 FAQ: General”
Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 17.4.1.37, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 3.6.9, “Using AUTO_INCREMENT”

auto_increment_offset
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.1, “MySQL 5.5 FAQ: General”
Section 18.1.7.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 17.4.1.37, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 3.6.9, “Using AUTO_INCREMENT”

AUTOCOMMIT
Section 17.4.1.34, “Replication and Transactions”

autocommit
Section 14.10.2.2, “autocommit, Commit, and Rollback”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 14.10.5.2, “Deadlock Detection and Rollback”
Section 13.2.2, “DELETE Statement”
Section 14.10, “InnoDB Locking and Transaction Model”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 14.10.2.4, “Locking Reads”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 14.9.1.2, “Moving or Copying InnoDB Tables”
NDB Cluster System Variables
Section 14.11.9, “Purge Configuration”
Section 17.4.1.34, “Replication and Transactions”
Section 5.1.7, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 5.5.3.3, “Thread Pool Operation”
Section 14.10.2.1, “Transaction Isolation Levels”

automatic_sp_privileges
Section 13.1.5, “ALTER PROCEDURE Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 20.2.2, “Stored Routines and MySQL Privileges”
B

[back_log]
Section 5.1.7, “Server System Variables”

basedir
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

big_tables
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.7, “Server System Variables”

binlog_cache_size
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.9, “Server Status Variables”
Section 5.4.4, “The Binary Log”

binlog_checksum
MySQL Glossary

binlog_direct_non_transactional_updates
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.4.1.34, “Replication and Transactions”

binlog_format
Section 17.1.3.4, “Binary Log Options and Variables”
Section 12.6, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section 12.15, “Information Functions”
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 12.14, “Locking Functions”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 12.5.2, “Mathematical Functions”
Section 12.18, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files"
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.4.1.2, “Replication and BLACKHOLE Tables”
Section 17.4.1.17, “Replication and LOAD DATA”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.30, “Replication and Temporary Tables”
Section 17.4.1.34, “Replication and Transactions”
Section 17.1.2, “Replication Formats”
Section 17.4.1.21, “Replication of the mysql System Database”
Section 12.13, “Encryption and Compression Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 10.16, “MySQL Server Locale Support”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Statement”
Section 13.7.4.3, “SET NAMES Statement”
Section 9.1.1, “String Literals”
Section 12.2, “Type Conversion in Expression Evaluation”

character_set_database
Section 13.1.7, “ALTER TABLE Statement”
Section 10.4, “Connection Character Sets and Collations”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 10.3.3, “Database Character Set and Collation”
Section 13.2.6, “LOAD DATA Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Statement”

character_set_filesystem
Section 13.2.6, “LOAD DATA Statement”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 5.1.7, “Server System Variables”
Section 12.7, “String Functions and Operators”

character_set_results
Section 23.7.4, “C API Data Structures”
Section 2.11.3, “Changes in MySQL 5.5”
Section 10.4, “Connection Character Sets and Collations”
Section 10.6, “Error Message Character Set”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 5.1.7, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Statement”
Section 13.7.4.3, “SET NAMES Statement”
Section 10.2.2, “UTF-8 for Metadata”

character_set_server
Section 10.15, “Character Set Configuration”
Section 10.4, “Connection Character Sets and Collations”
Section 10.3.3, “Database Character Set and Collation”
Section 12.9.4, “Full-Text Stopwords”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.3, “Replication and Character Sets”
Section 17.4.1.37, “Replication and Variables”
Section 10.3.2, “Server Character Set and Collation”
Section 5.1.7, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

character_set_system
Section 10.15, “Character Set Configuration”
Section 1.4, “What Is New in MySQL 5.5”

**completion_type**
Section 23.7.6.6, “mysql_commit()”
Section 23.7.6.57, “mysql_rollback()”
Section 5.1.7, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”

**concurrent_insert**
Section 8.11.3, “Concurrent Inserts”
Section 8.11.1, “Internal Locking Methods”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

**connect_timeout**
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section B.4.2.3, “Lost connection to MySQL server”
Section 23.7.6.52, “mysql_real_connect()”
Section 5.1.7, “Server System Variables”

**D**

[index top]

**datadir**
Section 14.11.1, “InnoDB Startup Configuration”
Section 2.3, “Installing MySQL on Microsoft Windows”
MySQL Glossary
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

**date_format**
Section 5.1.7, “Server System Variables”

**datetime_format**
Section 5.1.7, “Server System Variables”

**debug**
Section 5.1.7, “Server System Variables”
Section 24.5.3, “The DBUG Package”

**debug_sync**
Section 5.1.7, “Server System Variables”

**default**
Section 15.1, “Setting the Storage Engine”
Section 14.1.5, “Testing and Benchmarking with InnoDB”

**default_storage_engine**
Section 13.1.14, “CREATE LOGFILE GROUP Statement”
**default_week_format**
Section 12.6, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 5.1.7, “Server System Variables”

**delay_key_write**
Section 13.1.17, “CREATE TABLE Statement”
Section 8.11.5, “External Locking”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”
Section B.4.3.3, “What to Do If MySQL Keeps Crashing”

**delayed_insert_limit**
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.7, “Server System Variables”

**delayed_insert_timeout**
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.7, “Server System Variables”

**delayed_queue_size**
Section 13.2.5.3, “INSERT DELAYED Statement”
Section 5.1.7, “Server System Variables”

**div_precision_increment**
Section 12.5.1, “Arithmetic Operators”
Section 5.1.7, “Server System Variables”

E

[index top]

**engine_condition_pushdown**
Section 5.1.7, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

**error_count**
Section B.2, “Error Information Interfaces”
Section 5.1.7, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Statement”
event_scheduler
Section 20.4.2, “Event Scheduler Configuration”
Section 23.6.2, “Restrictions When Using the Embedded MySQL Server”
Section 5.1.7, “Server System Variables”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

expire_logs_days
Section 13.4.1.1, “PURGE BINARY LOGS Statement”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.7, “Server System Variables”

external_user
Implementing Proxy User Support in Authentication Plugins
Section 6.2.11, “Proxy Users”
Section 5.1.7, “Server System Variables”
Writing the Server-Side Authentication Plugin

flush
Section 5.1.7, “Server System Variables”

flush_time
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

foreign_key_checks
Section 13.1.7, “ALTER TABLE Statement”
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 5.4.4, “The Binary Log”

ft_boolean_syntax
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.7, “Server System Variables”

ft_max_word_len
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.7, “Server System Variables”
Section 24.2.1, “Types of Plugins”

ft_min_word_len
Section 12.9.2, “Boolean Full-Text Searches”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
ft_query_expansion_limit
Section 5.1.7, "Server System Variables"

ft_stopword_file
Section 17.1.1.6, "Creating a Data Snapshot Using Raw Data Files"
Section 12.9.6, "Fine-Tuning MySQL Full-Text Search"
Section 5.1.7, "Server System Variables"

G

general_log
MySQL Glossary
Section 5.4.1, "Selecting General Query Log and Slow Query Log Output Destinations"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 5.4.3, "The General Query Log"

general_log_file
Section 5.4.1, "Selecting General Query Log and Slow Query Log Output Destinations"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 5.4.3, "The General Query Log"

group_concat_max_len
Section 12.17.1, "Aggregate (GROUP BY) Function Descriptions"
Section 5.1.7, "Server System Variables"

H

have_compress
Section 5.1.7, "Server System Variables"

have_crypt
Section 5.1.7, "Server System Variables"

have_csv
Section 5.1.7, "Server System Variables"

have_dynamicLoading
Section 17.3.8.2, "Semisynchronous Replication Installation and Configuration"
Section 5.1.7, "Server System Variables"

have_geometry
Section 5.1.7, "Server System Variables"
have_innodb
Section B.4.4.5, “Rollback Failure for Nontransactional Tables”
Section 5.1.7, “Server System Variables”

have_ndbcluster
NDB Cluster System Variables

have_openssl
Section 5.1.7, “Server System Variables”

have_partitioning
Chapter 19, Partitioning
Section 5.1.7, “Server System Variables”

have_profiling
Section 5.1.7, “Server System Variables”

have_query_cache
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.7, “Server System Variables”

have_rtree_keys
Section 5.1.7, “Server System Variables”

have_ssl
Section 2.9.6, “Configuring SSL Library Support”
Section 5.1.7, “Server System Variables”

have_symlink
Section 5.1.7, “Server System Variables”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

hostname
Section 5.1.7, “Server System Variables”

I

[index top]

identity
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”

ignore_builtin_innodb
Section 1.4, “What Is New in MySQL 5.5”

init_connect
Section 10.5, “Configuring Application Character Set and Collation”
Section 6.2.2, “Privileges Provided by MySQL”
init_file
Section 8.10.2.2, “Multiple Key Caches”
Section 22.4, “Performance Schema Runtime Configuration”
Resetting the Root Password: Unix and Unix-Like Systems
Resetting the Root Password: Windows Systems
Section 5.1.7, “Server System Variables”
Section 15.4, “The MEMORY Storage Engine”

init_slave
Section 17.1.3.3, “Replication Slave Options and Variables”

innodb
Section A.16, “MySQL 5.5 FAQ: InnoDB Change Buffer”

innodb_adaptive_flushing
Section 14.11.2.4, “Configuring Buffer Pool Flushing”

innodb_adaptive_hash_index
Section 14.8.3, “Adaptive Hash Index”
Section 14.11.4, “Configuring Thread Concurrency for InnoDB”
MySQL Glossary
Section 8.5.8, “Optimizing InnoDB Configuration Variables”
Section 13.1.33, “TRUNCATE TABLE Statement”
Section 1.4, “What Is New in MySQL 5.5”

innodb_additional_mem_pool_size
Section 14.11.3, “Configuring the Memory Allocator for InnoDB”
Section 14.11.1, “InnoDB Startup Configuration”

innodb_autoextend_increment
Section 14.9.3.2, “File-Per-Table Tablespaces”
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 14.9.3.1, “The System Tablespace”

innodb_autoinc_lock_mode
Section 14.9.1.4, “AUTO_INCREMENT Handling in InnoDB”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 12.15, “Information Functions’
Section 14.10.1, “InnoDB Locking”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
MySQL Glossary

innodb_buffer_pool_dump_at_shutdown
MySQL Glossary

innodb_buffer_pool_instances
Section 14.11.2.1, “Configuring Multiple Buffer Pool Instances”
innodb_buffer_pool_load_at_startup
MySQL Glossary

innodb_buffer_pool_size
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_change_buffer_max_size
MySQL Glossary

innodb_change_buffering
Section 14.8.2, “Change Buffer”
MySQL Glossary
Section 8.5.2, “Optimizing InnoDB Transaction Management”

innodb_checksum_algorithm
MySQL Glossary

innodb_checksums
MySQL Glossary

innodb_commit_concurrency
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_compression_failure_threshold_pct
MySQL Glossary

innodb_compression_level
MySQL Glossary

innodb_compression_pad_pct_max
MySQL Glossary

innodb_concurrency_tickets
Section 14.11.4, “Configuring Thread Concurrency for InnoDB”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 8.5.8, “Optimizing InnoDB Configuration Variables”
Section 21.29.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
innodb_data_file_path
   Section 14.15.2, “File Space Management”
   Section 14.11.1, “InnoDB Startup Configuration”
   Section 14.17, “InnoDB Startup Options and System Variables”
   Section 14.9.3.1, “The System Tablespace”
   Section 14.23.1, “Troubleshooting InnoDB I/O Problems”

innodb_data_home_dir
   Section 14.11.1, “InnoDB Startup Configuration”
   Section 14.17, “InnoDB Startup Options and System Variables”
   Section 14.23.1, “Troubleshooting InnoDB I/O Problems”

innodb_deadlock_detect
   MySQL Glossary

innodb_default_row_format
   MySQL Glossary

innodb_doublewrite
   Section 14.9.5, “Doublewrite Buffer”
   Section 14.5, “InnoDB and the ACID Model”
   Section 14.15.1, “InnoDB Disk I/O”
   Section 14.11.1, “InnoDB Startup Configuration”
   MySQL Glossary

innodb_fast_shutdown
   Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
   Section 2.12.4, “Downgrading MySQL Binary and Package Installations on Unix/Linux”
   Section 14.21.2, “InnoDB Recovery”
   MySQL Glossary
   Section 14.9.6, “Redo Log”
   Section 5.1.14, “The Server Shutdown Process”
   Section 2.11.4, “Upgrading MySQL Binary or Package-based Installations on Unix/Linux”

innodb_file_format
   Section 14.13.2.2, “Compatibility Check When a Table Is Opened”
   Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
   Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
   Section 13.1.17, “CREATE TABLE Statement”
   Section 14.9.1.1, “Creating InnoDB Tables”
   Section 14.12.2, “Enabling Compression for a Table”
   Section 14.13.1, “Enabling File Formats”
   Section 14.13.3, “Identifying the File Format in Use”
   Section 14.14, “InnoDB Row Formats”
   Section 14.17, “InnoDB Startup Options and System Variables”
   MySQL Glossary
   Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
   Section 14.1.4, “Upward and Downward Compatibility”

innodb_file_format_check
   Section 14.13.2.2, “Compatibility Check When a Table Is Opened”
   Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
innodb_file_format_max
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_file_per_table
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 13.1.17, “CREATE TABLE Statement”
Section 14.9.1.1, “Creating InnoDB Tables”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.13.1, “Enabling File Formats”
Section 14.15.2, “File Space Management”
Section 14.9.3.2, “File-Per-Table Tablespaces”
Section 13.1.17.2, “Files Created by CREATE TABLE”
Section 14.5, “InnoDB and the ACID Model”
Section 14.14, “InnoDB Row Formats”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.20.4, “InnoDB Tablespace Monitor Output”
MySQL Glossary
Section 13.7.2.4, “OPTIMIZE TABLE Statement”
Section 14.15.5, “Reclaiming Disk Space with TRUNCATE TABLE”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 1.4, “What Is New in MySQL 5.5”

innodb_flush_log_at_timeout
Section 14.8.4, “Log Buffer”

innodb_flush_log_at_trx_commit
Section 17.1.3.4, “Binary Log Options and Variables”
Section 14.5, “InnoDB and the ACID Model”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.8.4, “Log Buffer”
Section 8.5.2, “Optimizing InnoDB Transaction Management”

innodb_flush_method
Section 14.9.3.2, “File-Per-Table Tablespaces”
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 2.3, “Installing MySQL on Microsoft Windows”
Section 8.5.7, “Optimizing InnoDB Disk I/O”

innodb_flush_neighbors
MySQL Glossary

innodb_force_load_corrupted
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_force_recovery
Section 14.23.2, “Forcing InnoDB Recovery”
Section 1.6, “How to Report Bugs or Problems”
Section 14.21.2, “InnoDB Recovery”
innodb_ft_cache_size
MySQL Glossary

innodb_io_capacity
Section 14.11.2.4, "Configuring Buffer Pool Flushing"
Section 14.11.7, "Configuring InnoDB I/O Capacity"
Section 14.17, "InnoDB Startup Options and System Variables"
Section A.16, "MySQL 5.5 FAQ: InnoDB Change Buffer"
Section 8.5.7, "Optimizing InnoDB Disk I/O"
Section 1.4, "What Is New in MySQL 5.5"

innodb_large_prefix
Section 8.3.4, "Column Indexes"
Section 13.1.13, "CREATE INDEX Statement"
Section 13.1.17, "CREATE TABLE Statement"
Section 2.12.3, "Downgrade Notes"
Section 14.24, "InnoDB Limits"
Section 14.14, "InnoDB Row Formats"
MySQL Glossary

innodb_lock_wait_timeout
Section 14.10.5.2, "Deadlock Detection and Rollback"
Section 14.17, "InnoDB Startup Options and System Variables"
MySQL Glossary
Section 17.4.1.31, "Replication Retries and Timeouts"
Section 17.1.3.3, "Replication Slave Options and Variables"
Section B.3.1, "Server Error Message Reference"
Section 1.4, "What Is New in MySQL 5.5"

innodb_locks_unsafe_for_binlog
Section 14.10.2.3, "Consistent Nonlocking Reads"
Section 14.10.1, "InnoDB Locking"
Section 14.17, "InnoDB Startup Options and System Variables"
Section 14.10.3, "Locks Set by Different SQL Statements in InnoDB"
MySQL Glossary
Section 14.10.2.1, "Transaction Isolation Levels"

innodb_log_buffer_size
Section 14.11.1, "InnoDB Startup Configuration"
Section 14.8.4, "Log Buffer"
MySQL Glossary
Section 8.5.3, "Optimizing InnoDB Redo Logging"

innodb_log_file_size
Section 14.11.1, "InnoDB Startup Configuration"
Section 14.17, "InnoDB Startup Options and System Variables"
MySQL Glossary
Section 8.5.7, "Optimizing InnoDB Disk I/O"
Section 8.5.3, "Optimizing InnoDB Redo Logging"
innodb_log_files_in_group
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.3, “Optimizing InnoDB Redo Logging”

innodb_log_group_home_dir
Section 14.11.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_max_dirty_pages_pct
Section 14.11.2.4, “Configuring Buffer Pool Flushing”
Section 8.5.7, “Optimizing InnoDB Disk I/O”

innodb_max_purge_lag
Section 14.6, “InnoDB Multi-Versioning”
MySQL Glossary
Section 14.11.9, “Purge Configuration”

innodb_old_blocks_pct
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”
MySQL Glossary

innodb_old_blocks_time
Section 14.8.1, “Buffer Pool”
Section 14.11.2.2, “Making the Buffer Pool Scan Resistant”

innodb_online_alter_log_max_size
MySQL Glossary

innodb_page_cleaners
MySQL Glossary

innodb_page_size
MySQL Glossary
Section 14.9.3.1, “The System Tablespace”

innodb_print_all_deadlocks
Section 14.10.5, “Deadlocks in InnoDB”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 14.23, “InnoDB Troubleshooting”

innodb_purge_batch_size
Section 14.11.9, “Purge Configuration”

innodb_purge_threads
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
innodb_random_read_ahead
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
MySQL Glossary
Section 1.4, “What Is New in MySQL 5.5”

innodb_read_ahead_threshold
Section 14.11.2.3, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)"
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_read_io_threads
Section 2.11.3, “Changes in MySQL 5.5”
Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 24.1.1, “MySQL Threads”
Section 14.11.6, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

innodb_rollback_segments
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.9.7, “Undo Logs”

innodb_sort_buffer_size
MySQL Glossary

innodb_spin_wait_delay
Section 14.11.8, “Configuring Spin Lock Polling”

innodb_stats_method
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
MySQL Glossary

innodb_stats_on_metadata
Section 1.4, “What Is New in MySQL 5.5”

innodb_stats_sample_pages
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 14.11.10, “Configuring Optimizer Statistics for InnoDB”
Section 14.11.10.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”

innodb_strict_mode
Section 13.1.17, “CREATE TABLE Statement”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 14.14, “InnoDB Row Formats”
Section 14.2, “Installing the InnoDB Storage Engine”
Section 8.4.7, “Limits on Table Column Count and Row Size”
MySQL Glossary
Section 5.1.10, “Server SQL Modes”
Section 14.12.6, “SQL Compression Syntax WARNINGS and ERRORS”
Section 1.4, “What Is New in MySQL 5.5”
innodb_support_xa
MySQL Glossary
Section 8.5.2, “Optimizing InnoDB Transaction Management”

innodb_table_locks
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”

innodb_temp_data_file_path
MySQL Glossary

innodb_thread_concurrency
Section 14.11.4, “Configuring Thread Concurrency for InnoDB”
Section 14.17, “InnoDB Startup Options and System Variables”
Section A.15, “MySQL 5.5 FAQ: MySQL Enterprise Thread Pool”
Section 8.5.8, “Optimizing InnoDB Configuration Variables”

innodb_thread_sleep_delay
Section 14.11.4, “Configuring Thread Concurrency for InnoDB”

innodb_undo_tablespaces
MySQL Glossary

innodb_use_native_aio
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 14.11.6, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

innodb_use_sys_malloc
Section 14.11.3, “Configuring the Memory Allocator for InnoDB”
Section 14.11.4, “Configuring Thread Concurrency for InnoDB”
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_write_io_threads
Section 2.11.3, “Changes in MySQL 5.5”
Section 14.11.5, “Configuring the Number of Background InnoDB I/O Threads”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 24.1.1, “MySQL Threads”
Section 14.11.6, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

insert_id
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 5.1.7, “Server System Variables”

interactive_timeout
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section 23.7.6.52, “mysql_real_connect()”
Section 5.1.7, “Server System Variables”

J

join_buffer_size
Section 8.2.1.5, “Nested-Loop Join Algorithms”
Section 5.1.7, “Server System Variables”

K

keep_files_on_create
Section 5.1.7, “Server System Variables”

key_buffer_size
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 5.1.1, “Configuring the Server”
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 8.8.4, “Estimating Query Performance”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 14.11.1, “InnoDB Startup Configuration”
Section B.4.7, “Known Issues in MySQL”
Section 8.10.2.2, “Multiple Key Caches”
Section 8.2.4.3, “Optimizing DELETE Statements”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 8.10.2.6, “Restructuring a Key Cache”
Section 5.1.6, “Server Command Options”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 5.1.8.3, “Structured System Variables”
Section 8.10.2, “The MyISAM Key Cache”

key_cache_age_threshold
Section 8.10.2.3, “Midpoint Insertion Strategy”
Section 5.1.7, “Server System Variables”
Section 5.1.8.3, “Structured System Variables”

key_cache_block_size
Section 8.10.2.5, “Key Cache Block Size”
Section 8.10.2.6, “Restructuring a Key Cache”
Section 5.1.7, “Server System Variables”
Section 5.1.8.3, “Structured System Variables”

key_cache_division_limit
Section 8.10.2.3, “Midpoint Insertion Strategy”
Section 5.1.7, “Server System Variables”
Section 5.1.8.3, “Structured System Variables”
language
Section 2.11.3, “Changes in MySQL 5.5”
Section 5.1.7, “Server System Variables”

large_files_support
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.7, “Server System Variables”

large_page_size
Section 5.1.7, “Server System Variables”

large_pages
Section 5.1.7, “Server System Variables”

last_insert_id
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”

lc_messages
Section 2.11.3, “Changes in MySQL 5.5”
Section 5.1.7, “Server System Variables”
Section 10.12, “Setting the Error Message Language”
Section 1.4, “What Is New in MySQL 5.5”

lc_messages_dir
Section 2.11.3, “Changes in MySQL 5.5”
Section 5.1.7, “Server System Variables”
Section 10.12, “Setting the Error Message Language”
Section 1.4, “What Is New in MySQL 5.5”

lc_time_names
Section 12.6, “Date and Time Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 10.16, “MySQL Server Locale Support”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 12.7, “String Functions and Operators”

license
Section 5.1.7, “Server System Variables”

local
Section 13.2.7, “LOAD XML Statement”

local_infile
Section 13.2.6, “LOAD DATA Statement”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 5.1.7, “Server System Variables”

lock_wait_timeout
Section 5.1.7, “Server System Variables”

locked_in_memory
Section 5.1.7, “Server System Variables”

log
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

log_bin
Section 17.1.3.4, “Binary Log Options and Variables”
NDB Cluster System Variables

log_bin_trust_function_creators
Section 17.1.3.4, “Binary Log Options and Variables”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 20.7, “Stored Program Binary Logging”
Section 1.4, “What Is New in MySQL 5.5”

log_bin_use_v
Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Server Options for NDB Cluster
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

log_error
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”
Section 5.4.2.1, “Error Logging on Windows”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section 5.1.7, “Server System Variables”

log_output
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 5.4.3, “The General Query Log”
Section 5.4.5, “The Slow Query Log”

log_queries_not_using_indexes
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

log_slave_updates
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.3.5, “Improving Replication Performance”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
log_slow_queries
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

log_warnings
Section 5.4.2.4, “Error Log Filtering”
Section 5.1.7, “Server System Variables”

long_query_time
Section 5.4, “MySQL Server Logs”
Section 4.5.2, "mysqladmin — Client for Administering a MySQL Server"
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

low_priority_updates
Section A.14, “MySQL 5.5 FAQ: Replication”
Section 5.1.7, “Server System Variables”
Section 8.11.2, “Table Locking Issues”

lower_case_file_system
Section 5.1.7, “Server System Variables”

lower_case_table_names
Advanced Options
Section 13.1.17.6, “FOREIGN KEY Constraints”
Section 13.7.1.3, “GRANT Statement”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 1.6, “How to Report Bugs or Problems”
Section 9.2.3, “Identifier Case Sensitivity”
Section 17.4.1.37, “Replication and Variables”
Section 13.7.1.5, “REVOKE Statement”
Section 5.1.7, “Server System Variables”
Section 13.7.5.38, “SHOW TABLES Statement”
Section 10.8.7, “Using Collation in INFORMATION_SCHEMA Searches”

master_verify_checksum
MySQL Glossary

max_allowed_packet
Section 12.17.1, “Aggregate (GROUP BY) Function Descriptions”
max_binlog_cache_size
Section 17.1.3.4, "Binary Log Options and Variables"
Section 5.4.4, "The Binary Log"

max_binlog_size
Section 17.1.3.4, "Binary Log Options and Variables"
Section 5.4, "MySQL Server Logs"
Section 17.1.3.3, "Replication Slave Options and Variables"
Section 5.4.7, "Server Log Maintenance"
Section 5.1.7, "Server System Variables"
Section 5.4.4, "The Binary Log"
Section 17.2.2.1, "The Slave Relay Log"

max_binlog_stmt_cache_size
Section 17.1.3.4, "Binary Log Options and Variables"

max_connect_errors
Section 8.12.5.2, "DNS Lookup Optimization and the Host Cache"
Section 13.7.6.3, "FLUSH Statement"
Section B.4.2.6, "Host 'host_name' is blocked"
Section 5.1.7, "Server System Variables"

max_connections
Section 24.5.1.4, "Debugging mysqld under gdb"
Section B.4.2.18, "File Not Found and Similar Errors"
Section 8.12.5.1, "How MySQL Handles Client Connections"
Section 8.4.3.1, "How MySQL Opens and Closes Tables"
Section 22.12, "Performance Schema System Variables"
Section 6.2.2, "Privileges Provided by MySQL"
Section 5.1.7, "Server System Variables"
Section 5.5.3.3, "Thread Pool Operation"
Section B.4.2.7, "Too many connections"

max_delayed_threads
Section 22.12, "Performance Schema System Variables"
max_error_count
Section 13.2.6, “LOAD DATA Statement”
Section 13.6.7.3, “RESIGNAL Statement”
Section 5.1.7, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”

max_heap_table_size
Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 8.4.6, “Limits on Table Size”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.37, “Replication and Variables”
Section 13.6.6.5, “Restrictions on Server-Side Cursors”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 15.4, “The MEMORY Storage Engine”

max_insert_delayed_threads
Section 5.1.7, “Server System Variables”

max_join_size
Section 8.8.2, “EXPLAIN Output Format”
Section 4.5.1.6, “mysql Client Tips”
Section 5.1.7, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”

max_length_for_sort_data
Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.7, “Server System Variables”

max_long_data_size
Section 23.7.10.26, “mysql_stmt_send_long_data()”
Section 5.1.7, “Server System Variables”

max_prepared_stmt_count
Section 13.5, “Prepared Statements”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

max_relay_log_size
Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.7, “Server System Variables”
Section 17.2.2.1, “The Slave Relay Log”

max_seeks_for_key
Section 13.7.2.1, “ANALYZE TABLE Statement”
Section 5.1.7, “Server System Variables”
max_sort_length
Section B.4.7, “Known Issues in MySQL”
Section 8.2.1.10, “ORDER BY Optimization”
Section 13.2.9, “SELECT Statement”
Section 5.1.7, “Server System Variables”
Section 11.3.4, “The BLOB and TEXT Types”

max_sp_recursion_depth
Section 5.1.7, “Server System Variables”
Section 20.2.1, “Stored Routine Syntax”

max_tmp_tables
Section 5.1.7, “Server System Variables”

max_user_connections
Section 13.7.6.3, “FLUSH Statement”
Section 13.7.1.3, “GRANT Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.7, “Server System Variables”
Section 6.2.12, “Setting Account Resource Limits”

max_write_lock_count
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Statements”
Section 8.11.4, “Metadata Locking”
Section 5.1.7, “Server System Variables”
Section 8.11.2, “Table Locking Issues”

metadata_locks_cache_size
Section 5.1.7, “Server System Variables”

min_examined_row_limit
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

multi_range_count
Section 5.1.7, “Server System Variables”

myisam_data_pointer_size
Section 13.1.17, “CREATE TABLE Statement”
Section 8.4.6, “Limits on Table Size”
Section 5.1.7, “Server System Variables”

myisam_max_sort_file_size
Section 15.3.1, “MyISAM Startup Options”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.7, “Server System Variables”

myisam_mmap_size
Section 5.1.7, “Server System Variables”
myisam_recover_options
Section 15.3.1, “MyISAM Startup Options”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 5.1.7, “Server System Variables”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section B.4.2.19, “Table-Corruption Issues”
Section 15.3, “The MyISAM Storage Engine”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”

myisam_repair_threads
Section 5.1.7, “Server System Variables”

myisam_sort_buffer_size
Section 13.1.7, “ALTER TABLE Statement”
Section 15.3.1, “MyISAM Startup Options”
Section 4.6.3.1, “myisamchk General Options”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 5.1.7, “Server System Variables”

myisam_stats_method
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 5.1.7, “Server System Variables”

myisam_use_mmap
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.7, “Server System Variables”

N

[nindex top]

named_pipe
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlexport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqllap — Load Emulation Client”
Section 2.3.6.3, “Selecting a MySQL Server Type”
Section 5.1.7, “Server System Variables”
Section 1.3.2, “The Main Features of MySQL”
Type and Networking

ndb_autoincrement_prefetch_sz
NDB Cluster System Variables
ndb_cache_check_time
NDB Cluster System Variables

ndb_deferred_constraints
NDB Cluster System Variables

ndb_distribution
NDB Cluster System Variables

ndb_eventbuffer_max_alloc
NDB Cluster System Variables

ndb_extra_logging
NDB Cluster System Variables

ndb_force_send
NDB Cluster System Variables

ndb_index_stat_cache_entries
NDB Cluster System Variables

ndb_index_stat_enable
NDB Cluster System Variables

ndb_index_stat_option
NDB Cluster System Variables

ndb_index_stat_update_freq
NDB Cluster System Variables

ndb_join_pushdown
Section 8.8.2, “EXPLAIN Output Format”
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

ndb_log_apply_status
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
NDB Cluster System Variables

ndb_log_bin
NDB Cluster System Variables

ndb_log_binlog_index
NDB Cluster System Variables

ndb_log_empty_epochs
NDB Cluster System Variables

ndb_log_empty_update
NDB Cluster System Variables
ndb_log_orig
NDB Cluster System Variables

ndb_log_transaction_id
NDB Cluster System Variables

ndb_optimized_node_selection
NDB Cluster System Variables
Section 18.3.3.9, “NDB Cluster TCP/IP Connections”
Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”

ndb_report_thresh_binlog_epoch_slip
NDB Cluster System Variables

ndb_report_thresh_binlog_mem_usage
NDB Cluster System Variables

ndb_table_no_logging
NDB Cluster System Variables

ndb_table_temporary
NDB Cluster System Variables

ndb_use_copying_alter_table
NDB Cluster System Variables

ndb_use_exact_count
NDB Cluster System Variables

ndb_use_transactions
NDB Cluster System Variables

ndb_version
NDB Cluster System Variables

ndb_version_string
NDB Cluster System Variables

ndbinfo_database
NDB Cluster System Variables

ndbinfo_max_bytes
NDB Cluster System Variables

ndbinfo_max_rows
NDB Cluster System Variables

ndbinfo_offline
NDB Cluster System Variables
ndbinfo_show_hidden
NDB Cluster System Variables
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.5, “The ndbinfo cluster_transactions Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”

ndbinfo_table_prefix
NDB Cluster System Variables

ndbinfo_version
NDB Cluster System Variables

net_buffer_length
Section 8.12.4.1, “How MySQL Uses Memory”
Section 23.7, “MySQL C API”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 5.1.7, “Server System Variables”

net_read_timeout
Section B.4.2.3, “Lost connection to MySQL server”
Section 5.1.7, “Server System Variables”

net_retry_count
Section 5.1.7, “Server System Variables”

net_write_timeout
Section 5.1.7, “Server System Variables”

new
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”
Section 5.1.7, “Server System Variables”

O
[index top]

old
Section 8.9.3, “Index Hints”
Section 5.1.7, “Server System Variables”

old_alter_table
Section 13.1.7, “ALTER TABLE Statement”
Section 5.1.7, “Server System Variables”

old_passwords
Section 6.2.9, “Assigning Account Passwords”
Section B.4.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Statement”
Section 12.13, “Encryption and Compression Functions”
performance_schema_max_cond_classes
Section 22.12, “Performance Schema System Variables”

performance_schema_max_cond_instances
Section 22.12, “Performance Schema System Variables”

performance_schema_max_file_classes
Section 22.12, “Performance Schema System Variables”

performance_schema_max_file_handles
Section 22.12, “Performance Schema System Variables”

performance_schema_max_file_instances
Section 22.12, “Performance Schema System Variables”

performance_schema_max_mutex_classes
Section 22.7, “Performance Schema Status Monitoring”
Section 22.12, “Performance Schema System Variables”

performance_schema_max_mutex_instances
Section 22.12, “Performance Schema System Variables”

performance_schema_max_rwlock_classes
Section 22.12, “Performance Schema System Variables”

performance_schema_max_rwlock_instances
Section 22.12, “Performance Schema System Variables”

performance_schema_max_table_handles
Section 22.12, “Performance Schema System Variables”

performance_schema_max_table_instances
Section 22.12, “Performance Schema System Variables”

performance_schema_max_thread_classes
Section 22.12, “Performance Schema System Variables”

performance_schema_max_thread_instances
Section 22.13, “Performance Schema Status Variables”
Section 22.12, “Performance Schema System Variables”
Section 13.7.5.16, “SHOW ENGINE Statement”

pid_file
Section 5.1.7, “Server System Variables”

plugin_dir
Section 24.4.2, “Adding a User-Defined Function”
Section 6.1.2.2, “Administrator Guidelines for Password Security”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 2.10.1, “Initializing the Data Directory”
Section 13.7.3.3, “INSTALL PLUGIN Statement”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.4.2.1, “Installing MySQL Enterprise Audit”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.6.2, “Obtaining User-Defined Function Information”
Section 6.4.1.4, “PAM Pluggable Authentication”
Section 6.2.10, “Pluggable Authentication”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.7.5.26, “SHOW PLUGINS Statement”
Section 6.4.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.4.1.7, “Test Pluggable Authentication”
Section 21.14, “The INFORMATION_SCHEMA PLUGINS Table”
Section 5.5.3.2, “Thread Pool Installation”
Using the Authentication Plugins
Section 6.4.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Section 24.2.4.7, “Writing Semisynchronous Replication Plugins”

**port**
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 5.1.7, “Server System Variables”

**preload_buffer_size**
Section 5.1.7, “Server System Variables”

**profiling**
Section 5.1.7, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Statement”
Section 21.16, “The INFORMATION_SCHEMA PROFILING Table”

**profiling_history_size**
Section 5.1.7, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Statement”

**protocol_version**
Section 5.1.7, “Server System Variables”

**proxy_user**
Section 6.2.11, “Proxy Users”
Section 5.1.7, “Server System Variables”

**pseudo_slave_mode**
Section 5.1.7, “Server System Variables”
pseudo_thread_id
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”

Q

query_alloc_block_size
Section 5.1.7, “Server System Variables”

query_cache_limit
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.7, “Server System Variables”

query_cache_min_res_unit
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.7, “Server System Variables”

query_cache_size
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.7, “Server System Variables”
Section 8.10.3, “The MySQL Query Cache”

query_cache_type
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.2, “Query Cache SELECT Options”
Section 13.2.9, “SELECT Statement”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

query_cache_wlock_invalidate
Section 5.1.7, “Server System Variables”

query_prealloc_size
Section 5.1.7, “Server System Variables”

R

rand_seed
Section 5.1.7, “Server System Variables”

range_alloc_block_size
Section 5.1.7, “Server System Variables”

read_buffer_size
Section 8.12.4.1, “How MySQL Uses Memory”
read_only
Section 13.7.1, “Account Management Statements”
Section 6.2.9, “Assigning Account Passwords”
Section 17.3.1.3, “Backing Up a Master or Slave by Making It Read Only”
Section 13.7.1.1, “CREATE USER Statement”
Section 13.7.1.2, “DROP USER Statement”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Statement”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Statement”
Section 17.4.1.37, “Replication and Variables”
Section 13.7.1.5, “REVOKE Statement”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.7, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Statement”

read_rnd_buffer_size
Section 5.1.1, “Configuring the Server”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.7, “Server System Variables”

relay_log
Section 17.3.5, “Improving Replication Performance”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.1, “The Slave Relay Log”

relay_log_index
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.1, “The Slave Relay Log”

relay_log_info_file
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.2, “Slave Status Logs”

relay_log_purge
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 5.1.7, “Server System Variables”

relay_log_recovery
Section 17.1.3.3, “Replication Slave Options and Variables”

relay_log_space_limit
Section 8.14.6, “Replication Slave I/O Thread States”
Section 5.1.7, “Server System Variables”
report_host
Section 17.1.3.3, "Replication Slave Options and Variables"

report_password
Section 17.1.3.3, "Replication Slave Options and Variables"

report_port
Section 17.1.3.3, "Replication Slave Options and Variables"

report_user
Section 17.1.3.3, "Replication Slave Options and Variables"

rpl_recovery_rank
Section 17.1.3.3, "Replication Slave Options and Variables"

rpl_semi_sync_master_enabled
Section 17.3.8.1, "Semisynchronous Replication Administrative Interface"
Section 17.3.8.2, "Semisynchronous Replication Installation and Configuration"
Section 17.3.8.3, "Semisynchronous Replication Monitoring"
Section 5.1.7, "Server System Variables"

rpl_semi_sync_master_timeout
Section 17.3.8.1, "Semisynchronous Replication Administrative Interface"
Section 17.3.8.2, "Semisynchronous Replication Installation and Configuration"
Section 5.1.7, "Server System Variables"

rpl_semi_sync_master_trace_level
Section 5.1.7, "Server System Variables"

rpl_semi_sync_master_wait_no_slave
Section 5.1.7, "Server System Variables"

rpl_semi_sync_slave_enabled
Section 17.3.8.1, "Semisynchronous Replication Administrative Interface"
Section 17.3.8.2, "Semisynchronous Replication Installation and Configuration"
Section 5.1.7, "Server System Variables"

rpl_semi_sync_slave_trace_level
Section 5.1.7, "Server System Variables"

S

secure_auth
Section 6.1.2.4, "Password Hashing in MySQL"
Section 5.1.7, "Server System Variables"

secure_file_priv
Section 2.10.1, "Initializing the Data Directory"
Section 2.5.1, "Installing MySQL on Linux Using RPM Packages"
Section 13.2.6, “LOAD DATA Statement”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 2.9.7, “MySQL Source-Configuration Options”
Section 6.2.2, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Statement”
Section 5.1.7, “Server System Variables”
Set SELinux context for MySQL Server
Section 12.7, “String Functions and Operators”

**server_id**
Advanced Options
Section 6.4.2.3, “Audit Log File Formats”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 12.18, “Miscellaneous Functions”
MySQL Server Options for NDB Cluster
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster System Variables
Section 17.1.3, “Replication and Binary Logging Options and Variables”
Section 17.1.1, “Replication Configuration”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.1.1, “Setting the Replication Master Configuration”
Section 17.1.1.2, “Setting the Replication Slave Configuration”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”
Section 17.4.4, “Troubleshooting Replication”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

**server_id_bits**
MySQL Server Options for NDB Cluster
NDB Cluster System Variables

**shared_memory**
Section 4.2.3, “Command Options for Connecting to the Server”
Section 4.2.4, “Connecting to the MySQL Server Using Command Options”
Section 4.5.1.1, “mysql Client Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqslap — Load Emulation Client”
Section 5.1.7, “Server System Variables”
Section 5.7.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 2.3.6.4, “Starting the Server for the First Time”
Section 1.3.2, “The Main Features of MySQL”
Type and Networking

**shared_memory_base_name**
Section 23.7.6.49, “mysql_options()”
skip_external_locking
Section 8.11.5, “External Locking”
Section 5.1.7, “Server System Variables”

skip_name_resolve
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 5.1.7, “Server System Variables”
Section 2.3.6.8, “Testing The MySQL Installation”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

skip_networking
Section B.4.2.2, “Can't connect to [local] MySQL server”
Section 2.11.3, “Changes in MySQL 5.5”
Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section A.14, “MySQL 5.5 FAQ: Replication”
Section B.4.2.9, “MySQL server has gone away”
Section 6.2.10, “Pluggable Authentication”
Resetting the Root Password: Generic Instructions
Section 5.1.7, “Server System Variables”
Section 17.1.1.1, “Setting the Replication Master Configuration”
Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”
Section 17.4.4, “Troubleshooting Replication”
Section 17.4.3, “Upgrading a Replication Setup”

skip_show_database
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

slave_allow_batching
NDB Cluster System Variables
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”

slave_compressed_protocol
Section 4.2.5, “Connection Compression Control”
Section 17.1.3.3, “Replication Slave Options and Variables”

slave_exec_mode
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

slave_load_tmpdir
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.2, “Database Backup Methods”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.7, “Server System Variables”
Section B.4.3.5, “Where MySQL Stores Temporary Files”
slave_max_allowed_packet
Section 17.1.3.3, “Replication Slave Options and Variables”

slave_net_timeout
Section 13.4.2.1, “CHANGE MASTER TO Statement”
Section 17.1.4.1, “Checking Replication Status”
Section 17.4.1.27, “Replication and Master or Slave Shutdowns”
Section 8.14.6, “Replication Slave I/O Thread States”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.7, “Server System Variables”

slave_skip_errors
Section 17.1.3.3, “Replication Slave Options and Variables”

slave_sql_verify_checksum
MySQL Glossary

slave_transaction_retries
Section 17.4.1.31, “Replication Retries and Timeouts”
Section 17.1.3.3, “Replication Slave Options and Variables”

slave_type_conversions
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”

slow_launch_time
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

slow_query_log
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

slow_query_log_file
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.7, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

socket
Section 5.1.7, “Server System Variables”

sort_buffer_size
Section 7.6.3, “How to Repair MyISAM Tables”
Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”

sql_auto_is_null
Section 12.3.2, “Comparison Functions and Operators”
Section 13.1.17, “CREATE TABLE Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 5.4.4, “The Binary Log”

sql_big_selects
Section 5.1.7, “Server System Variables”

sql_buffer_result
Section 5.1.7, “Server System Variables”

sql_log_bin
Section 17.1.3.4, “Binary Log Options and Variables”
Section 18.1.7.8, “Issues Exclusive to NDB Cluster”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 4.6.7, “mysqldbinlog — Utility for Processing Binary Log Files”
Section 18.1.7.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.1.3.1, “Replication and Binary Logging Option and Variable Reference”
Section 5.1.7, “Server System Variables”
Section 13.4.1.3, “SET sql_log_bin Statement”
Section 5.1.8.1, “System Variable Privileges”
Section 17.4.3, “Upgrading a Replication Setup”

sql_log_off
Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Glossary
Section 6.2.2, “Privileges Provided by MySQL”
Section 17.1.3.1, “Replication and Binary Logging Option and Variable Reference”
Section 5.4.1, “Selecting General Query Log and Slow Query Log Output Destinations”
Section 5.1.7, “Server System Variables”
Section 5.4.3, “The General Query Log”

sql_mode
Section 14.1.2, “Best Practices for InnoDB Tables”
Section 13.1.11, “CREATE EVENT Statement”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Statements”
Section 13.1.19, “CREATE TRIGGER Statement”
Section 12.19.3, “Expression Handling”
Section 1.6, “How to Report Bugs or Problems”
Section 13.2.6, “LOAD DATA Statement”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 1.7, “MySQL Standards Compliance”
Section B.4.4.2, “Problems Using DATE Columns”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.10, “Server SQL Modes”
Section 5.1.7, “Server System Variables”
Section 13.7.5.14, “SHOW CREATE VIEW Statement”
Section 13.6.7.4, “SIGNAL Statement”
Section 5.4.4, “The Binary Log”
Section 21.28, “The INFORMATION_SCHEMA VIEWS Table”
Section 4.2.2.2, “Using Option Files”

3728
Section 5.1.8, “Using System Variables”

**sql_notes**
Section B.2, “Error Information Interfaces”
Section 5.1.7, “Server System Variables”
Section 13.7.5.41, “SHOW WARNINGS Statement”

**sql_quote_show_create**
Section 5.1.7, “Server System Variables”
Section 13.7.5.8, “SHOW CREATE DATABASE Statement”
Section 13.7.5.12, “SHOW CREATE TABLE Statement”

**sql_safe_updates**
Section 4.5.1.6, “mysql Client Tips”
Section 5.1.7, “Server System Variables”

**sql_select_limit**
Section 4.5.1.6, “mysql Client Tips”
Section 5.1.7, “Server System Variables”

**sql_slave_skip_counter**
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Statement”

**sql_warnings**
Section 5.1.7, “Server System Variables”

**ssl_ca**
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.7, “Server System Variables”

**ssl_capath**
Section 5.1.7, “Server System Variables”

**ssl_cert**
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.7, “Server System Variables”

**ssl_cipher**
Section 5.1.7, “Server System Variables”

**ssl_key**
Section 6.3.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.7, “Server System Variables”

**storage_engine**
Section 13.1.14, “CREATE LOGFILE GROUP Statement”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 1.4, “What Is New in MySQL 5.5”

**stored_program_cache**
Section 5.1.7, “Server System Variables”

**sync_binlog**
Section 17.1.3.4, “Binary Log Options and Variables”
Section 14.5, “InnoDB and the ACID Model”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 17.4.1.27, “Replication and Master or Slave Shutdowns”
Section 5.4.4, “The Binary Log”

**sync_frm**
Section 5.1.7, “Server System Variables”

**sync_master_info**
Section 17.1.3.3, “Replication Slave Options and Variables”

**sync_relay_log**
Section 17.1.3.3, “Replication Slave Options and Variables”

**sync_relay_log_info**
Section 17.4.1.27, “Replication and Master or Slave Shutdowns”
Section 17.1.3.3, “Replication Slave Options and Variables”

**system_time_zone**
Section 5.1.12, “MySQL Server Time Zone Support”
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”

T

[<index top>]

**table_definition_cache**
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.7, “Server System Variables”

**table_open_cache**
Section 5.1.1, “Configuring the Server”
Section B.4.2.18, “File Not Found and Similar Errors”
Section 8.14.2, “General Thread States”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”

**thread_cache_size**
Section 24.5.1.4, “Debugging mysqld under gdb”
Section 8.12.5.1, “How MySQL Handles Client Connections”
Section 5.1.9, “Server Status Variables”
Section 5.1.7, “Server System Variables”
thread_concurrency
Section 5.1.7, “Server System Variables”

thread_handling
Section 5.1.7, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_algorithm
Section 5.1.7, “Server System Variables”
Section 21.31.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_high_priority_connection
Section 5.1.7, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”

thread_pool_max_unused_threads
Section 5.1.7, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_prio_kickup_timer
Section 5.1.7, “Server System Variables”
Section 21.31.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 21.31.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_pool_size
Section 5.1.7, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_pool_stall_limit
Section 5.1.7, “Server System Variables”
Section 21.31.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 21.31.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_stack
Section 8.12.5.1, “How MySQL Handles Client Connections”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.7, “Server System Variables”
Section 20.2.1, “Stored Routine Syntax”

time_format
Section 5.1.7, “Server System Variables”
time_zone
Section 13.1.11, "CREATE EVENT Statement"
Section 12.6, "Date and Time Functions"
Section 20.4.4, "Event Metadata"
Section 5.4.4.3, "Mixed Binary Logging Format"
Section 5.1.12, "MySQL Server Time Zone Support"
Section 17.4.1.37, "Replication and Variables"
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 11.2.2, "The DATE, DATETIME, and TIMESTAMP Types"

timed_mutexes
Section 5.1.7, "Server System Variables"
Section 1.4, "What Is New in MySQL 5.5"

timestamp
Section 15.9.3, "FEDERATED Storage Engine Notes and Tips"
Section 5.4.4.3, "Mixed Binary Logging Format"
Section 17.4.1.37, "Replication and Variables"
Section 5.1.7, "Server System Variables"

tmp_table_size
Section 8.12.4.1, "How MySQL Uses Memory"
Section 8.4.4, "Internal Temporary Table Use in MySQL"
Section 13.6.6.5, "Restrictions on Server-Side Cursors"
Section 5.1.9, "Server Status Variables"
Section 5.1.7, "Server System Variables"

tmpdir
Section 17.3.1.2, "Backing Up Raw Data from a Slave"
Section B.4.2.13, "Can't create/write to file"
Section 7.2, "Database Backup Methods"
Section 14.16.6, "Limitations of Fast Index Creation"
Section 2.9.7, "MySQL Source-Configuration Options"
Section 8.2.1.10, "ORDER BY Optimization"
Section 17.1.3.3, "Replication Slave Options and Variables"
Section 5.1.7, "Server System Variables"

transaction_alloc_block_size
Section 5.1.7, "Server System Variables"

transaction_allow_batching
NDB Cluster System Variables

transaction_prealloc_size
Section 5.1.7, "Server System Variables"

tax_isolation
Section 5.1.6, "Server Command Options"
Section 5.1.7, "Server System Variables"
Section 13.3.6, "SET TRANSACTION Statement"
**unique_checks**
Section 14.9.1.3, “Converting Tables from MyISAM to InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.37, “Replication and Variables”
Section 5.1.7, “Server System Variables”
Section 5.4.4, “The Binary Log”

**updatable_views_with_limit**
Section 5.1.7, “Server System Variables”
Section 20.5.3, “Updatable and Insertable Views”

**version**
Section 6.4.2.3, “Audit Log File Formats”
Section 12.15, “Information Functions”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.7, “Server System Variables”

**version_comment**
Section 5.1.7, “Server System Variables”
Section 13.7.5.40, “SHOW VARIABLES Statement”

**version_compile_machine**
Section 5.1.7, “Server System Variables”

**version_compile_os**
Section 5.1.7, “Server System Variables”

**wait_timeout**
Section B.4.2.11, “Communication Errors and Aborted Connections”
Section B.4.2.9, “MySQL server has gone away”
Section 23.7.6.52, “mysql_real_connect()”
Section 5.1.7, “Server System Variables”

**warning_count**
Section B.2, “Error Information Interfaces”
Section 5.1.7, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Statement”
Section 13.7.5.41, “SHOW WARNINGS Statement”
Section 13.6.7.4, “SIGNAL Statement”
Transaction Isolation Level Index

<table>
<thead>
<tr>
<th>R</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R</strong></td>
<td>index top</td>
</tr>
</tbody>
</table>

**READ COMMITTED**
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 18.1.6.1, “Differences Between the NDB and InnoDB Storage Engines”
Section 14.10.5.3, “How to Minimize and Handle Deadlocks”
Section 14.10.1, “InnoDB Locking”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section A.1, “MySQL 5.5 FAQ: General”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.1.6.3, “NDB and InnoDB Feature Usage Summary”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 13.3.6, “SET TRANSACTION Statement”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 13.1.33, “TRUNCATE TABLE Statement”

**READ UNCOMMITTED**
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.3.6, “SET TRANSACTION Statement”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 13.1.33, “TRUNCATE TABLE Statement”

**READ-COMMITTED**
Section 5.1.6, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Statement”

**READ-UNCOMMITTED**
Section 5.1.6, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Statement”

**REPEATABLE READ**
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 14.10.1, “InnoDB Locking”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 13.3.6, “SET TRANSACTION Statement”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 13.3.7, “XA Transactions”
REPEATABLE-READ
Section 5.1.6, “Server Command Options”
Section 5.1.7, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Statement”

SERIALIZABLE
Section 8.10.3.1, “How the Query Cache Operates”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Statements”
Section 14.10.2.1, “Transaction Isolation Levels”
Section 14.10.2.3, “Consistent Nonlocking Reads”
Section 18.1.7.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.10.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 5.1.6, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Statement”
Section 13.3.7, “XA Transactions”
MySQL Glossary

These terms are commonly used in information about the MySQL database server. This glossary originated as a reference for terminology about the InnoDB storage engine, and the majority of definitions are InnoDB-related.

A

.ARM file
Metadata for ARCHIVE tables. Contrast with .ARZ file. Files with this extension are always included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.
See Also .ARZ file, MySQL Enterprise Backup, mysqlbackup command.

.ARZ file
Data for ARCHIVE tables. Contrast with .ARM file. Files with this extension are always included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.
See Also .ARM file, MySQL Enterprise Backup, mysqlbackup command.

ACID
An acronym standing for atomicity, consistency, isolation, and durability. These properties are all desirable in a database system, and are all closely tied to the notion of a transaction. The transactional features of InnoDB adhere to the ACID principles.

Transactions are atomic units of work that can be committed or rolled back. When a transaction makes multiple changes to the database, either all the changes succeed when the transaction is committed, or all the changes are undone when the transaction is rolled back.

The database remains in a consistent state at all times — after each commit or rollback, and while transactions are in progress. If related data is being updated across multiple tables, queries see either all old values or all new values, not a mix of old and new values.

Transactions are protected (isolated) from each other while they are in progress; they cannot interfere with each other or see each other's uncommitted data. This isolation is achieved through the locking mechanism. Experienced users can adjust the isolation level, trading off less protection in favor of increased performance and concurrency, when they can be sure that the transactions really do not interfere with each other.

The results of transactions are durable: once a commit operation succeeds, the changes made by that transaction are safe from power failures, system crashes, race conditions, or other potential dangers that many non-database applications are vulnerable to. Durability typically involves writing to disk storage, with a certain amount of redundancy to protect against power failures or software crashes during write operations. (In InnoDB, the doublewrite buffer assists with durability.)
See Also atomic, commit, concurrency, doublewrite buffer, isolation level, locking, rollback, transaction.

adaptive flushing
An algorithm for InnoDB tables that smooths out the I/O overhead introduced by checkpoints. Instead of flushing all modified pages from the buffer pool to the data files at once, MySQL periodically flushes small sets of modified pages. The adaptive flushing algorithm extends this process by estimating the optimal rate to perform these periodic flushes, based on the rate of flushing and how fast redo information is generated.
See Also buffer pool, checkpoint, data files, flush, InnoDB, page, redo log.

adaptive hash index
An optimization for InnoDB tables that can speed up lookups using = and IN operators, by constructing a hash index in memory. MySQL monitors index searches for InnoDB tables, and if queries could benefit from a hash index, it builds one automatically for index pages that are frequently accessed. In a sense, the adaptive hash index configures MySQL at runtime to take advantage of ample main memory, coming closer to the architecture
of main-memory databases. This feature is controlled by the `innodb_adaptive_hash_index` configuration option. Because this feature benefits some workloads and not others, and the memory used for the hash index is reserved in the buffer pool, typically you should benchmark with this feature both enabled and disabled.

The hash index is always built based on an existing B-tree index on the table. MySQL can build a hash index on a prefix of any length of the key defined for the B-tree, depending on the pattern of searches against the index. A hash index can be partial; the whole B-tree index does not need to be cached in the buffer pool.

In MySQL 5.6 and higher, another way to take advantage of fast single-value lookups with InnoDB tables is to use the InnoDB memcached plugin. See InnoDB memcached Plugin for details. See Also B-tree, buffer pool, hash index, memcached, page, secondary index.

AIO
Acronym for asynchronous I/O. You might see this acronym in InnoDB messages or keywords. See Also asynchronous I/O.

Antelope
The code name for the original InnoDB file format. It supports the REDUNDANT and COMPACT row formats, but not the newer DYNAMIC and COMPRESSED row formats available in the Barracuda file format. See Also Barracuda, compact row format, compressed row format, dynamic row format, file format, innodb_file_format, redundant row format.

application programming interface (API)
A set of functions or procedures. An API provides a stable set of names and types for functions, procedures, parameters, and return values.

apply
When a backup produced by the MySQL Enterprise Backup product does not include the most recent changes that occurred while the backup was underway, the process of updating the backup files to include those changes is known as the apply step. It is specified by the apply-log option of the mysqlbackup command.

Before the changes are applied, we refer to the files as a raw backup. After the changes are applied, we refer to the files as a prepared backup. The changes are recorded in the ibbackup_logfile file; once the apply step is finished, this file is no longer necessary.

See Also hot backup, ibbackup_logfile, MySQL Enterprise Backup, prepared backup, raw backup.

asynchronous I/O
A type of I/O operation that allows other processing to proceed before the I/O is completed. Also known as nonblocking I/O and abbreviated as AIO. InnoDB uses this type of I/O for certain operations that can run in parallel without affecting the reliability of the database, such as reading pages into the buffer pool that have not actually been requested, but might be needed soon.

Historically, InnoDB used asynchronous I/O on Windows systems only. Starting with the InnoDB Plugin 1.1 and MySQL 5.5, InnoDB uses asynchronous I/O on Linux systems. This change introduces a dependency on libaio. Asynchronous I/O on Linux systems is configured using the innodb_use_native_aio option, which is enabled by default. On other Unix-like systems, InnoDB uses synchronous I/O only.

See Also buffer pool, nonblocking I/O.

atomic
In the SQL context, transactions are units of work that either succeed entirely (when committed) or have no effect at all (when rolled back). The indivisible ("atomic") property of transactions is the “A” in the acronym ACID. See Also ACID, commit, rollback, transaction.

atomic DDL
An atomic DDL statement is one that combines the data dictionary updates, storage engine operations, and binary log writes associated with a DDL operation into a single, atomic transaction. The transaction is either fully
committed or rolled back, even if the server halts during the operation. Atomic DDL support was added in MySQL 8.0. For more information, see Atomic Data Definition Statement Support. See Also binary log, data dictionary, DDL, storage engine.

atomic instruction
Special instructions provided by the CPU, to ensure that critical low-level operations cannot be interrupted.

auto-increment
A property of a table column (specified by the AUTO_INCREMENT keyword) that automatically adds an ascending sequence of values in the column.

It saves work for the developer, not to have to produce new unique values when inserting new rows. It provides useful information for the query optimizer, because the column is known to be not null and with unique values. The values from such a column can be used as lookup keys in various contexts, and because they are auto-generated there is no reason to ever change them; for this reason, primary key columns are often specified as auto-incrementing.

Auto-increment columns can be problematic with statement-based replication, because replaying the statements on a slave might not produce the same set of column values as on the master, due to timing issues. When you have an auto-incrementing primary key, you can use statement-based replication only with the setting innodb_autoinc_lock_mode=1. If you have innodb_autoinc_lock_mode=2, which allows higher concurrency for insert operations, use row-based replication rather than statement-based replication. The setting innodb_autoinc_lock_mode=0 should not be used except for compatibility purposes.

Consecutive lock mode (innodb_autoinc_lock_mode=1) is the default setting prior to MySQL 8.0.3. As of MySQL 8.0.3, interleaved lock mode (innodb_autoinc_lock_mode=2) is the default, which reflects the change from statement-based to row-based replication as the default replication type. See Also auto-increment locking, innodb_autoinc_lock_mode, primary key, row-based replication, statement-based replication.

auto-increment locking
The convenience of an auto-increment primary key involves some tradeoff with concurrency. In the simplest case, if one transaction is inserting values into the table, any other transactions must wait to do their own inserts into that table, so that rows inserted by the first transaction receive consecutive primary key values. InnoDB includes optimizations and the innodb_autoinc_lock_mode option so that you can configure and optimal balance between predictable sequences of auto-increment values and maximum concurrency for insert operations.

See Also auto-increment, concurrency, innodb_autoinc_lock_mode.

autocommit
A setting that causes a commit operation after each SQL statement. This mode is not recommended for working with InnoDB tables with transactions that span several statements. It can help performance for read-only transactions on InnoDB tables, where it minimizes overhead from locking and generation of undo data, especially in MySQL 5.6.4 and up. It is also appropriate for working with MyISAM tables, where transactions are not applicable.

See Also commit, locking, read-only transaction, SQL, transaction, undo.

availability
The ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware and maintenance activity that may otherwise cause downtime. Often paired with scalability as critical aspects of a large-scale deployment.

See Also scalability.
B-tree
A tree data structure that is popular for use in database indexes. The structure is kept sorted at all times, enabling fast lookup for exact matches (equals operator) and ranges (for example, greater than, less than, and BETWEEN operators). This type of index is available for most storage engines, such as InnoDB and MyISAM.

Because B-tree nodes can have many children, a B-tree is not the same as a binary tree, which is limited to 2 children per node.

Contrast with hash index, which is only available in the MEMORY storage engine. The MEMORY storage engine can also use B-tree indexes, and you should choose B-tree indexes for MEMORY tables if some queries use range operators.

The use of the term B-tree is intended as a reference to the general class of index design. B-tree structures used by MySQL storage engines may be regarded as variants due to sophistications not present in a classic B-tree design. For related information, refer to the InnoDB Page Structure Fil Header section of the MySQL Internals Manual.
See Also hash index.

backticks
Identifiers within MySQL SQL statements must be quoted using the backtick character (` `) if they contain special characters or reserved words. For example, to refer to a table named FOO#BAR or a column named SELECT, you would specify the identifiers as `FOO#BAR` and `SELECT`. Since the backticks provide an extra level of safety, they are used extensively in program-generated SQL statements, where the identifier names might not be known in advance.

Many other database systems use double quotation marks (" ") around such special names. For portability, you can enable ANSI_QUOTES mode in MySQL and use double quotation marks instead of backticks to qualify identifier names.
See Also SQL.

backup
The process of copying some or all table data and metadata from a MySQL instance, for safekeeping. Can also refer to the set of copied files. This is a crucial task for DBAs. The reverse of this process is the restore operation.

With MySQL, physical backups are performed by the MySQL Enterprise Backup product, and logical backups are performed by the mysqldump command. These techniques have different characteristics in terms of size and representation of the backup data, and speed (especially speed of the restore operation).

Backups are further classified as hot, warm, or cold depending on how much they interfere with normal database operation. (Hot backups have the least interference, cold backups the most.)
See Also cold backup, hot backup, logical backup, MySQL Enterprise Backup, mysqldump, physical backup, warm backup.

Barracuda
The code name for an InnoDB file format that supports the COMPRESSED row format that enables InnoDB table compression, and the DYNAMIC row format that improves the storage layout for long variable-length columns.

The MySQL Enterprise Backup product version 3.5 and above supports backing up tablespaces that use the Barracuda file format.
See Also Antelope, compact row format, compressed row format, dynamic row format, file format, file-per-table, general tablespace, innodb_file_format, MySQL Enterprise Backup, row format, system tablespace.
**beta**

An early stage in the life of a software product, when it is available only for evaluation, typically without a definite release number or a number less than 1. *InnoDB* does not use the beta designation, preferring an early adopter phase that can extend over several point releases, leading to a GA release.

See Also early adopter, GA.

**binary log**

A file containing a record of all statements that attempt to change table data. These statements can be replayed to bring slave servers up to date in a replication scenario, or to bring a database up to date after restoring table data from a backup. The binary logging feature can be turned on and off, although Oracle recommends always enabling it if you use replication or perform backups.

You can examine the contents of the binary log, or replay those statements during replication or recovery, by using the `mysqlbinlog` command. For full information about the binary log, see Section 5.4.4, “The Binary Log”. For MySQL configuration options related to the binary log, see Section 17.1.3.4, “Binary Log Options and Variables”.

For the *MySQL Enterprise Backup* product, the file name of the binary log and the current position within the file are important details. To record this information for the master server when taking a backup in a replication context, you can specify the `--slave-info` option.

Prior to MySQL 5.0, a similar capability was available, known as the update log. In MySQL 5.0 and higher, the binary log replaces the update log.

See Also binlog, MySQL Enterprise Backup, replication.

**binlog**

An informal name for the binary log file. For example, you might see this abbreviation used in e-mail messages or forum discussions.

See Also binary log.

**blind query expansion**

A special mode of full-text search enabled by the WITH QUERY EXPANSION clause. It performs the search twice, where the search phrase for the second search is the original search phrase concatenated with the few most highly relevant documents from the first search. This technique is mainly applicable for short search phrases, perhaps only a single word. It can uncover relevant matches where the precise search term does not occur in the document.

See Also full-text search.

**bottleneck**

A portion of a system that is constrained in size or capacity, that has the effect of limiting overall throughput. For example, a memory area might be smaller than necessary; access to a single required resource might prevent multiple CPU cores from running simultaneously; or waiting for disk I/O to complete might prevent the CPU from running at full capacity. Removing bottlenecks tends to improve concurrency. For example, the ability to have multiple *InnoDB* buffer pool instances reduces contention when multiple sessions read from and write to the buffer pool simultaneously.

See Also buffer pool, concurrency.

**bounce**

A shutdown operation immediately followed by a restart. Ideally with a relatively short warmup period so that performance and throughput quickly return to a high level.

See Also shutdown.

**buddy allocator**

A mechanism for managing different-sized pages in the *InnoDB* buffer pool.

See Also buffer pool, page, page size.
buffer
A memory or disk area used for temporary storage. Data is buffered in memory so that it can be written to disk efficiently, with a few large I/O operations rather than many small ones. Data is buffered on disk for greater reliability, so that it can be recovered even when a crash or other failure occurs at the worst possible time. The main types of buffers used by InnoDB are the buffer pool, the doublewrite buffer, and the change buffer. See Also buffer pool, change buffer, crash, doublewrite buffer.

buffer pool
The memory area that holds cached InnoDB data for both tables and indexes. For efficiency of high-volume read operations, the buffer pool is divided into pages that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the LRU algorithm. On systems with large memory, you can improve concurrency by dividing the buffer pool into multiple buffer pool instances.

Several InnoDB status variables, INFORMATION_SCHEMA tables, and performance_schema tables help to monitor the internal workings of the buffer pool. Starting in MySQL 5.6, you can avoid a lengthy warmup period after restarting the server, particularly for instances with large buffer pools, by saving the buffer pool state at server shutdown and restoring the buffer pool to the same state at server startup. See Saving and Restoring the Buffer Pool State. See Also buffer pool instance, LRU, page, warm up.

buffer pool instance
Any of the multiple regions into which the buffer pool can be divided, controlled by the innodb_buffer_pool_instances configuration option. The total memory size specified by innodb_buffer_pool_size is divided among all buffer pool instances. Typically, having multiple buffer pool instances is appropriate for systems that allocate multiple gigabytes to the InnoDB buffer pool, with each instance being one gigabyte or larger. On systems loading or looking up large amounts of data in the buffer pool from many concurrent sessions, having multiple buffer pool instances reduces contention for exclusive access to data structures that manage the buffer pool. See Also buffer pool.

built-in
The built-in InnoDB storage engine within MySQL is the original form of distribution for the storage engine. Contrast with the InnoDB Plugin. Starting with MySQL 5.5, the InnoDB Plugin is merged back into the MySQL code base as the built-in InnoDB storage engine (known as InnoDB 1.1).

This distinction is important mainly in MySQL 5.1, where a feature or bug fix might apply to the InnoDB Plugin but not the built-in InnoDB, or vice versa. See Also InnoDB.

business rules
The relationships and sequences of actions that form the basis of business software, used to run a commercial company. Sometimes these rules are dictated by law, other times by company policy. Careful planning ensures that the relationships encoded and enforced by the database, and the actions performed through application logic, accurately reflect the real policies of the company and can handle real-life situations.

For example, an employee leaving a company might trigger a sequence of actions from the human resources department. The human resources database might also need the flexibility to represent data about a person who has been hired, but not yet started work. Closing an account at an online service might result in data being removed from a database, or the data might be moved or flagged so that it could be recovered if the account is re-opened. A company might establish policies regarding salary maximums, minimums, and adjustments, in addition to basic sanity checks such as the salary not being a negative number. A retail database might not allow a purchase with the same serial number to be returned more than once, or might not allow credit card purchases above a certain value, while a database used to detect fraud might allow these kinds of things.
See Also relational.

C

cfg file
A metadata file used with the InnoDB transportable tablespace feature. It is produced by the command FLUSH TABLES ... FOR EXPORT, puts one or more tables in a consistent state that can be copied to another server. The .cfg file is copied along with the corresponding .ibd file, and used to adjust the internal values of the .ibd file, such as the space ID, during the ALTER TABLE ... IMPORT TABLESPACE step. See Also .ibd file, space ID, transportable tablespace.

cache
The general term for any memory area that stores copies of data for frequent or high-speed retrieval. In InnoDB, the primary kind of cache structure is the buffer pool. See Also buffer, buffer pool.

cardinality
The number of different values in a table column. When queries refer to columns that have an associated index, the cardinality of each column influences which access method is most efficient. For example, for a column with a unique constraint, the number of different values is equal to the number of rows in the table. If a table has a million rows but only 10 different values for a particular column, each value occurs (on average) 100,000 times. A query such as SELECT c1 FROM t1 WHERE c1 = 50; thus might return 1 row or a huge number of rows, and the database server might process the query differently depending on the cardinality of c1.

If the values in a column have a very uneven distribution, the cardinality might not be a good way to determine the best query plan. For example, SELECT c1 FROM t1 WHERE c1 = x; might return 1 row when x=50 and a million rows when x=30. In such a case, you might need to use index hints to pass along advice about which lookup method is more efficient for a particular query.

Cardinality can also apply to the number of distinct values present in multiple columns, as in a composite index. See Also column, composite index, index, index hint, random dive, selectivity, unique constraint.

cache buffer
A special data structure that records changes to pages in secondary indexes. These values could result from SQL INSERT, UPDATE, or DELETE statements (DML). The set of features involving the change buffer is known collectively as change buffering, consisting of insert buffering, delete buffering, and purge buffering.

Changes are only recorded in the change buffer when the relevant page from the secondary index is not in the buffer pool. When the relevant index page is brought into the buffer pool while associated changes are still in the change buffer, the changes for that page are applied in the buffer pool (merged) using the data from the change buffer. Periodically, the purge operation that runs during times when the system is mostly idle, or during a slow shutdown, writes the new index pages to disk. The purge operation can write the disk blocks for a series of index values more efficiently than if each value were written to disk immediately.

Physically, the change buffer is part of the system tablespace, so that the index changes remain buffered across database restarts. The changes are only applied (merged) when the pages are brought into the buffer pool due to some other read operation.

The kinds and amount of data stored in the change buffer are governed by the innodb_change_buffering and innodb_change_buffer_max_size configuration options. To see information about the current data in the change buffer, issue the SHOW ENGINE INNODB STATUS command.

Formerly known as the insert buffer. See Also buffer pool, change buffering, delete buffering, DML, insert buffer, insert buffering, merge, page, purge, purge buffering, secondary index, system tablespace.
change buffering
The general term for the features involving the change buffer, consisting of insert buffering, delete buffering, and purge buffering. Index changes resulting from SQL statements, which could normally involve random I/O operations, are held back and performed periodically by a background thread. This sequence of operations can write the disk blocks for a series of index values more efficiently than if each value were written to disk immediately. Controlled by the innodb_change_buffering and innodb_change_buffer_max_size configuration options.
See Also change buffer, delete buffering, insert buffering, purge buffering.

checkpoint
As changes are made to data pages that are cached in the buffer pool, those changes are written to the data files sometime later, a process known as flushing. The checkpoint is a record of the latest changes (represented by an LSN value) that have been successfully written to the data files.
See Also buffer pool, data files, flush, fuzzy checkpointing, LSN.

checksum
In InnoDB, a validation mechanism to detect corruption when a page in a tablespace is read from disk into the InnoDB buffer pool. This feature is controlled by the innodb_checksums configuration option in MySQL 5.5. innodb_checksums is deprecated in MySQL 5.6.3, replaced by innodb_checksum_algorithm.

The innochecksum command helps diagnose corruption problems by testing the checksum values for a specified tablespace file while the MySQL server is shut down.

MySQL also uses checksums for replication purposes. For details, see the configuration options binlog_checksum, master_verify_checksum, and slave_sql_verify_checksum. See Also buffer pool, page, checksum.

child table
In a foreign key relationship, a child table is one whose rows refer (or point) to rows in another table with an identical value for a specific column. This is the table that contains the FOREIGN KEY ... REFERENCES clause and optionally ON UPDATE and ON DELETE clauses. The corresponding row in the parent table must exist before the row can be created in the child table. The values in the child table can prevent delete or update operations on the parent table, or can cause automatic deletion or updates in the child table, based on the ON CASCADE option used when creating the foreign key.
See Also foreign key, parent table.

clean page
A page in the InnoDB buffer pool where all changes made in memory have also been written (flushed) to the data files. The opposite of a dirty page.
See Also buffer pool, data files, dirty page, flush, page.

clean shutdown
A shutdown that completes without errors and applies all changes to InnoDB tables before finishing, as opposed to a crash or a fast shutdown. Synonym for slow shutdown.
See Also crash, fast shutdown, shutdown, slow shutdown.

client
A type of program that sends requests to a server, and interprets or processes the results. The client software might run only some of the time (such as a mail or chat program), and might run interactively (such as the mysql command processor).
See Also mysql, server.

clustered index
The InnoDB term for a primary key index. InnoDB table storage is organized based on the values of the primary key columns, to speed up queries and sorts involving the primary key columns. For best performance, choose the primary key columns carefully based on the most performance-critical queries. Because modifying
the columns of the clustered index is an expensive operation, choose primary columns that are rarely or never updated.

In the Oracle Database product, this type of table is known as an index-organized table.
See Also index, primary key, secondary index.

cold backup
A backup taken while the database is shut down. For busy applications and websites, this might not be practical, and you might prefer a warm backup or a hot backup.
See Also backup, hot backup, warm backup.

column
A data item within a row, whose storage and semantics are defined by a data type. Each table and index is largely defined by the set of columns it contains.

Each column has a cardinality value. A column can be the primary key for its table, or part of the primary key. A column can be subject to a unique constraint, a NOT NULL constraint, or both. Values in different columns, even across different tables, can be linked by a foreign key relationship.

In discussions of MySQL internal operations, sometimes field is used as a synonym.
See Also cardinality, foreign key, index, NOT NULL constraint, primary key, row, table, unique constraint.

column index
An index on a single column.
See Also composite index, index.

column prefix
When an index is created with a length specification, such as CREATE INDEX idx ON t1 (c1(N)), only the first N characters of the column value are stored in the index. Keeping the index prefix small makes the index compact, and the memory and disk I/O savings help performance. (Although making the index prefix too small can hinder query optimization by making rows with different values appear to the query optimizer to be duplicates.)

For columns containing binary values or long text strings, where sorting is not a major consideration and storing the entire value in the index would waste space, the index automatically uses the first N (typically 768) characters of the value to do lookups and sorts.
See Also index.

commit
A SQL statement that ends a transaction, making permanent any changes made by the transaction. It is the opposite of rollback, which undoes any changes made in the transaction.

InnoDB uses an optimistic mechanism for commits, so that changes can be written to the data files before the commit actually occurs. This technique makes the commit itself faster, with the tradeoff that more work is required in case of a rollback.

By default, MySQL uses the autocommit setting, which automatically issues a commit following each SQL statement.
See Also autocommit, optimistic, rollback, SQL, transaction.

compact row format
The default InnoDB row format for InnoDB tables since MySQL 5.0.3. The COMPACT row format provides a more compact representation for nulls and variable-length columns than the prior default (REduNDant row format).

For additional information about InnoDB COMPACT row format, see Section 14.14, "InnoDB Row Formats".
See Also Antelope, dynamic row format, file format, redundant row format, row format.
composite index

An index that includes multiple columns.
See Also index.

compressed backup

The compression feature of the MySQL Enterprise Backup product makes a compressed copy of each tablespace, changing the extension from .ibd to .ibz. Compressing backup data allows you to keep more backups on hand, and reduces the time to transfer backups to a different server. The data is uncompressed during the restore operation. When a compressed backup operation processes a table that is already compressed, it skips the compression step for that table, because compressing again would result in little or no space savings.

A set of files produced by the MySQL Enterprise Backup product, where each tablespace is compressed. The compressed files are renamed with a .ibz file extension.

Applying compression at the start of the backup process helps to avoid storage overhead during the compression process, and to avoid network overhead when transferring the backup files to another server. The process of applying the binary log takes longer, and requires uncompressing the backup files.
See Also apply, binary log, compression, hot backup, MySQL Enterprise Backup, tablespace.

compressed row format

A row format that enables data and index compression for InnoDB tables. It was introduced in the InnoDB Plugin, available as part of the Barracuda file format. Large fields are stored away from the page that holds the rest of the row data, as in dynamic row format. Both index pages and large fields are compressed, yielding memory and disk savings. Depending on the structure of the data, the decrease in memory and disk usage might or might not outweigh the performance overhead of uncompressing the data as it is used. See Section 14.12, “InnoDB Table Compression” for usage details.

For additional information about InnoDB COMPRESSED row format, see DYNAMIC Row Format.
See Also Barracuda, compression, dynamic row format, row format.

compressed table

A table for which the data is stored in compressed form. For InnoDB, it is a table created with ROW_FORMAT=COMPRESSED. See Section 14.12, “InnoDB Table Compression” for more information.
See Also compressed row format, compression.

compression

A feature with wide-ranging benefits from using less disk space, performing less I/O, and using less memory for caching. InnoDB table and index data can be kept in a compressed format during database operation.

The data is uncompresses when needed for queries, and re-compressed when changes are made by DML operations. After you enable compression for a table, this processing is transparent to users and application developers. DBAs can consult InnoDB INFORMATION_SCHEMA tables to monitor how efficiently the compression parameters work for the MySQL instance and for particular compressed tables.

When InnoDB table data is compressed, the compression applies to the table itself, any associated index data, and the pages loaded into the buffer pool. Compression does not apply to pages in the undo buffer.

The table compression feature requires using MySQL 5.5 or higher, or the InnoDB Plugin in MySQL 5.1 or earlier, and creating the table using the Barracuda file format and compressed row format, with the innodb_file_per_table setting enabled.

Compression for each table is influenced by the KEY_BLOCK_SIZE clause of the CREATE TABLE and ALTER TABLE statements. In MySQL 5.6 and higher, compression is also affected by the server-wide configuration options innodb_compression_failure_threshold_pct, innodb_compression_level, and innodb_compression_pad_pct_max. See Section 14.12, “InnoDB Table Compression” for usage details.

Another type of compression is the compressed backup feature of the MySQL Enterprise Backup product.
See Also Barracuda, buffer pool, compressed backup, compressed row format, DML, transparent page compression.

**compression failure**

Not actually an error, rather an expensive operation that can occur when using compression in combination with DML operations. It occurs when: updates to a compressed page overflow the area on the page reserved for recording modifications; the page is compressed again, with all changes applied to the table data; the re-compressed data does not fit on the original page, requiring MySQL to split the data into two new pages and compress each one separately. To check the frequency of this condition, query the INFORMATION_SCHEMA.INNODB_CMP table and check how much the value of the COMPRESS_OPS column exceeds the value of the COMPRESS_OPS_OK column. Ideally, compression failures do not occur often; when they do, you can adjust the innodb_compression_level, innodb_compression_failure_threshold_pct, and innodb_compression_pad_pct_max configuration options.

See Also compression, DML, page.

**concatenated index**

See composite index.

**concurrency**

The ability of multiple operations (in database terminology, transactions) to run simultaneously, without interfering with each other. Concurrency is also involved with performance, because ideally the protection for multiple simultaneous transactions works with a minimum of performance overhead, using efficient mechanisms for locking.

See Also ACID, locking, transaction.

**configuration file**

The file that holds the option values used by MySQL at startup. Traditionally, on Linux and Unix this file is named my.cnf, and on Windows it is named my.ini. You can set a number of options related to InnoDB under the [mysqld] section of the file.

See Section 4.2.2.2, “Using Option Files” for information about where MySQL searches for configuration files.

When you use the MySQL Enterprise Backup product, you typically use two configuration files: one that specifies where the data comes from and how it is structured (which could be the original configuration file for your server), and a stripped-down one containing only a small set of options that specify where the backup data goes and how it is structured. The configuration files used with the MySQL Enterprise Backup product must contain certain options that are typically left out of regular configuration files, so you might need to add options to your existing configuration file for use with MySQL Enterprise Backup.

See Also my.cnf, MySQL Enterprise Backup, option, option file.

**consistent read**

A read operation that uses snapshot information to present query results based on a point in time, regardless of changes performed by other transactions running at the same time. If queried data has been changed by another transaction, the original data is reconstructed based on the contents of the undo log. This technique avoids some of the locking issues that can reduce concurrency by forcing transactions to wait for other transactions to finish.

With REPEATABLE READ isolation level, the snapshot is based on the time when the first read operation is performed. With READ COMMITTED isolation level, the snapshot is reset to the time of each consistent read operation.

Consistent read is the default mode in which InnoDB processes SELECT statements in READ COMMITTED and REPEATABLE READ isolation levels. Because a consistent read does not set any locks on the tables it accesses, other sessions are free to modify those tables while a consistent read is being performed on the table.

For technical details about the applicable isolation levels, see Section 14.10.2.3, “Consistent Nonlocking Reads”. See Also concurrency, isolation level, locking, READ COMMITTED, REPEATABLE READ, snapshot, transaction, undo log.
constraint
An automatic test that can block database changes to prevent data from becoming inconsistent. (In computer science terms, a kind of assertion related to an invariant condition.) Constraints are a crucial component of the ACID philosophy, to maintain data consistency. Constraints supported by MySQL include FOREIGN KEY constraints and unique constraints. See Also ACID, foreign key, unique constraint.

counter
A value that is incremented by a particular kind of InnoDB operation. Useful for measuring how busy a server is, troubleshooting the sources of performance issues, and testing whether changes (for example, to configuration settings or indexes used by queries) have the desired low-level effects. Different kinds of counters are available through Performance Schema tables and INFORMATION_SCHEMA tables, particularly INFORMATION_SCHEMA.INNODB_METRICS. See Also INFORMATION_SCHEMA, metrics counter, Performance Schema.

covering index
An index that includes all the columns retrieved by a query. Instead of using the index values as pointers to find the full table rows, the query returns values from the index structure, saving disk I/O. InnoDB can apply this optimization technique to more indexes than MyISAM can, because InnoDB secondary indexes also include the primary key columns. InnoDB cannot apply this technique for queries against tables modified by a transaction, until that transaction ends.

Any column index or composite index could act as a covering index, given the right query. Design your indexes and queries to take advantage of this optimization technique wherever possible. See Also column index, composite index, index, primary key, secondary index.

CPU-bound
A type of workload where the primary bottleneck is CPU operations in memory. Typically involves read-intensive operations where the results can all be cached in the buffer pool. See Also bottleneck, buffer pool, workload.

crash
MySQL uses the term “crash” to refer generally to any unexpected shutdown operation where the server cannot do its normal cleanup. For example, a crash could happen due to a hardware fault on the database server machine or storage device; a power failure; a potential data mismatch that causes the MySQL server to halt; a fast shutdown initiated by the DBA; or many other reasons. The robust, automatic crash recovery for InnoDB tables ensures that data is made consistent when the server is restarted, without any extra work for the DBA. See Also crash recovery, fast shutdown, InnoDB, shutdown.

crash recovery
The cleanup activities that occur when MySQL is started again after a crash. For InnoDB tables, changes from incomplete transactions are replayed using data from the redo log. Changes that were committed before the crash, but not yet written into the data files, are reconstructed from the doublewrite buffer. When the database is shut down normally, this type of activity is performed during shutdown by the purge operation.

During normal operation, committed data can be stored in the change buffer for a period of time before being written to the data files. There is always a tradeoff between keeping the data files up-to-date, which introduces performance overhead during normal operation, and buffering the data, which can make shutdown and crash recovery take longer. See Also change buffer, commit, crash, data files, doublewrite buffer, InnoDB, purge, redo log.

CRUD
Acronym for “create, read, update, delete”, a common sequence of operations in database applications. Often denotes a class of applications with relatively simple database usage (basic DDL, DML and query statements in SQL) that can be implemented quickly in any language.
See Also DDL, DML, query, SQL.

cursor
An internal data structure that is used to represent the result set of a query, or other operation that performs a search using an SQL WHERE clause. It works like an iterator in other high-level languages, producing each value from the result set as requested.

Although SQL usually handles the processing of cursors for you, you might delve into the inner workings when dealing with performance-critical code.
See Also query.

data definition language
See DDL.

data dictionary
Metadata that keeps track of InnoDB-related objects such as tables, indexes, and table columns. This metadata is physically located in the InnoDB system tablespace. For historical reasons, it overlaps to some degree with information stored in the .frm files.

Because the MySQL Enterprise Backup product always backs up the system tablespace, all backups include the contents of the data dictionary.
See Also column, file-per-table, .frm file, index, MySQL Enterprise Backup, system tablespace, table.

data directory
The directory under which each MySQL instance keeps the data files for InnoDB and the directories representing individual databases. Controlled by the datadir configuration option.
See Also data files, instance.

data files
The files that physically contain table and index data.

The InnoDB system tablespace, which holds the InnoDB data dictionary and is capable of holding data for multiple InnoDB tables, is represented by one or more .ibdata data files.

File-per-table tablespaces, which hold data for a single InnoDB table, are represented by a .ibd data file.

General tablespaces (introduced in MySQL 5.7.6), which can hold data for multiple InnoDB tables, are also represented by a .ibd data file.
See Also data dictionary, file-per-table, general tablesapce, .ibd file, ibdata file, index, system tablespace, table, tablespace.

data manipulation language
See DML.

data warehouse
A database system or application that primarily runs large queries. The read-only or read-mostly data might be organized in denormalized form for query efficiency. Can benefit from the optimizations for read-only transactions in MySQL 5.6 and higher. Contrast with OLTP.
See Also denormalized, OLTP, query, read-only transaction.

data base
Within the MySQL data directory, each database is represented by a separate directory. The InnoDB system tablespace, which can hold table data from multiple databases within a MySQL instance, is kept in data files.
that reside outside of individual database directories. When **file-per-table** mode is enabled, the `.ibd files` representing individual InnoDB tables are stored inside the database directories unless created elsewhere using the `DATA DIRECTORY` clause. General tablespaces, introduced in MySQL 5.7.6, also hold table data in `.ibd files`. Unlike file-per-table `.ibd files`, general tablespace `.ibd files` can hold table data from multiple databases within a MySQL instance, and can be assigned to directories relative to or independent of the MySQL data directory.

For long-time MySQL users, a database is a familiar notion. Users coming from an Oracle Database background will find that the MySQL meaning of a database is closer to what Oracle Database calls a **schema**.

See Also data files, file-per-table, `.ibd file`, instance, schema, system tablespace.

**DCL**

Data control language, a set of **SQL** statements for managing privileges. In MySQL, consists of the `GRANT` and `REVOKE` statements. Contrast with **DDL** and **DML**.

See Also **DDL**, **DML**, **SQL**.

**DDL**

Data definition language, a set of **SQL** statements for manipulating the database itself rather than individual table rows. Includes all forms of the `CREATE`, `ALTER`, and `DROP` statements. Also includes the `TRUNCATE` statement, because it works differently than a `DELETE FROM table_name` statement, even though the ultimate effect is similar.

DDL statements automatically **commit** the current transaction; they cannot be **rolled back**.

The **InnoDB online DDL** feature enhances performance for `CREATE INDEX`, `DROP INDEX`, and many types of `ALTER TABLE` operations. See **InnoDB and Online DDL** for more information. Also, the **InnoDB file-per-table** setting can affect the behavior of `DROP TABLE` and `TRUNCATE TABLE` operations.

Contrast with **DML** and **DCL**.

See Also **commit**, **DCL**, **DML**, file-per-table, rollback, SQL, transaction.

deadlock

A situation where different transactions are unable to proceed, because each holds a lock that the other needs. Because both transactions are waiting for a resource to become available, neither will ever release the locks it holds.

A deadlock can occur when the transactions lock rows in multiple tables (through statements such as `UPDATE` or `SELECT ... FOR UPDATE`), but in the opposite order. A deadlock can also occur when such statements lock ranges of index records and gaps, with each transaction acquiring some locks but not others due to a timing issue.

For background information on how deadlocks are automatically detected and handled, see Section 14.10.5.2, “Deadlock Detection and Rollback”. For tips on avoiding and recovering from deadlock conditions, see Section 14.10.5.3, “How to Minimize and Handle Deadlocks”.

See Also gap, lock, transaction.

deadlock detection

A mechanism that automatically detects when a **deadlock** occurs, and automatically **rolls back** one of the transactions involved (the **victim**).

See Also deadlock, rollback, transaction, victim.

delete

When **InnoDB** processes a `DELETE` statement, the rows are immediately marked for deletion and no longer are returned by queries. The storage is reclaimed sometime later, during the periodic garbage collection known as the **purge** operation. For removing large quantities of data, related operations with their own performance characteristics are **TRUNCATE** and **DROP**.
delete buffering
The technique of storing changes to secondary index pages, resulting from DELETE operations, in the change buffer rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. (Because delete operations are a two-step process, this operation buffers the write that normally marks an index record for deletion.) It is one of the types of change buffering; the others are insert buffering and purge buffering.
See Also change buffer, change buffering, insert buffer, insert buffering, purge buffering.

denormalized
A data storage strategy that duplicates data across different tables, rather than linking the tables with foreign keys and join queries. Typically used in data warehouse applications, where the data is not updated after loading. In such applications, query performance is more important than making it simple to maintain consistent data during updates. Contrast with normalized.
See Also data warehouse, foreign key, join, normalized.

descending index
A type of index available with some database systems, where index storage is optimized to process ORDER BY column DESC clauses. Currently, although MySQL allows the DESC keyword in the CREATE TABLE statement, it does not use any special storage layout for the resulting index.
See Also index.

dirty page
A page in the InnoDB buffer pool that has been updated in memory, where the changes are not yet written (flushed) to the data files. The opposite of a clean page.
See Also buffer pool, clean page, data files, flush, page.

dirty read
An operation that retrieves unreliable data, data that was updated by another transaction but not yet committed. It is only possible with the isolation level known as read uncommitted.
This kind of operation does not adhere to the ACID principle of database design. It is considered very risky, because the data could be rolled back, or updated further before being committed; then, the transaction doing the dirty read would be using data that was never confirmed as accurate.
Its opposite is consistent read, where InnoDB ensures that a transaction does not read information updated by another transaction, even if the other transaction commits in the meantime.
See Also ACID, commit, consistent read, isolation level, READ UNCOMMITTED, rollback.

disk-based
A kind of database that primarily organizes data on disk storage (hard drives or equivalent). Data is brought back and forth between disk and memory to be operated upon. It is the opposite of an in-memory database. Although InnoDB is disk-based, it also contains features such as the buffer pool, multiple buffer pool instances, and the adaptive hash index that allow certain kinds of workloads to work primarily from memory.
See Also adaptive hash index, buffer pool, in-memory database.

disk-bound
A type of workload where the primary bottleneck is disk I/O. (Also known as I/O-bound.) Typically involves frequent writes to disk, or random reads of more data than can fit into the buffer pool.
See Also bottleneck, buffer pool, workload.

DML
Data manipulation language, a set of SQL statements for performing INSERT, UPDATE, and DELETE operations. The SELECT statement is sometimes considered as a DML statement, because the SELECT ... FOR UPDATE form is subject to the same considerations for locking as INSERT, UPDATE, and DELETE.
DML statements for an InnoDB table operate in the context of a transaction, so their effects can be committed or rolled back as a single unit.

Contrast with DDL and DCL.
See Also commit, DCL, DDL, locking, rollback, SQL, transaction.

document id
In the InnoDB full-text search feature, a special column in the table containing the FULLTEXT index, to uniquely identify the document associated with each ilist value. Its name is FTS_DOC_ID (uppercase required). The column itself must be of BIGINT UNSIGNED NOT NULL type, with a unique index named FTS_DOC_ID_INDEX. Preferably, you define this column when creating the table. If InnoDB must add the column to the table while creating a FULLTEXT index, the indexing operation is considerably more expensive.
See Also full-text search, FULLTEXT index, ilist.

doublewrite buffer
InnoDB uses a file flush technique called doublewrite. Before writing pages to the data files, InnoDB first writes them to a storage area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer have completed, does InnoDB write the pages to their proper positions in the data file. If there is an operating system, storage subsystem, or mysqld process crash in the middle of a page write, InnoDB can later find a good copy of the page from the doublewrite buffer during crash recovery.

Although data is always written twice, the doublewrite buffer does not require twice as much I/O overhead or twice as many I/O operations. Data is written to the buffer itself as a large sequential chunk, with a single fsync() call to the operating system.

To turn off the doublewrite buffer, specify the option innodb_doublewrite=0.
See Also crash recovery, data files, page, purge.

drop
A kind of DDL operation that removes a schema object, through a statement such as DROP TABLE or DROP INDEX. It maps internally to an ALTER TABLE statement. From an InnoDB perspective, the performance considerations of such operations involve the time that the data dictionary is locked to ensure that interrelated objects are all updated, and the time to update memory structures such as the buffer pool. For a table, the drop operation has somewhat different characteristics than a truncate operation (TRUNCATE TABLE statement).
See Also buffer pool, data dictionary, DDL, table, truncate.

dynamic row format
A row format introduced in the InnoDB Plugin, available as part of the Barracuda file format. Because long variable-length column values are stored outside of the page that holds the row data, it is very efficient for rows that include large objects. Since the large fields are typically not accessed to evaluate query conditions, they are not brought into the buffer pool as often, resulting in fewer I/O operations and better utilization of cache memory.

As of MySQL 5.7.9, the default row format is defined by innodb_default_row_format, which has a default value of DYNAMIC.

For additional information about InnoDB DYNAMIC row format, see DYNAMIC Row Format.
See Also Barracuda, buffer pool, file format, row format.

E
early adopter
A stage similar to beta, when a software product is typically evaluated for performance, functionality, and compatibility in a non-mission-critical setting.
See Also beta.
error log

A type of log showing information about MySQL startup and critical runtime errors and crash information. For details, see Section 5.4.2, “The Error Log”.
See Also crash, log.

eviction

The process of removing an item from a cache or other temporary storage area, such as the InnoDB buffer pool. Often, but not always, uses the LRU algorithm to determine which item to remove. When a dirty page is evicted, its contents are flushed to disk, and any dirty neighbor pages might be flushed also.
See Also buffer pool, dirty page, flush, LRU, neighbor page.

exclusive lock

A kind of lock that prevents any other transaction from locking the same row. Depending on the transaction isolation level, this kind of lock might block other transactions from writing to the same row, or might also block other transactions from reading the same row. The default InnoDB isolation level, REPEATABLE READ, enables higher concurrency by allowing transactions to read rows that have exclusive locks, a technique known as consistent read.
See Also concurrency, consistent read, isolation level, lock, REPEATABLE READ, shared lock, transaction.

extent

A group of pages within a tablespace. For the default page size of 16KB, an extent contains 64 pages. In MySQL 5.6, the page size for an InnoDB instance can be 4KB, 8KB, or 16KB, controlled by the innodb_page_size configuration option. For 4KB, 8KB, and 16KB pages sizes, the extent size is always 1MB (or 1048576 bytes).

Support for 32KB and 64KB InnoDB page sizes was added in MySQL 5.7.6. For a 32KB page size, the extent size is 2MB. For a 64KB page size, the extent size is 4MB.

InnoDB features such as segments, read-ahead requests and the doublewrite buffer use I/O operations that read, write, allocate, or free data one extent at a time.
See Also doublewrite buffer, page, page size, read-ahead, segment, tablespace.

F

.frn file

A file containing the metadata, such as the table definition, of a MySQL table.

For backups, you must always keep the full set of .frm files along with the backup data to be able to restore tables that are altered or dropped after the backup.

Although each InnoDB table has a .frm file, InnoDB maintains its own table metadata in the system tablespace; the .frm files are not needed for InnoDB to operate on InnoDB tables.

.frn files are backed up by the MySQL Enterprise Backup product. These files must not be modified by an ALTER TABLE operation while the backup is taking place, which is why backups that include non-InnoDB tables perform a FLUSH TABLES WITH READ LOCK operation to freeze such activity while backing up .frm files. Restoring a backup can result in .frm files being created, changed, or removed to match the state of the database at the time of the backup.
See Also data dictionary, MySQL Enterprise Backup, system tablespace.

Fast Index Creation

A capability first introduced in the InnoDB Plugin, now part of MySQL in 5.5 and higher, that speeds up creation of InnoDB secondary indexes by avoiding the need to completely rewrite the associated table. The speedup applies to dropping secondary indexes also.
Because index maintenance can add performance overhead to many data transfer operations, consider doing operations such as `ALTER TABLE ... ENGINE=INNODB` or `INSERT INTO ... SELECT * FROM ...` without any secondary indexes in place, and creating the indexes afterward.

In MySQL 5.6, this feature becomes more general. You can read and write to tables while an index is being created, and many more kinds of `ALTER TABLE` operations can be performed without copying the table, without blocking DML operations, or both. Thus in MySQL 5.6 and higher, this set of features is referred to as online DDL rather than Fast Index Creation.

For related information, see Section 14.16, "InnoDB Fast Index Creation", and InnoDB and Online DDL. See Also DML, index, online DDL, secondary index.

fast shutdown
The default shutdown procedure for InnoDB, based on the configuration setting `innodb_fast_shutdown=1`. To save time, certain flush operations are skipped. This type of shutdown is safe during normal usage, because the flush operations are performed during the next startup, using the same mechanism as in crash recovery. In cases where the database is being shut down for an upgrade or downgrade, do a slow shutdown instead to ensure that all relevant changes are applied to the data files during the shutdown. See Also crash recovery, data files, flush, shutdown, slow shutdown.

file format
The file format for InnoDB tables, enabled using the `innodb_file_format` configuration option. Supported file formats are Antelope and Barracuda. Antelope is the original InnoDB file format and supports the REDUNDANT and COMPACT row formats. Barracuda is the newer InnoDB file format and supports the COMPRESSED and DYNAMIC row formats. See Also Antelope, Barracuda, file-per-table, .ibd file, ibdata file, row format.

file-per-table
A general name for the setting controlled by the `innodb_file_per_table` option, which is an important configuration option that affects aspects of InnoDB file storage, availability of features, and I/O characteristics. As of MySQL 5.6.7, `innodb_file_per_table` is enabled by default.

With the `innodb_file_per_table` option enabled, you can create a table in its own .ibd file rather than in the shared ibdata files of the system tablespace. When table data is stored in an individual .ibd file, you have more flexibility to choose row formats required for features such as data compression. The TRUNCATE TABLE operation is also faster, and reclaimed space can be used by the operating system rather than remaining reserved for InnoDB.

The MySQL Enterprise Backup product is more flexible for tables that are in their own files. For example, tables can be excluded from a backup, but only if they are in separate files. Thus, this setting is suitable for tables that are backed up less frequently or on a different schedule. See Also compressed row format, compression, file format, .ibd file, ibdata file, innodb_file_per_table, MySQL Enterprise Backup, row format, system tablespace.

fill factor
In an InnoDB index, the proportion of a page that is taken up by index data before the page is split. The unused space when index data is first divided between pages allows for rows to be updated with longer string values without requiring expensive index maintenance operations. If the fill factor is too low, the index consumes more space than needed, causing extra I/O overhead when reading the index. If the fill factor is too high, any update that increases the length of column values can cause extra I/O overhead for index maintenance. See Section 14.9.2.2, “The Physical Structure of an InnoDB Index” for more information. See Also index, page.

fixed row format
This row format is used by the MyISAM storage engine, not by InnoDB. If you create an InnoDB table with the option `ROW_FORMAT=FIXED` in MySQL 5.7.6 or earlier, InnoDB uses the compact row format instead,
although the \texttt{FIXED} value might still show up in output such as \texttt{SHOW TABLE STATUS} reports. As of MySQL 5.7.7, \texttt{InnoDB} returns an error if \texttt{ROW_FORMAT=FIXED} is specified.

See Also compact row format, row format.

flush

To write changes to the database files, that had been buffered in a memory area or a temporary disk storage area. The \texttt{InnoDB} storage structures that are periodically flushed include the redo log, the undo log, and the buffer pool.

Flushing can happen because a memory area becomes full and the system needs to free some space, because a commit operation means the changes from a transaction can be finalized, or because a slow shutdown operation means that all outstanding work should be finalized. When it is not critical to flush all the buffered data at once, \texttt{InnoDB} can use a technique called fuzzy checkpointing to flush small batches of pages to spread out the I/O overhead.

See Also buffer pool, commit, fuzzy checkpointing, redo log, slow shutdown, undo log.

flush list

An internal \texttt{InnoDB} data structure that tracks dirty pages in the buffer pool: that is, pages that have been changed and need to be written back out to disk. This data structure is updated frequently by \texttt{InnoDB} internal mini-transactions, and so is protected by its own mutex to allow concurrent access to the buffer pool.

See Also buffer pool, dirty page, LRU, mini-transaction, mutex, page, page cleaner.

foreign key

A type of pointer relationship, between rows in separate \texttt{InnoDB} tables. The foreign key relationship is defined on one column in both the parent table and the child table.

In addition to enabling fast lookup of related information, foreign keys help to enforce referential integrity, by preventing any of these pointers from becoming invalid as data is inserted, updated, and deleted. This enforcement mechanism is a type of constraint. A row that points to another table cannot be inserted if the associated foreign key value does not exist in the other table. If a row is deleted or its foreign key value changed, and rows in another table point to that foreign key value, the foreign key can be set up to prevent the deletion, cause the corresponding column values in the other table to become \texttt{null}, or automatically delete the corresponding rows in the other table.

One of the stages in designing a normalized database is to identify data that is duplicated, separate that data into a new table, and set up a foreign key relationship so that the multiple tables can be queried like a single table, using a join operation.

See Also child table, FOREIGN KEY constraint, join, normalized, NULL, parent table, referential integrity, relational.

FOREIGN KEY constraint

The type of constraint that maintains database consistency through a foreign key relationship. Like other kinds of constraints, it can prevent data from being inserted or updated if data would become inconsistent; in this case, the inconsistency being prevented is between data in multiple tables. Alternatively, when a DML operation is performed, FOREIGN KEY constraints can cause data in child rows to be deleted, changed to different values, or set to \texttt{null}, based on the ON CASCADE option specified when creating the foreign key.

See Also child table, constraint, DML, foreign key, NULL.

FTS

In most contexts, an acronym for full-text search. Sometimes in performance discussions, an acronym for full table scan.

See Also full table scan, full-text search.

full backup

A backup that includes all the tables in each MySQL database, and all the databases in a MySQL instance. Contrast with partial backup.
See Also backup, database, instance, partial backup, table.

full table scan
An operation that requires reading the entire contents of a table, rather than just selected portions using an index. Typically performed either with small lookup tables, or in data warehousing situations with large tables where all available data is aggregated and analyzed. How frequently these operations occur, and the sizes of the tables relative to available memory, have implications for the algorithms used in query optimization and managing the buffer pool.

The purpose of indexes is to allow lookups for specific values or ranges of values within a large table, thus avoiding full table scans when practical.
See Also buffer pool, index.

full-text search
The MySQL feature for finding words, phrases, Boolean combinations of words, and so on within table data, in a faster, more convenient, and more flexible way than using the SQL LIKE operator or writing your own application-level search algorithm. It uses the SQL function MATCH() and FULLTEXT indexes.
See Also FULLTEXT index.

FULLTEXT index
The special kind of index that holds the search index in the MySQL full-text search mechanism. Represents the words from values of a column, omitting any that are specified as stopwords. Originally, only available for MyISAM tables. Starting in MySQL 5.6.4, it is also available for InnoDB tables.
See Also full-text search, index, InnoDB, search index, stopword.

fuzzy checkpointing
A technique that flushes small batches of dirty pages from the buffer pool, rather than flushing all dirty pages at once which would disrupt database processing.
See Also buffer pool, dirty page, flush.

G

GA
“Generally available”, the stage when a software product leaves beta and is available for sale, official support, and production use.
See Also beta.

gap
A place in an InnoDB index data structure where new values could be inserted. When you lock a set of rows with a statement such as SELECT ... FOR UPDATE, InnoDB can create locks that apply to the gaps as well as the actual values in the index. For example, if you select all values greater than 10 for update, a gap lock prevents another transaction from inserting a new value that is greater than 10. The supremum record and infimum record represent the gaps containing all values greater than or less than all the current index values.
See Also concurrency, gap lock, index, infimum record, isolation level, supremum record.

gap lock
A lock on a gap between index records, or a lock on the gap before the first or after the last index record. For example, SELECT c1 FROM t WHERE c1 BETWEEN 10 and 20 FOR UPDATE; prevents other transactions from inserting a value of 15 into the column t.c1, whether or not there was already any such value in the column, because the gaps between all existing values in the range are locked. Contrast with record lock and next-key lock.

Gap locks are part of the tradeoff between performance and concurrency, and are used in some transaction isolation levels and not others.
See Also gap, infimum record, lock, next-key lock, record lock, supremum record.

general log
    See general query log.

general query log
    A type of log used for diagnosis and troubleshooting of SQL statements processed by the MySQL server. Can be stored in a file or in a database table. You must enable this feature through the general_log configuration option to use it. You can disable it for a specific connection through the sql_log_off configuration option.

    Records a broader range of queries than the slow query log. Unlike the binary log, which is used for replication, the general query log contains SELECT statements and does not maintain strict ordering. For more information, see Section 5.4.3, “The General Query Log”.
    See Also binary log, log, slow query log.

general tablespace
    A shared InnoDB tablespace created using CREATE TABLESPACE syntax. General tablespaces can be created outside of the MySQL data directory, are capable of holding multiple tables, and support tables of all row formats. General tablespaces were introduced in MySQL 5.7.6.

    Tables are added to a general tablespace using CREATE TABLE tbl_name ... TABLESPACE [=] tablespace_name or ALTER TABLE tbl_name TABLESPACE [=] tablespace_name syntax.

    Contrast with system tablespace and file-per-table tablespace.

    For more information, see General Tablespaces.
    See Also file-per-table, system tablespace, table, tablespace.

global transaction
    A type of transaction involved in XA operations. It consists of several actions that are transactional in themselves, but that all must either complete successfully as a group, or all be rolled back as a group. In essence, this extends ACID properties “up a level” so that multiple ACID transactions can be executed in concert as components of a global operation that also has ACID properties.
    See Also ACID, transaction, XA.

group commit
    An InnoDB optimization that performs some low-level I/O operations (log write) once for a set of commit operations, rather than flushing and syncing separately for each commit.
    See Also binary log, commit.

H

hash index
    A type of index intended for queries that use equality operators, rather than range operators such as greater-than or BETWEEN. It is available for MEMORY tables. Although hash indexes are the default for MEMORY tables for historic reasons, that storage engine also supports B-tree indexes, which are often a better choice for general-purpose queries.

    MySQL includes a variant of this index type, the adaptive hash index, that is constructed automatically for InnoDB tables if needed based on runtime conditions.
    See Also adaptive hash index, B-tree, index, InnoDB.

HDD
    Acronym for “hard disk drive”. Refers to storage media using spinning platters, usually when comparing and contrasting with SSD. Its performance characteristics can influence the throughput of a disk-based workload.
heartbeat
A periodic message that is sent to indicate that a system is functioning properly. In a replication context, if the master stops sending such messages, one of the slaves can take its place. Similar techniques can be used between the servers in a cluster environment, to confirm that all of them are operating properly.
See Also master server, replication.

high-water mark
A value representing an upper limit, either a hard limit that should not be exceeded at runtime, or a record of the maximum value that was actually reached. Contrast with low-water mark.
See Also low-water mark.

history list
A list of transactions with delete-marked records scheduled to be processed by the InnoDB purge operation. Recorded in the undo log. The length of the history list is reported by the command SHOW ENGINE INNODB STATUS. If the history list grows longer than the value of the innodb_max_purge_lag configuration option, each DML operation is delayed slightly to allow the purge operation to finish flushing the deleted records.

Also known as purge lag.
See Also DML, flush, purge, purge lag, rollback segment, transaction, undo log.

hole punching
Releasing empty blocks from a page. The InnoDB transparent page compression feature relies on hole punching support. For more information, see InnoDB Page Compression.
See Also sparse file, transparent page compression.

hot
A condition where a row, table, or internal data structure is accessed so frequently, requiring some form of locking or mutual exclusion, that it results in a performance or scalability issue.

Although “hot” typically indicates an undesirable condition, a hot backup is the preferred type of backup.
See Also hot backup.

hot backup
A backup taken while the database is running and applications are reading and writing to it. The backup involves more than simply copying data files: it must include any data that was inserted or updated while the backup was in process; it must exclude any data that was deleted while the backup was in process; and it must ignore any changes that were not committed.

The Oracle product that performs hot backups, of InnoDB tables especially but also tables from MyISAM and other storage engines, is known as MySQL Enterprise Backup.

The hot backup process consists of two stages. The initial copying of the data files produces a raw backup. The apply step incorporates any changes to the database that happened while the backup was running. Applying the changes produces a prepared backup; these files are ready to be restored whenever necessary.
See Also apply, MySQL Enterprise Backup, prepared backup, raw backup.

.ibd file
The data file for file-per-table tablespaces and general tablespaces. File-per-table tablespace .ibd files contain a single table and associated index data. General tablespace .ibd files may contain table and index data for multiple tables. General tablespaces were introduced in MySQL 5.7.6.
The `.ibd` file extension does not apply to the system tablespace, which consists of one or more `ibdata` files.

If a file-per-table tablespace or general tablespace is created with the `DATA DIRECTORY =` clause, the `.ibd` file is located at the specified path, outside the normal data directory, and is pointed to by a `.isl` file.

When a `.ibd` file is included in a compressed backup by the MySQL Enterprise Backup product, the compressed equivalent is a `.ibz` file.

See Also database, file-per-table, general tablespace, `ibdata` file, `.ibz` file, `innodb_file_per_table`, `.isl` file, MySQL Enterprise Backup, system tablespace.

`.ibz` file

When the MySQL Enterprise Backup product performs a compressed backup, it transforms each tablespace file that is created using the file-per-table setting from a `.ibd` extension to a `.ibz` extension.

The compression applied during backup is distinct from the compressed row format that keeps table data compressed during normal operation. A compressed backup operation skips the compression step for a tablespace that is already in compressed row format, as compressing a second time would slow down the backup but produce little or no space savings.

See Also compressed backup, compressed row format, file-per-table, `.ibd` file, MySQL Enterprise Backup, tablespace.

`.isl` file

A file that specifies the location of an `.ibd` file for an InnoDB table created with the `DATA DIRECTORY =` clause in MySQL 5.6 and higher, or with the `CREATE TABLESPACE ... ADD DATAFILE` clause in MySQL 5.7 and higher. It functions like a symbolic link, without the platform restrictions of the actual symbolic link mechanism.

You can store InnoDB tables outside the database directory, for example, on an especially large or fast storage device depending on the usage of the table. For details, see Creating Tables Externally, and General Tablespace.

See Also database, `.ibd` file, table, tablespace.

I/O-bound

See disk-bound.

`ib-file` set

The set of files managed by InnoDB within a MySQL database: the system tablespace, file-per-table tablespace files, and redo log files. Depending on MySQL version and InnoDB configuration, may also include general tablespace, temporary tablespace, and undo tablespace files. This term is sometimes used in detailed discussions of InnoDB file structures and formats to refer to the set of files managed by InnoDB within a MySQL database.

See Also database, file-per-table, general tablespace, redo log, system tablespace, temporary tablespace, undo tablespace.

`ibbackup_logfile`

A supplemental backup file created by the MySQL Enterprise Backup product during a hot backup operation. It contains information about any data changes that occurred while the backup was running. The initial backup files, including `ibbackup_logfile`, are known as a raw backup, because the changes that occurred during the backup operation are not yet incorporated. After you perform the apply step to the raw backup files, the resulting files do include those final data changes, and are known as a prepared backup. At this stage, the `ibbackup_logfile` file is no longer necessary.

See Also apply, hot backup, MySQL Enterprise Backup, prepared backup, raw backup.

`ibdata` file

A set of files with names such as `ibdata1`, `ibdata2`, and so on, that make up the InnoDB system tablespace. These files contain metadata about InnoDB tables, (the InnoDB data dictionary), and the storage areas for one or more undo logs, the change buffer, and the doublewrite buffer. They also can contain some or all of the
table data also (depending on whether the file-per-table mode is in effect when each table is created). When the innodb_file_per_table option is enabled, data and indexes for newly created tables are stored in separate .ibd files rather than in the system tablespace.

The growth of the ibdata files is influenced by the innodb_autoextend_increment configuration option. See Also change buffer, data dictionary, doublewrite buffer, file-per-table, .ibd file, innodb_file_per_table, system tablespace, undo log.

ibtmp file

The InnoDB temporary tablespace data file for non-compressed InnoDB temporary tables and related objects. The configuration file option, innodb_temp_data_file_path, allows users to define a relative path for the temporary tablespace data file. If innodb_temp_data_file_path is not specified, the default behavior is to create a single auto-extending 12MB data file named ibtmp1 in the data directory, alongside ibdata1. See Also data files, temporary table, temporary tablespace.

ib_logfile

A set of files, typically named ib_logfile0 and ib_logfile1, that form the redo log. Also sometimes referred to as the log group. These files record statements that attempt to change data in InnoDB tables. These statements are replayed automatically to correct data written by incomplete transactions, on startup following a crash.

This data cannot be used for manual recovery; for that type of operation, use the binary log. See Also binary log, log group, redo log.

ilist

Within an InnoDB FULLTEXT index, the data structure consisting of a document ID and positional information for a token (that is, a particular word). See Also FULLTEXT index.

implicit row lock

A row lock that InnoDB acquires to ensure consistency, without you specifically requesting it. See Also row lock.

in-memory database

A type of database system that maintains data in memory, to avoid overhead due to disk I/O and translation between disk blocks and memory areas. Some in-memory databases sacrifice durability (the “D” in the ACID design philosophy) and are vulnerable to hardware, power, and other types of failures, making them more suitable for read-only operations. Other in-memory databases do use durability mechanisms such as logging changes to disk or using non-volatile memory.

MySQL features that address the same kinds of memory-intensive processing include the InnoDB buffer pool, adaptive hash index, and read-only transaction optimization, the MEMORY storage engine, the MyISAM key cache, and the MySQL query cache. See Also ACID, adaptive hash index, buffer pool, disk-based, read-only transaction.

incremental backup

A type of hot backup, performed by the MySQL Enterprise Backup product, that only saves data changed since some point in time. Having a full backup and a succession of incremental backups lets you reconstruct backup data over a long period, without the storage overhead of keeping several full backups on hand. You can restore the full backup and then apply each of the incremental backups in succession, or you can keep the full backup up-to-date by applying each incremental backup to it, then perform a single restore operation.

The granularity of changed data is at the page level. A page might actually cover more than one row. Each changed page is included in the backup. See Also hot backup, MySQL Enterprise Backup, page.
index

A data structure that provides a fast lookup capability for rows of a table, typically by forming a tree structure (B-tree) representing all the values of a particular column or set of columns.

InnoDB tables always have a clustered index representing the primary key. They can also have one or more secondary indexes defined on one or more columns. Depending on their structure, secondary indexes can be classified as partial, column, or composite indexes.

Indexes are a crucial aspect of query performance. Database architects design tables, queries, and indexes to allow fast lookups for data needed by applications. The ideal database design uses a covering index where practical; the query results are computed entirely from the index, without reading the actual table data. Each foreign key constraint also requires an index, to efficiently check whether values exist in both the parent and child tables.

Although a B-tree index is the most common, a different kind of data structure is used for hash indexes, as in the MEMORY storage engine and the InnoDB adaptive hash index. R-tree indexes are used for spatial indexing of multi-dimensional information.

See Also adaptive hash index, B-tree, child table, clustered index, column index, composite index, covering index, foreign key, hash index, parent table, partial index, primary key, query, R-tree, row, secondary index, table.

index cache

A memory area that holds the token data for InnoDB full-text search. It buffers the data to minimize disk I/O when data is inserted or updated in columns that are part of a FULLTEXT index. The token data is written to disk when the index cache becomes full. Each InnoDB FULLTEXT index has its own separate index cache, whose size is controlled by the configuration option innodb_ft_cache_size.

See Also full-text search, FULLTEXT index.

index condition pushdown

Index condition pushdown (ICP) is an optimization that pushes part of a WHERE condition down to the storage engine if parts of the condition can be evaluated using fields from the index. ICP can reduce the number of times the storage engine must access the base table and the number of times the MySQL server must access the storage engine. For more information, see Index Condition Pushdown Optimization.

See Also index, storage engine.

index hint

Extended SQL syntax for overriding the indexes recommended by the optimizer. For example, the FORCE INDEX, USE INDEX, and IGNORE INDEX clauses. Typically used when indexed columns have unevenly distributed values, resulting in inaccurate cardinality estimates.

See Also cardinality, index.

index prefix

In an index that applies to multiple columns (known as a composite index), the initial or leading columns of the index. A query that references the first 1, 2, 3, and so on columns of a composite index can use the index, even if the query does not reference all the columns in the index.

See Also composite index, index.

index statistics

See statistics.

infimum record

A pseudo-record in an index, representing the gap below the smallest value in that index. If a transaction has a statement such as SELECT ... FROM ... WHERE col < 10 FOR UPDATE;, and the smallest value in the column is 5, it is a lock on the infimum record that prevents other transactions from inserting even smaller values such as 0, -10, and so on.

See Also gap, index, pseudo-record, supremum record.
INFORMATION_SCHEMA

The name of the database that provides a query interface to the MySQL data dictionary. (This name is defined by the ANSI SQL standard.) To examine information (metadata) about the database, you can query tables such as INFORMATION_SCHEMA.TABLES and INFORMATION_SCHEMA.COLUMNS, rather than using SHOW commands that produce unstructured output.

The INFORMATION_SCHEMA database also contains tables specific to InnoDB that provide a query interface to the InnoDB data dictionary. You use these tables not to see how the database is structured, but to get real-time information about the workings of InnoDB tables to help with performance monitoring, tuning, and troubleshooting.

See Also data dictionary, database, InnoDB.

InnoDB

A MySQL component that combines high performance with transactional capability for reliability, robustness, and concurrent access. It embodies the ACID design philosophy. Represented as a storage engine; it handles tables created or altered with the ENGINE=INNODB clause. See Chapter 14, The InnoDB Storage Engine for architectural details and administration procedures, and Section 8.5, “Optimizing for InnoDB Tables” for performance advice.

In MySQL 5.5 and higher, InnoDB is the default storage engine for new tables and the ENGINE=INNODB clause is not required.

InnoDB tables are ideally suited for hot backups. See Section 25.2, “MySQL Enterprise Backup Overview” for information about the MySQL Enterprise Backup product for backing up MySQL servers without interrupting normal processing.

See Also ACID, hot backup, MySQL Enterprise Backup, storage engine, transaction.

innodb_autoinc_lock_mode

The innodb_autoinc_lock_mode option controls the algorithm used for auto-increment locking. When you have an auto-incrementing primary key, you can use statement-based replication only with the setting innodb_autoinc_lock_mode=1. This setting is known as consecutive lock mode, because multi-row inserts within a transaction receive consecutive auto-increment values. If you have innodb_autoinc_lock_mode=2, which allows higher concurrency for insert operations, use row-based replication rather than statement-based replication. This setting is known as interleaved lock mode, because multiple multi-row insert statements running at the same time can receive auto-increment values that are interleaved. The setting innodb_autoinc_lock_mode=0 should not be used except for compatibility purposes.

Consecutive lock mode (innodb_autoinc_lock_mode=1) is the default setting prior to MySQL 8.0.3. As of MySQL 8.0.3, interleaved lock mode (innodb_autoinc_lock_mode=2) is the default, which reflects the change from statement-based to row-based replication as the default replication type.

See Also auto-increment, auto-increment locking, mixed-mode insert, primary key.

innodb_file_format

The innodb_file_format option defines the file format to use for new InnoDB file-per-table tablespaces. Currently, you can specify the Antelope and Barracuda file formats.

See Also Antelope, Barracuda, file format, file-per-table, general tablespace, innodb_file_per_table, system tablespace, tablescape.

innodb_file_per_table

An important configuration option that affects many aspects of InnoDB file storage, availability of features, and I/O characteristics. In MySQL 5.6.7 and higher, it is enabled by default. The innodb_file_per_table option turns on file-per-table mode. With this mode enabled, a newly created InnoDB table and associated indexes can be stored in a file-per-table .ibd file, outside the system tablespace.

This option affects the performance and storage considerations for a number of SQL statements, such as DROP TABLE and TRUNCATE TABLE.
Enabling the `innodb_file_per_table` option allows you to take advantage of features such as table compression and named-table backups in MySQL Enterprise Backup.

For more information, see `innodb_file_per_table`, and Section 14.9.3.2, “File-Per-Table Tablespaces”. See Also compression, file-per-table, .ibd file, MySQL Enterprise Backup, system tablespace.

`innodb_lock_wait_timeout`

The `innodb_lock_wait_timeout` option sets the balance between waiting for shared resources to become available, or giving up and handling the error, retrying, or doing alternative processing in your application. Rolls back any InnoDB transaction that waits more than a specified time to acquire a lock. Especially useful if deadlocks are caused by updates to multiple tables controlled by different storage engines; such deadlocks are not detected automatically.

See Also deadlock, deadlock detection, lock, wait.

`innodb_strict_mode`

The `innodb_strict_mode` option controls whether InnoDB operates in strict mode, where conditions that are normally treated as warnings, cause errors instead (and the underlying statements fail).

See Also strict mode.

`insert`

One of the primary DML operations in SQL. The performance of inserts is a key factor in data warehouse systems that load millions of rows into tables, and OLTP systems where many concurrent connections might insert rows into the same table, in arbitrary order. If insert performance is important to you, you should learn about InnoDB features such as the insert buffer used in change buffering, and auto-increment columns.

See Also auto-increment, change buffering, data warehouse, DML, InnoDB, insert buffer, OLTP, SQL.

`insert buffer`

The former name of the change buffer. In MySQL 5.5, support was added for buffering changes to secondary index pages for DELETE and UPDATE operations. Previously, only changes resulting from INSERT operations were buffered. The preferred term is now change buffer.

See Also change buffer, change buffering.

`insert buffering`

The technique of storing changes to secondary index pages, resulting from INSERT operations, in the change buffer rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. It is one of the types of change buffering; the others are delete buffering and purge buffering.

Insert buffering is not used if the secondary index is unique, because the uniqueness of new values cannot be verified before the new entries are written out. Other kinds of change buffering do work for unique indexes.

See Also change buffer, change buffering, delete buffering, insert buffer, purge buffering, unique index.

`insert intention lock`

A type of gap lock that is set by INSERT operations prior to row insertion. This type of lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. For more information, see Section 14.10.1, “InnoDB Locking”.

See Also gap lock, lock, next-key lock.

`instance`

A single mysqld daemon managing a data directory representing one or more databases with a set of tables. It is common in development, testing, and some replication scenarios to have multiple instances on the same server machine, each managing its own data directory and listening on its own port or socket. With one instance running a disk-bound workload, the server might still have extra CPU and memory capacity to run additional instances.

See Also data directory, database, disk-bound, mysqld, replication, server, table.
instrumentation

Modifications at the source code level to collect performance data for tuning and debugging. In MySQL, data collected by instrumentation is exposed through an SQL interface using the INFORMATION_SCHEMA and PERFORMANCE_SCHEMA databases.

See Also INFORMATION_SCHEMA, Performance Schema.

intention exclusive lock

See intention lock.

intention lock

A kind of lock that applies to the table, used to indicate the kind of lock the transaction intends to acquire on rows in the table. Different transactions can acquire different kinds of intention locks on the same table, but the first transaction to acquire an intention exclusive (IX) lock on a table prevents other transactions from acquiring any S or X locks on the table. Conversely, the first transaction to acquire an intention shared (IS) lock on a table prevents other transactions from acquiring any X locks on the table. The two-phase process allows the lock requests to be resolved in order, without blocking locks and corresponding operations that are compatible. For more information about this locking mechanism, see Section 14.10.1, “InnoDB Locking”.

See Also lock, lock mode, locking, transaction.

intention shared lock

See intention lock.

inverted index

A data structure optimized for document retrieval systems, used in the implementation of InnoDB full-text search. The InnoDB FULLTEXT index, implemented as an inverted index, records the position of each word within a document, rather than the location of a table row. A single column value (a document stored as a text string) is represented by many entries in the inverted index.

See Also full-text search, FULLTEXT index, ilist.

IOPS

Acronym for I/O operations per second. A common measurement for busy systems, particularly OLTP applications. If this value is near the maximum that the storage devices can handle, the application can become disk-bound, limiting scalability.

See Also disk-bound, OLTP, scalability.

isolation level

One of the foundations of database processing. Isolation is the I in the acronym ACID; the isolation level is the setting that fine-tunes the balance between performance and reliability, consistency, and reproducibility of results when multiple transactions are making changes and performing queries at the same time.

From highest amount of consistency and protection to the least, the isolation levels supported by InnoDB are: SERIALIZABLE, REPEATABLE READ, READ COMMITTED, and READ UNCOMMITTED.

With InnoDB tables, many users can keep the default isolation level (REPEATABLE READ) for all operations. Expert users might choose the READ COMMITTED level as they push the boundaries of scalability with OLTP processing, or during data warehousing operations where minor inconsistencies do not affect the aggregate results of large amounts of data. The levels on the edges (SERIALIZABLE and READ UNCOMMITTED) change the processing behavior to such an extent that they are rarely used.

See Also ACID, OLTP, READ COMMITTED, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

J

join

A query that retrieves data from more than one table, by referencing columns in the tables that hold identical values. Ideally, these columns are part of an InnoDB foreign key relationship, which ensures referential
**integrity** and that the join columns are **indexed**. Often used to save space and improve query performance by replacing repeated strings with numeric IDs, in a **normalized** data design.

See Also **foreign key**, **index**, **normalized**, **query**, **referential integrity**.

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**K**

**KEY_BLOCK_SIZE**

An option to specify the size of data pages within an InnoDB table that uses **compressed row format**. The default is 8 kilobytes. Lower values risk hitting internal limits that depend on the combination of row size and compression percentage.

For **MyISAM** tables, **KEY_BLOCK_SIZE** optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A **KEY_BLOCK_SIZE** value specified for an individual index definition overrides a table-level **KEY_BLOCK_SIZE** value.

See Also **compressed row format**.

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**L**

**latch**

A lightweight structure used by InnoDB to implement a **lock** for its own internal memory structures, typically held for a brief time measured in milliseconds or microseconds. A general term that includes both **mutexes** (for exclusive access) and **rw-locks** (for shared access). Certain latches are the focus of InnoDB performance tuning. Statistics about latch use and contention are available through the **Performance Schema** interface.

See Also **lock**, **locking**, **mutex**, **Performance Schema**, **rw-lock**.

**list**

The **InnoDB** buffer pool is represented as a list of memory **pages**. The list is reordered as new pages are accessed and enter the buffer pool, as pages within the buffer pool are accessed again and are considered newer, and as pages that are not accessed for a long time are **evicted** from the buffer pool. The buffer pool is divided into **sublists**, and the replacement policy is a variation of the familiar **LRU** technique.

See Also **buffer pool**, **eviction**, **LRU**, **page**, **sublist**.

**lock**

The high-level notion of an object that controls access to a resource, such as a table, row, or internal data structure, as part of a **locking** strategy. For intensive performance tuning, you might delve into the actual structures that implement locks, such as **mutexes** and **latches**.

See Also **latch**, **lock mode**, **locking**, **mutex**.

**lock escalation**

An operation used in some database systems that converts many **row locks** into a single **table lock**, saving memory space but reducing concurrent access to the table. InnoDB uses a space-efficient representation for row locks, so that **lock** escalation is not needed.

See Also **locking**, **row lock**, **table lock**.

**lock mode**

A shared (S) **lock** allows a **transaction** to read a row. Multiple transactions can acquire an S lock on that same row at the same time.

An exclusive (X) lock allows a transaction to update or delete a row. No other transaction can acquire any kind of lock on that same row at the same time.

**Intention locks** apply to the table, and are used to indicate what kind of lock the transaction intends to acquire on rows in the table. Different transactions can acquire different kinds of intention locks on the same table, but the
first transaction to acquire an intention exclusive (IX) lock on a table prevents other transactions from acquiring any S or X locks on the table. Conversely, the first transaction to acquire an intention shared (IS) lock on a table prevents other transactions from acquiring any X locks on the table. The two-phase process allows the lock requests to be resolved in order, without blocking locks and corresponding operations that are compatible. See Also intention lock, lock, locking, transaction.

locking
The system of protecting a transaction from seeing or changing data that is being queried or changed by other transactions. The locking strategy must balance reliability and consistency of database operations (the principles of the ACID philosophy) against the performance needed for good concurrency. Fine-tuning the locking strategy often involves choosing an isolation level and ensuring all your database operations are safe and reliable for that isolation level. See Also ACID, concurrency, isolation level, locking, transaction.

locking read
A SELECT statement that also performs a locking operation on an InnoDB table. Either SELECT ... FOR UPDATE or SELECT ... LOCK IN SHARE MODE. It has the potential to produce a deadlock, depending on the isolation level of the transaction. The opposite of a non-locking read. Not allowed for global tables in a read-only transaction.

SELECT ... FOR SHARE replaces SELECT ... LOCK IN SHARE MODE in MySQL 8.0.1, but LOCK IN SHARE MODE remains available for backward compatibility.

See Section 14.10.2.4, “Locking Reads”. See Also deadlock, isolation level, locking, non-locking read, read-only transaction.

log
In the InnoDB context, “log” or “log files” typically refers to the redo log represented by the ib_logfileN files. Another type of InnoDB log is the undo log, which is a storage area that holds copies of data modified by active transactions.

Other kinds of logs that are important in MySQL are the error log (for diagnosing startup and runtime problems), binary log (for working with replication and performing point-in-time restores), the general query log (for diagnosing application problems), and the slow query log (for diagnosing performance problems). See Also binary log, error log, general query log, ib_logfile, redo log, slow query log, undo log.

log buffer
The memory area that holds data to be written to the log files that make up the redo log. It is controlled by the innodb_log_buffer_size configuration option. See Also log file, redo log.

log file
One of the ib_logfileN files that make up the redo log. Data is written to these files from the log buffer memory area. See Also ib_logfile, log buffer, redo log.

log group
The set of files that make up the redo log, typically named ib_logfile0 and ib_logfile1. (For that reason, sometimes referred to collectively as ib_logfile.) See Also ib_logfile, redo log.

logical
A type of operation that involves high-level, abstract aspects such as tables, queries, indexes, and other SQL concepts. Typically, logical aspects are important to make database administration and application development convenient and usable. Contrast with physical.
logical backup

A backup that reproduces table structure and data, without copying the actual data files. For example, the `mysqldump` command produces a logical backup, because its output contains statements such as `CREATE TABLE` and `INSERT` that can re-create the data. Contrast with physical backup. A logical backup offers flexibility (for example, you could edit table definitions or insert statements before restoring), but can take substantially longer to restore than a physical backup.

See Also `backup`, `mysqldump`, `physical backup`, `restore`.

loose_

A prefix added to InnoDB configuration options after server startup, so any new configuration options not recognized by the current level of MySQL do not cause a startup failure. MySQL processes configuration options that start with this prefix, but gives a warning rather than a failure if the part after the prefix is not a recognized option.

See Also `startup`.

low-water mark

A value representing a lower limit, typically a threshold value at which some corrective action begins or becomes more aggressive. Contrast with high-water mark.

See Also `high-water mark`.

LRU

An acronym for “least recently used”, a common method for managing storage areas. The items that have not been used recently are evicted when space is needed to cache newer items. InnoDB uses the LRU mechanism by default to manage the pages within the buffer pool, but makes exceptions in cases where a page might be read only a single time, such as during a full table scan. This variation of the LRU algorithm is called the midpoint insertion strategy. For more information, see Section 14.8.1, “Buffer Pool”.

See Also `buffer pool`, `eviction`, `full table scan`, `midpoint insertion strategy`, `page`.

LSN

Acronym for “log sequence number”. This arbitrary, ever-increasing value represents a point in time corresponding to operations recorded in the redo log. (This point in time is regardless of transaction boundaries; it can fall in the middle of one or more transactions.) It is used internally by InnoDB during crash recovery and for managing the buffer pool.

Prior to MySQL 5.6.3, the LSN was a 4-byte unsigned integer. The LSN became an 8-byte unsigned integer in MySQL 5.6.3 when the redo log file size limit increased from 4GB to 512GB, as additional bytes were required to store extra size information. Applications built on MySQL 5.6.3 or later that use LSN values should use 64-bit rather than 32-bit variables to store and compare LSN values.

In the MySQL Enterprise Backup product, you can specify an LSN to represent the point in time from which to take an incremental backup. The relevant LSN is displayed by the output of the `mysqlbackup` command. Once you have the LSN corresponding to the time of a full backup, you can specify that value to take a subsequent incremental backup, whose output contains another LSN for the next incremental backup.

See Also `buffer pool`, `crash recovery`, `incremental backup`, `MySQL Enterprise Backup`, `redo log`, `transaction`.

M

.MRG file

A file containing references to other tables, used by the MERGE storage engine. Files with this extension are always included in backups produced by the `mysqlbackup` command of the MySQL Enterprise Backup product.

See Also MySQL Enterprise Backup, `mysqlbackup` command.
.MYD file
A file that MySQL uses to store data for a MyISAM table.
See Also .MYI file, MySQL Enterprise Backup, mysqlbackup command.

.MYI file
A file that MySQL uses to store indexes for a MyISAM table.
See Also .MYD file, MySQL Enterprise Backup, mysqlbackup command.

master server
Frequently shortened to “master”. A database server machine in a replication scenario that processes the initial insert, update, and delete requests for data. These changes are propagated to, and repeated on, other servers known as slave servers.
See Also replication, slave server.

master thread
An InnoDB thread that performs various tasks in the background. Most of these tasks are I/O related, such as writing changes from the change buffer to the appropriate secondary indexes.

To improve concurrency, sometimes actions are moved from the master thread to separate background threads. For example, in MySQL 5.6 and higher, dirty pages are flushed from the buffer pool by the page cleaner thread rather than the master thread.
See Also buffer pool, change buffer, concurrency, dirty page, flush, page cleaner, thread.

MDL
Acronym for “metadata lock”.
See Also metadata lock.

memcached
A popular component of many MySQL and NoSQL software stacks, allowing fast reads and writes for single values and caching the results entirely in memory. Traditionally, applications required extra logic to write the same data to a MySQL database for permanent storage, or to read data from a MySQL database when it was not cached yet in memory. Now, applications can use the simple memcached protocol, supported by client libraries for many languages, to communicate directly with MySQL servers using InnoDB or NDB tables. These NoSQL interfaces to MySQL tables allow applications to achieve higher read and write performance than by issuing SQL statements directly, and can simplify application logic and deployment configurations for systems that already incorporate memcached for in-memory caching.

The memcached interface to InnoDB tables is available in MySQL 5.6 and higher; see InnoDB memcached Plugin for details. The memcached interface to NDB tables is available in NDB Cluster 7.2 and later; see http://dev.mysql.com/doc/ndbapi/en/ndbmemcache.html for details.
See Also InnoDB, NoSQL.

merge
To apply changes to data cached in memory, such as when a page is brought into the buffer pool, and any applicable changes recorded in the change buffer are incorporated into the page in the buffer pool. The updated data is eventually written to the tablespace by the flush mechanism.
See Also buffer pool, change buffer, flush, tablespace.

metadata lock
A type of lock that prevents DDL operations on a table that is being used at the same time by another transaction. For details, see Section 8.11.4, “Metadata Locking”.

Enhancements to online operations, particularly in MySQL 5.6 and higher, are focused on reducing the amount of metadata locking. The objective is for DDL operations that do not change the table structure (such as CREATE INDEX and DROP INDEX for InnoDB tables) to proceed while the table is being queried, updated, and so on by other transactions.
metrics counter
A feature implemented by the `INNODB_METRICS` table in the `INFORMATION_SCHEMA`, in MySQL 5.6 and higher. You can query counts and totals for low-level InnoDB operations, and use the results for performance tuning in combination with data from the `Performance Schema`.
See Also `counter`, `INFORMATION_SCHEMA`, `Performance Schema`.

midpoint insertion strategy
The technique of initially bringing pages into the InnoDB buffer pool not at the “newest” end of the list, but instead somewhere in the middle. The exact location of this point can vary, based on the setting of the `innodb_old_blocks_pct` option. The intent is that pages that are only read once, such as during a full table scan, can be aged out of the buffer pool sooner than with a strict LRU algorithm. For more information, see Section 14.8.1, “Buffer Pool”.
See Also `buffer pool`, `full table scan`, `LRU`, `page`.

mini-transaction
An internal phase of InnoDB processing, when making changes at the physical level to internal data structures during DML operations. A mini-transaction (mtr) has no notion of rollback; multiple mini-transactions can occur within a single transaction. Mini-transactions write information to the redo log that is used during crash recovery. A mini-transaction can also happen outside the context of a regular transaction, for example during purge processing by background threads.
See Also `commit`, `crash recovery`, `DML`, `physical`, `purge`, `redo log`, `rollback`, `transaction`.

mixed-mode insert
An `INSERT` statement where auto-increment values are specified for some but not all of the new rows. For example, a multi-value `INSERT` could specify a value for the auto-increment column in some cases and `NULL` in other cases. InnoDB generates auto-increment values for the rows where the column value was specified as `NULL`. Another example is an `INSERT ... ON DUPLICATE KEY UPDATE` statement, where auto-increment values might be generated but not used, for any duplicate rows that are processed as `UPDATE` rather than `INSERT` statements.

Can cause consistency issues between master and slave servers in a replication configuration. Can require adjusting the value of the `innodb_autoinc_lock_mode` configuration option.
See Also `auto-increment`, `innodb_autoinc_lock_mode`, `master server`, `replication`, `slave server`.

mtr
See mini-transaction.

multi-core
A type of processor that can take advantage of multithreaded programs, such as the MySQL server.

multiversion concurrency control
See MVCC.

mutex
Informal abbreviation for “mutex variable”. (Mutex itself is short for “mutual exclusion”.) The low-level object that InnoDB uses to represent and enforce exclusive-access locks to internal in-memory data structures. Once the lock is acquired, any other process, thread, and so on is prevented from acquiring the same lock. Contrast with rw-locks, which InnoDB uses to represent and enforce shared-access locks to internal in-memory data structures. Mutexes and rw-locks are known collectively as latches.
See Also latch, lock, Performance Schema, Pthreads, rw-lock.

MVCC
Acronym for “multiversion concurrency control”. This technique lets InnoDB transactions with certain isolation levels perform consistent read operations; that is, to query rows that are being updated by other transactions,
and see the values from before those updates occurred. This is a powerful technique to increase concurrency, by allowing queries to proceed without waiting due to locks held by the other transactions.

This technique is not universal in the database world. Some other database products, and some other MySQL storage engines, do not support it.

See Also ACID, concurrency, consistent read, isolation level, lock, transaction.

my.cnf
The name, on Unix or Linux systems, of the MySQL option file. See Also my.ini, option file.

my.ini
The name, on Windows systems, of the MySQL option file. See Also my.cnf, option file.

mysql
The mysql program is the command-line interpreter for the MySQL database. It processes SQL statements, and also MySQL-specific commands such as SHOW TABLES, by passing requests to the mysqld daemon. See Also mysqld, SQL.

MySQL Enterprise Backup
A licensed product that performs hot backups of MySQL databases. It offers the most efficiency and flexibility when backing up InnoDB tables, but can also back up MyISAM and other kinds of tables. See Also hot backup, InnoDB.

mysqldump command
A command-line tool of the MySQL Enterprise Backup product. It performs a hot backup operation for InnoDB tables, and a warm backup for MyISAM and other kinds of tables. See Section 25.2, “MySQL Enterprise Backup Overview” for more information about this command. See Also hot backup, MySQL Enterprise Backup, warm backup.

mysqld
The mysqld program is the database engine for the MySQL database. It runs as a Unix daemon or Windows service, constantly waiting for requests and performing maintenance work in the background. See Also mysql.

mysqldump
A command that performs a logical backup of some combination of databases, tables, and table data. The results are SQL statements that reproduce the original schema objects, data, or both. For substantial amounts of data, a physical backup solution such as MySQL Enterprise Backup is faster, particularly for the restore operation. See Also logical backup, MySQL Enterprise Backup, physical backup, restore.

N
natural key
An indexed column, typically a primary key, where the values have some real-world significance. Usually advised against because:

- If the value should ever change, there is potentially a lot of index maintenance to re-sort the clustered index and update the copies of the primary key value that are repeated in each secondary index.

- Even seemingly stable values can change in unpredictable ways that are difficult to represent correctly in the database. For example, one country can change into two or several, making the original country code obsolete. Or, rules about unique values might have exceptions. For example, even if taxpayer IDs are intended to be unique to a single person, a database might have to handle records that violate that rule, such as in cases of
identity theft. Taxpayer IDs and other sensitive ID numbers also make poor primary keys, because they may need to be secured, encrypted, and otherwise treated differently than other columns.

Thus, it is typically better to use arbitrary numeric values to form a **synthetic key**, for example using an **auto-increment** column.

See Also auto-increment, clustered index, primary key, secondary index, synthetic key.

neighbor page

Any page in the same extent as a particular page. When a page is selected to be flushed, any neighbor pages that are dirty are typically flushed as well, as an I/O optimization for traditional hard disks. In MySQL 5.6 and up, this behavior can be controlled by the configuration variable innodb_flush_neighbors; you might turn that setting off for SSD drives, which do not have the same overhead for writing smaller batches of data at random locations.

See Also dirty page, extent, flush, page.

next-key lock

A combination of a **record lock** on the index record and a **gap lock** on the gap before the index record.

See Also gap lock, locking, record lock.

non-locking read

A query that does not use the **SELECT ... FOR UPDATE** or **SELECT ... LOCK IN SHARE MODE** clauses.

The only kind of query allowed for global tables in a **read-only transaction**. The opposite of a **locking read**. See Section 14.10.2.3, “Consistent Nonlocking Reads”.

**SELECT ... FOR SHARE** replaces **SELECT ... LOCK IN SHARE MODE** in MySQL 8.0.1, but **LOCK IN SHARE MODE** remains available for backward compatibility.

See Also locking read, query, read-only transaction.

non-repeatable read

The situation when a query retrieves data, and a later query within the same transaction retrieves what should be the same data, but the queries return different results (changed by another transaction committing in the meantime).

This kind of operation goes against the **ACID** principle of database design. Within a transaction, data should be consistent, with predictable and stable relationships.

Among different isolation levels, non-repeatable reads are prevented by the **serializable read** and **repeatable read** levels, and allowed by the **consistent read**, and **read uncommitted** levels.

See Also ACID, consistent read, isolation level, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

nonblocking I/O

An industry term that means the same as **asynchronous I/O**.

See Also asynchronous I/O.

normalized

A database design strategy where data is split into multiple tables, and duplicate values condensed into single rows represented by an ID, to avoid storing, querying, and updating redundant or lengthy values. It is typically used in **OLTP** applications.

For example, an address might be given a unique ID, so that a census database could represent the relationship **lives at this address** by associating that ID with each member of a family, rather than storing multiple copies of a complex value such as **123 Main Street, Anytown, USA**.

For another example, although a simple address book application might store each phone number in the same table as a person's name and address, a phone company database might give each phone number a special
ID, and store the numbers and IDs in a separate table. This normalized representation could simplify large-scale updates when area codes split apart.

Normalization is not always recommended. Data that is primarily queried, and only updated by deleting entirely and reloading, is often kept in fewer, larger tables with redundant copies of duplicate values. This data representation is referred to as **denormalized**, and is frequently found in data warehousing applications. See Also denormalized, foreign key, OLTP, relational.

**NoSQL**

A broad term for a set of data access technologies that do not use the SQL language as their primary mechanism for reading and writing data. Some NoSQL technologies act as key-value stores, only accepting single-value reads and writes; some relax the restrictions of the ACID methodology; still others do not require a pre-planned schema. MySQL users can combine NoSQL-style processing for speed and simplicity with SQL operations for flexibility and convenience, by using the memcached API to directly access some kinds of MySQL tables. The memcached interface to InnoDB tables is available in MySQL 5.6 and higher; see InnoDB memcached Plugin for details. The memcached interface to NDB tables is available in NDB Cluster 7.2 and later; see ndbmemcache—Memcache API for NDB Cluster.

See Also ACID, InnoDB, memcached, schema, SQL.

**NOT NULL constraint**

A type of constraint that specifies that a column cannot contain any NULL values. It helps to preserve referential integrity, as the database server can identify data with erroneous missing values. It also helps in the arithmetic involved in query optimization, allowing the optimizer to predict the number of entries in an index on that column.

See Also column, constraint, NULL, primary key, referential integrity.

**NULL**

A special value in SQL, indicating the absence of data. Any arithmetic operation or equality test involving a NULL value, in turn produces a NULL result. (Thus it is similar to the IEEE floating-point concept of NaN, “not a number”.) Any aggregate calculation such as \texttt{AVG()} ignores rows with NULL values, when determining how many rows to divide by. The only test that works with NULL values uses the SQL idiom IS NULL or IS NOT NULL.

NULL values play a part in index operations, because for performance a database must minimize the overhead of keeping track of missing data values. Typically, NULL values are not stored in an index, because a query that tests an indexed column using a standard comparison operator could never match a row with a NULL value for that column. For the same reason, unique indexes do not prevent NULL values; those values simply are not represented in the index. Declaring a NOT NULL constraint on a column provides reassurance that there are no rows left out of the index, allowing for better query optimization (accurate counting of rows and estimation of whether to use the index).

Because the primary key must be able to uniquely identify every row in the table, a single-column primary key cannot contain any NULL values, and a multi-column primary key cannot contain any rows with NULL values in all columns.

Although the Oracle database allows a NULL value to be concatenated with a string, InnoDB treats the result of such an operation as NULL.

See Also index, primary key, SQL.

**.OPT file**

A file containing database configuration information. Files with this extension are included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.

See Also MySQL Enterprise Backup, mysqlbackup command.
off-page column
A column containing variable-length data (such as BLOB and VARCHAR) that is too long to fit on a B-tree page. The data is stored in overflow pages. The DYNAMIC row format is more efficient for such storage than the older COMPACT row format.
See Also B-tree, compact row format, dynamic row format, overflow page.

OLTP
Acronym for “Online Transaction Processing”. A database system, or a database application, that runs a workload with many transactions, with frequent writes as well as reads, typically affecting small amounts of data at a time. For example, an airline reservation system or an application that processes bank deposits. The data might be organized in normalized form for a balance between DML (insert/update/delete) efficiency and query efficiency. Contrast with data warehouse.

With its row-level locking and transactional capability, InnoDB is the ideal storage engine for MySQL tables used in OLTP applications.
See Also data warehouse, DML, InnoDB, query, row lock, transaction.

online
A type of operation that involves no downtime, blocking, or restricted operation for the database. Typically applied to DDL. Operations that shorten the periods of restricted operation, such as fast index creation, have evolved into a wider set of online DDL operations in MySQL 5.6.

In the context of backups, a hot backup is an online operation and a warm backup is partially an online operation.
See Also DDL, Fast Index Creation, hot backup, online DDL, warm backup.

online DDL
A feature that improves the performance, concurrency, and availability of InnoDB tables during DDL (primarily ALTER TABLE) operations. See InnoDB and Online DDL for details.

The details vary according to the type of operation. In some cases, the table can be modified concurrently while the ALTER TABLE is in progress. The operation might be able to be performed without a table copy, or using a specially optimized type of table copy. DML log space usage for in-place operations is controlled by the innodb_online_alter_log_max_size configuration option.

This feature is an enhancement of the Fast Index Creation feature in MySQL 5.5.
See Also DDL, Fast Index Creation, online.

optimistic
A methodology that guides low-level implementation decisions for a relational database system. The requirements of performance and concurrency in a relational database mean that operations must be started or dispatched quickly. The requirements of consistency and referential integrity mean that any operation could fail: a transaction might be rolled back, a DML operation could violate a constraint, a request for a lock could cause a deadlock, a network error could cause a timeout. An optimistic strategy is one that assumes most requests or attempts will succeed, so that relatively little work is done to prepare for the failure case. When this assumption is true, the database does little unnecessary work; when requests do fail, extra work must be done to clean up and undo changes.

InnoDB uses optimistic strategies for operations such as locking and commits. For example, data changed by a transaction can be written to the data files before the commit occurs, making the commit itself very fast, but requiring more work to undo the changes if the transaction is rolled back.

The opposite of an optimistic strategy is a pessimistic one, where a system is optimized to deal with operations that are unreliable and frequently unsuccessful. This methodology is rare in a database system, because so much care goes into choosing reliable hardware, networks, and algorithms.
See Also commit, concurrency, DML, locking, pessimistic, referential integrity.

optimizer

The MySQL component that determines the best indexes and join order to use for a query, based on characteristics and data distribution of the relevant tables.
See Also index, join, query, table.

option

A configuration parameter for MySQL, either stored in the option file or passed on the command line.

For the options that apply to InnoDB tables, each option name starts with the prefix innodb_.
See Also InnoDB, option, option file.

option file

The file that holds the configuration options for the MySQL instance. Traditionally, on Linux and Unix this file is named my.cnf, and on Windows it is named my.ini.
See Also configuration file, my.cnf, my.ini, option.

overflow page

Separately allocated disk pages that hold variable-length columns (such as BLOB and VARCHAR) that are too long to fit on a B-tree page. The associated columns are known as off-page columns.
See Also B-tree, off-page column, page.

P

.par file

A file containing partition definitions. Files with this extension are included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.

With the introduction of native partitioning support for InnoDB tables in MySQL 5.7.6, .par files are no longer created for partitioned InnoDB tables. Partitioned MyISAM tables continue to use .par files in MySQL 5.7. In MySQL 8.0, partitioning support is only provided by the InnoDB storage engine. As such, .par files are no longer used as of MySQL 8.0.
See Also MySQL Enterprise Backup, mysqlbackup command.

page

A unit representing how much data InnoDB transfers at any one time between disk (the data files) and memory (the buffer pool). A page can contain one or more rows, depending on how much data is in each row. If a row does not fit entirely into a single page, InnoDB sets up additional pointer-style data structures so that the information about the row can be stored in one page.

One way to fit more data in each page is to use compressed row format. For tables that use BLOBs or large text fields, compact row format allows those large columns to be stored separately from the rest of the row, reducing I/O overhead and memory usage for queries that do not reference those columns.

When InnoDB reads or writes sets of pages as a batch to increase I/O throughput, it reads or writes an extent at a time.

All the InnoDB disk data structures within a MySQL instance share the same page size.
See Also buffer pool, compact row format, compressed row format, data files, extent, page size, row.

page cleaner

An InnoDB background thread that flushes dirty pages from the buffer pool. Prior to MySQL 5.6, this activity was performed by the master thread. The number of page cleaner threads is controlled by the innodb_page_cleaners configuration option, introduced in MySQL 5.7.4.
See Also buffer pool, dirty page, flush, master thread, thread.
page size

For releases up to and including MySQL 5.5, the size of each InnoDB page is fixed at 16 kilobytes. This value represents a balance: large enough to hold the data for most rows, yet small enough to minimize the performance overhead of transferring unneeded data to memory. Other values are not tested or supported.

Starting in MySQL 5.6, the page size for an InnoDB instance can be either 4KB, 8KB, or 16KB, controlled by the innodb_page_size configuration option. As of MySQL 5.7.6, InnoDB also supports 32KB and 64KB page sizes. For 32KB and 64KB page sizes, ROW_FORMAT=COMPRESSED is not supported and the maximum record size is 16KB.

Page size is set when creating the MySQL instance, and it remains constant afterward. The same page size applies to all InnoDB tablespaces, including the system tablespace, file-per-table tablespaces, and general tablespaces.

Smaller page sizes can help performance with storage devices that use small block sizes, particularly for SSD devices in disk-bound workloads, such as for OLTP applications. As individual rows are updated, less data is copied into memory, written to disk, reorganized, locked, and so on. See Also disk-bound, file-per-table, general tablesapce, instance, OLTP, page, SSD, system tablespace, tablesapce.

parent table

The table in a foreign key relationship that holds the initial column values pointed to from the child table. The consequences of deleting, or updating rows in the parent table depend on the ON UPDATE and ON DELETE clauses in the foreign key definition. Rows with corresponding values in the child table could be automatically deleted or updated in turn, or those columns could be set to NULL, or the operation could be prevented. See Also child table, foreign key.

partial backup

A backup that contains some of the tables in a MySQL database, or some of the databases in a MySQL instance. Contrast with full backup. See Also backup, full backup, table.

partial index

An index that represents only part of a column value, typically the first N characters (the prefix) of a long VARCHAR value. See Also index, index prefix.

Performance Schema

The performance_schema schema, in MySQL 5.5 and up, presents a set of tables that you can query to get detailed information about the performance characteristics of many internal parts of the MySQL server. See Chapter 22, MySQL Performance Schema. See Also INFORMATION_SCHEMA, latch, mutex, rw-lock.

pessimistic

A methodology that sacrifices performance or concurrency in favor of safety. It is appropriate if a high proportion of requests or attempts might fail, or if the consequences of a failed request are severe. InnoDB uses what is known as a pessimistic locking strategy, to minimize the chance of deadlocks. At the application level, you might avoid deadlocks by using a pessimistic strategy of acquiring all locks needed by a transaction at the very beginning.

Many built-in database mechanisms use the opposite optimistic methodology. See Also deadlock, locking, optimistic.

phantom

A row that appears in the result set of a query, but not in the result set of an earlier query. For example, if a query is run twice within a transaction, and in the meantime, another transaction commits after inserting a new row or updating a row so that it matches the WHERE clause of the query.
This occurrence is known as a phantom read. It is harder to guard against than a **non-repeatable read**, because locking all the rows from the first query result set does not prevent the changes that cause the phantom to appear.

Among different **isolation levels**, phantom reads are prevented by the **serializable read** level, and allowed by the **repeatable read**, **consistent read**, and **read uncommitted** levels.

See Also consistent read, isolation level, non-repeatable read, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

**physical**

A type of operation that involves hardware-related aspects such as disk blocks, memory pages, files, bits, disk reads, and so on. Typically, physical aspects are important during expert-level performance tuning and problem diagnosis. Contrast with **logical**.

See Also logical, physical backup.

**physical backup**

A **backup** that copies the actual data files. For example, the `mysqlbackup` command of the MySQL Enterprise Backup product produces a physical backup, because its output contains data files that can be used directly by the `mysqld` server, resulting in a faster **restore** operation. Contrast with **logical backup**.

See Also backup, logical backup, MySQL Enterprise Backup, restore.

**PITR**

Acronym for **point-in-time recovery**.

See Also point-in-time recovery.

**plan stability**

A property of a **query execution plan**, where the optimizer makes the same choices each time for a given **query**, so that performance is consistent and predictable.

See Also query, query execution plan.

**point-in-time recovery**

The process of restoring a **backup** to recreate the state of the database at a specific date and time. Commonly abbreviated “PITR”. Because it is unlikely that the specified time corresponds exactly to the time of a backup, this technique usually requires a combination of a **physical backup** and a **logical backup**. For example, with the MySQL Enterprise Backup product, you restore the last backup that you took before the specified point in time, then replay changes from the **binary log** between the time of the backup and the PITR time.

See Also backup, binary log, logical backup, MySQL Enterprise Backup, physical backup.

**prefix**

See index prefix.

**prepared backup**

A set of backup files, produced by the MySQL Enterprise Backup product, after all the stages of applying **binary logs** and **incremental backups** are finished. The resulting files are ready to be **restored**. Prior to the apply steps, the files are known as a **raw backup**.

See Also binary log, hot backup, incremental backup, MySQL Enterprise Backup, raw backup, restore.

**primary key**

A set of columns—and by implication, the index based on this set of columns—that can uniquely identify every row in a table. As such, it must be a unique index that does not contain any **NULL** values.

InnoDB requires that every table has such an index (also called the **clustered index** or **cluster index**), and organizes the table storage based on the column values of the primary key.

When choosing primary key values, consider using arbitrary values (a **synthetic key**) rather than relying on values derived from some other source (a **natural key**).

See Also clustered index, index, natural key, synthetic key.
process
An instance of an executing program. The operating system switches between multiple running processes, allowing for a certain degree of concurrency. On most operating systems, processes can contain multiple threads of execution that share resources. Context-switching between threads is faster than the equivalent switching between processes.
See Also concurrency, thread.

pseudo-record
An artificial record in an index, used for locking key values or ranges that do not currently exist.
See Also infimum record, locking, supremum record.

Pthreads
The POSIX threads standard, which defines an API for threading and locking operations on Unix and Linux systems. On Unix and Linux systems, InnoDB uses this implementation for mutexes.
See Also mutex.

purge
A type of garbage collection that runs on a periodic schedule. Purge parses and processes undo log pages from the history list for the purpose of removing clustered and secondary index records that were marked for deletion (by previous DELETE statements) and are no longer required for MVCC or rollback. Purge frees undo log pages from the history list after processing them. Purge operations are performed by the master thread.
See Also history list, MVCC, rollback, undo log.

purge buffering
The technique of storing changes to secondary index pages, resulting from DELETE operations, in the change buffer rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. (Because delete operations are a two-step process, this operation buffers the write that normally purges an index record that was previously marked for deletion.) It is one of the types of change buffering; the others are insert buffering and delete buffering.
See Also change buffer, change buffering, delete buffering, insert buffer, insert buffering.

purge lag
Another name for the InnoDB history list. Related to the innodb_max_purge_lag configuration option.
See Also history list, purge.

purge thread
A thread within the InnoDB process that is dedicated to performing the periodic purge operation. In MySQL 5.6 and higher, multiple purge threads are enabled by the innodb_purge_threads configuration option.
See Also purge, thread.

Q

query
In SQL, an operation that reads information from one or more tables. Depending on the organization of data and the parameters of the query, the lookup might be optimized by consulting an index. If multiple tables are involved, the query is known as a join.

For historical reasons, sometimes discussions of internal processing for statements use “query” in a broader sense, including other types of MySQL statements such as DDL and DML statements.
See Also DDL, DML, index, join, SQL, table.

query execution plan
The set of decisions made by the optimizer about how to perform a query most efficiently, including which index or indexes to use, and the order in which to join tables. Plan stability involves the same choices being made consistently for a given query.
See Also index, join, plan stability, query.

query log
See general query log.

quiesce
To reduce the amount of database activity, often in preparation for an operation such as an ALTER TABLE, a backup, or a shutdown. Might or might not involve doing as much flushing as possible, so that InnoDB does not continue doing background I/O.

In MySQL 5.6 and higher, the syntax FLUSH TABLES ... FOR EXPORT writes some data to disk for InnoDB tables that make it simpler to back up those tables by copying the data files.
See Also backup, flush, InnoDB, shutdown.

R

R-tree
A tree data structure used for spatial indexing of multi-dimensional data such as geographical coordinates, rectangles or polygons.
See Also B-tree.

RAID
Acronym for “Redundant Array of Inexpensive Drives”. Spreading I/O operations across multiple drives enables greater concurrency at the hardware level, and improves the efficiency of low-level write operations that otherwise would be performed in sequence.
See Also concurrency.

random dive
A technique for quickly estimating the number of different values in a column (the column’s cardinality). InnoDB samples pages at random from the index and uses that data to estimate the number of different values.
See Also cardinality.

raw backup
The initial set of backup files produced by the MySQL Enterprise Backup product, before the changes reflected in the binary log and any incremental backups are applied. At this stage, the files are not ready to restore. After these changes are applied, the files are known as a prepared backup.
See Also binary log, hot backup, ibbackup_logfile, incremental backup, MySQL Enterprise Backup, prepared backup, restore.

READ COMMITTED
An isolation level that uses a locking strategy that relaxes some of the protection between transactions, in the interest of performance. Transactions cannot see uncommitted data from other transactions, but they can see data that is committed by another transaction after the current transaction started. Thus, a transaction never sees any bad data, but the data that it does see may depend to some extent on the timing of other transactions.

When a transaction with this isolation level performs UPDATE ... WHERE or DELETE ... WHERE operations, other transactions might have to wait. The transaction can perform SELECT ... FOR UPDATE, and LOCK IN SHARE MODE operations without making other transactions wait.

SELECT ... FOR SHARE replaces SELECT ... LOCK IN SHARE MODE in MySQL 8.0.1, but LOCK IN SHARE MODE remains available for backward compatibility.
See Also ACID, isolation level, locking, REPEATABLE READ, SERIALIZABLE, transaction.

read phenomena
Phenomena such as dirty reads, non-repeatable reads, and phantom reads which can occur when a transaction reads data that another transaction has modified.
**READ UNCOMMITTED**

The **isolation level** that provides the least amount of protection between transactions. Queries employ a **locking** strategy that allows them to proceed in situations where they would normally wait for another transaction. However, this extra performance comes at the cost of less reliable results, including data that has been changed by other transactions and not committed yet (known as **dirty read**). Use this isolation level with great caution, and be aware that the results might not be consistent or reproducible, depending on what other transactions are doing at the same time. Typically, transactions with this isolation level only do queries, not insert, update, or delete operations.

See Also **ACID**, **dirty read**, **isolation level**, **locking**, **transaction**.

**read view**

An internal snapshot used by the **MVCC** mechanism of **InnoDB**. Certain transactions, depending on their **isolation level**, see the data values as they were at the time the transaction (or in some cases, the statement) started. Isolation levels that use a read view are **REPEATABLE READ**, **READ COMMITTED**, and **READ UNCOMMITTED**.

See Also **isolation level**, **MVCC**, **READ COMMITTED**, **READ UNCOMMITTED**, **REPEATABLE READ**, **transaction**.

**read-ahead**

A type of I/O request that prefetches a group of **pages** (an entire **extent**) into the **buffer pool** asynchronously, in anticipation that these pages will be needed soon. The linear read-ahead technique prefetches all the pages of one extent based on access patterns for pages in the preceding extent. The random read-ahead technique prefetches all the pages for an extent once a certain number of pages from the same extent are in the buffer pool. Random read-ahead is not part of MySQL 5.5, but is re-introduced in MySQL 5.6 under the control of the **innodb_random_read_ahead** configuration option.

See Also **buffer pool**, **extent**, **page**.

**read-only transaction**

A type of **transaction** that can be optimized for **InnoDB** tables by eliminating some of the bookkeeping involved with creating a **read view** for each transaction. Can only perform **non-locking read** queries. It can be started explicitly with the syntax **START TRANSACTION READ ONLY**, or automatically under certain conditions. See **Optimizing InnoDB Read-Only Transactions** for details.

See Also **non-locking read**, **read view**, **transaction**.

**record lock**

A **lock** on an index record. For example, **SELECT c1 FROM t WHERE c1 = 10 FOR UPDATE**; prevents any other transaction from inserting, updating, or deleting rows where the value of **t.c1** is 10. Contrast with **gap lock** and **next-key lock**.

See Also **gap lock**, **lock**, **next-key lock**.

**redo**

The data, in units of records, recorded in the **redo log** when **DML** statements make changes to **InnoDB** tables. It is used during **crash recovery** to correct data written by incomplete **transactions**. The ever-increasing **LSN** value represents the cumulative amount of redo data that has passed through the redo log.

See Also **crash recovery**, **DML**, **LSN**, **redo log**, **transaction**.

**redo log**

A disk-based data structure used during **crash recovery**, to correct data written by incomplete **transactions**. During normal operation, it encodes requests to change **InnoDB** table data, which result from SQL statements or low-level API calls through NoSQL interfaces. Modifications that did not finish updating the **data files** before an unexpected **shutdown** are replayed automatically.

The redo log is physically represented as a set of files, typically named **ib_logfile0** and **ib_logfile1**. The data in the redo log is encoded in terms of records affected; this data is collectively referred to as **redo**. The
passage of data through the redo logs is represented by the ever-increasing LSN value. The original 4GB limit on maximum size for the redo log is raised to 512GB in MySQL 5.6.3.

The disk layout of the redo log is influenced by the configuration options innodb_log_file_size, innodb_log_group_home_dir, and (rarely) innodb_log_files_in_group. The performance of redo log operations is also affected by the log buffer, which is controlled by the innodb_log_buffer_size configuration option.

See Also crash recovery, data files, ib_logfile, log buffer, LSN, redo, shutdown, transaction.

redo log archiving
An InnoDB feature that, when enabled, sequentially writes redo log records to an archive file to avoid potential loss of data than can occur when a backup utility fails to keep pace with redo log generation while a backup operation is in progress. For more information, see Redo Log Archiving.

See Also redo log.

redundant row format
The oldest InnoDB row format. Prior to MySQL 5.0.3, it was the only row format available in InnoDB. From MySQL 5.0.3 to MySQL 5.7.8, the default row format is COMPACT. As of MySQL 5.7.9, the default row format is defined by the innodb_default_row_format configuration option, which has a default setting of DYNAMIC. You can still specify the REDUNDANT row format for compatibility with older InnoDB tables.

For more information, see Section 14.14, “InnoDB Row Formats”.

See Also compact row format, dynamic row format, row format.

referential integrity
The technique of maintaining data always in a consistent format, part of the ACID philosophy. In particular, data in different tables is kept consistent through the use of foreign key constraints, which can prevent changes from happening or automatically propagate those changes to all related tables. Related mechanisms include the unique constraint, which prevents duplicate values from being inserted by mistake, and the NOT NULL constraint, which prevents blank values from being inserted by mistake.

See Also ACID, FOREIGN KEY constraint, NOT NULL constraint, unique constraint.

relational
An important aspect of modern database systems. The database server encodes and enforces relationships such as one-to-one, one-to-many, many-to-one, and uniqueness. For example, a person might have zero, one, or many phone numbers in an address database; a single phone number might be associated with several family members. In a financial database, a person might be required to have exactly one taxpayer ID, and any taxpayer ID could only be associated with one person.

The database server can use these relationships to prevent bad data from being inserted, and to find efficient ways to look up information. For example, if a value is declared to be unique, the server can stop searching as soon as the first match is found, and it can reject attempts to insert a second copy of the same value.

At the database level, these relationships are expressed through SQL features such as columns within a table, unique and NOT NULL constraints, foreign keys, and different kinds of join operations. Complex relationships typically involve data split between more than one table. Often, the data is normalized, so that duplicate values in one-to-many relationships are stored only once.

In a mathematical context, the relations within a database are derived from set theory. For example, the OR and AND operators of a WHERE clause represent the notions of union and intersection.

See Also ACID, column, constraint, foreign key, normalized.

relevance
In the full-text search feature, a number signifying the similarity between the search string and the data in the FULLTEXT index. For example, when you search for a single word, that word is typically more relevant for a row where it occurs several times in the text than a row where it appears only once.
See Also full-text search, FULLTEXT index.

REPEATABLE READ

The default isolation level for InnoDB. It prevents any rows that are queried from being changed by other transactions, thus blocking non-repeatable reads but not phantom reads. It uses a moderately strict locking strategy so that all queries within a transaction see data from the same snapshot, that is, the data as it was at the time the transaction started.

When a transaction with this isolation level performs UPDATE ... WHERE, DELETE ... WHERE, SELECT ... FOR UPDATE, and LOCK IN SHARE MODE operations, other transactions might have to wait.

SELECT ... FOR SHARE replaces SELECT ... LOCK IN SHARE MODE in MySQL 8.0.1, but LOCK IN SHARE MODE remains available for backward compatibility.

See Also ACID, consistent read, isolation level, locking, phantom, transaction.

repertoire

Repertoire is a term applied to character sets. A character set repertoire is the collection of characters in the set. See Section 10.2.1, “Character Set Repertoire”.

replication

The practice of sending changes from a master database, to one or more slave databases, so that all databases have the same data. This technique has a wide range of uses, such as load-balancing for better scalability, disaster recovery, and testing software upgrades and configuration changes. The changes can be sent between the database by methods called row-based replication and statement-based replication.

See Also master server, row-based replication, slave server, statement-based replication.

restore

The process of putting a set of backup files from the MySQL Enterprise Backup product in place for use by MySQL. This operation can be performed to fix a corrupted database, to return to some earlier point in time, or (in a replication context) to set up a new slave database. In the MySQL Enterprise Backup product, this operation is performed by the copy-back option of the mysqlbackup command.

See Also hot backup, MySQL Enterprise Backup, mysqlbackup command, prepared backup, replication, slave server.

rollback

A SQL statement that ends a transaction, undoing any changes made by the transaction. It is the opposite of commit, which makes permanent any changes made in the transaction.

By default, MySQL uses the autocommit setting, which automatically issues a commit following each SQL statement. You must change this setting before you can use the rollback technique.

See Also ACID, autocommit, commit, SQL, transaction.

rollback segment

The storage area containing the undo logs. Rollback segments have traditionally resided in the system tablespace. As of MySQL 5.6, rollback segments can reside in undo tablespaces. As of MySQL 5.7, rollback segments are also allocated to the global temporary tablespace.

See Also system tablespace, undo log, undo tablespace.

row

The logical data structure defined by a set of columns. A set of rows makes up a table. Within InnoDB data files, each page can contain one or more rows.

Although InnoDB uses the term row format for consistency with MySQL syntax, the row format is a property of each table and applies to all rows in that table.

See Also column, data files, page, row format, table.
row format

The disk storage format for rows of an InnoDB table. As InnoDB gains new capabilities such as compression, new row formats are introduced to support the resulting improvements in storage efficiency and performance.

The row format of an InnoDB table is specified by the ROW_FORMAT option or by the
innodb_default_row_format configuration option (introduced in MySQL 5.7.9). Row formats include REDUNDANT, COMPACT, COMPRESSED, and DYNAMIC. To view the row format of an InnoDB table, issue the SHOW TABLE STATUS statement or query InnoDB table metadata in the INFORMATION_SCHEMA.

See Also compact row format, compressed row format, compression, dynamic row format, redundant row format, row, table.

row lock

A lock that prevents a row from being accessed in an incompatible way by another transaction. Other rows in the same table can be freely written to by other transactions. This is the type of locking done by DML operations on InnoDB tables.

Contrast with table locks used by MyISAM, or during DDL operations on InnoDB tables that cannot be done with online DDL; those locks block concurrent access to the table.

See Also DDL, DML, InnoDB, lock, locking, online DDL, table lock, transaction.

row-based replication

A form of replication where events are propagated from the master server specifying how to change individual rows on the slave server. It is safe to use for all settings of the innodb_autoinc_lock_mode option.

See Also auto-increment locking, innodb_autoinc_lock_mode, master server, replication, slave server, statement-based replication.

row-level locking

The locking mechanism used for InnoDB tables, relying on row locks rather than table locks. Multiple transactions can modify the same table concurrently. Only if two transactions try to modify the same row does one of the transactions wait for the other to complete (and release its row locks).

See Also InnoDB, locking, row lock, table lock, transaction.

rw-lock

The low-level object that InnoDB uses to represent and enforce shared-access locks to internal in-memory data structures following certain rules. Contrast with mutexes, which InnoDB uses to represent and enforce exclusive access to internal in-memory data structures. Mutexes and rw-locks are known collectively as latches.

rw-lock types include s-locks (shared locks), x-locks (exclusive locks), and sx-locks (shared-exclusive locks).

• An s-lock provides read access to a common resource.

• An x-lock provides write access to a common resource while not permitting inconsistent reads by other threads.

• An sx-lock provides write access to a common resource while permitting inconsistent reads by other threads. sx-locks were introduced in MySQL 5.7 to optimize concurrency and improve scalability for read-write workloads.

The following matrix summarizes rw-lock type compatibility.

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>SX</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Compatible</td>
<td>Compatible</td>
<td>Conflict</td>
</tr>
<tr>
<td>SX</td>
<td>Compatible</td>
<td>Conflict</td>
<td>Conflict</td>
</tr>
</tbody>
</table>
see also latch, lock, mutex, performance schema.

s

savepoint

Savepoints help to implement nested transactions. They can be used to provide scope to operations on tables that are part of a larger transaction. For example, scheduling a trip in a reservation system might involve booking several different flights; if a desired flight is unavailable, you might roll back the changes involved in booking that one leg, without rolling back the earlier flights that were successfully booked.

See Also rollback, transaction.

scalability

The ability to add more work and issue more simultaneous requests to a system, without a sudden drop in performance due to exceeding the limits of system capacity. Software architecture, hardware configuration, application coding, and type of workload all play a part in scalability. When the system reaches its maximum capacity, popular techniques for increasing scalability are scale up (increasing the capacity of existing hardware or software) and scale out (adding new servers and more instances of MySQL). Often paired with availability as critical aspects of a large-scale deployment.

See Also availability, scale out, scale up.

scale out

A technique for increasing scalability by adding new servers and more instances of MySQL. For example, setting up replication, NDB Cluster, connection pooling, or other features that spread work across a group of servers. Contrast with scale up.

See Also scalability, scale up.

scale up

A technique for increasing scalability by increasing the capacity of existing hardware or software. For example, increasing the memory on a server and adjusting memory-related parameters such as innodb_buffer_pool_size and innodb_buffer_pool_instances. Contrast with scale out.

See Also scalability, scale out.

schema

Conceptually, a schema is a set of interrelated database objects, such as tables, table columns, data types of the columns, indexes, foreign keys, and so on. These objects are connected through SQL syntax, because the columns make up the tables, the foreign keys refer to tables and columns, and so on. Ideally, they are also connected logically, working together as part of a unified application or flexible framework. For example, the INFORMATION_SCHEMA and performance_schema databases use “schema” in their names to emphasize the close relationships between the tables and columns they contain.

In MySQL, physically, a schema is synonymous with a database. You can substitute the keyword SCHEMA instead of DATABASE in MySQL SQL syntax, for example using CREATE SCHEMA instead of CREATE DATABASE.

Some other database products draw a distinction. For example, in the Oracle Database product, a schema represents only a part of a database: the tables and other objects owned by a single user.

See Also database, INFORMATION_SCHEMA, Performance Schema.

search index

In MySQL, full-text search queries use a special kind of index, the FULLTEXT index. In MySQL 5.6.4 and up, InnoDB and MyISAM tables both support FULLTEXT indexes; formerly, these indexes were only available for MyISAM tables.

See Also full-text search, FULLTEXT index.
secondary index
A type of InnoDB index that represents a subset of table columns. An InnoDB table can have zero, one, or many secondary indexes. (Contrast with the clustered index, which is required for each InnoDB table, and stores the data for all the table columns.)

A secondary index can be used to satisfy queries that only require values from the indexed columns. For more complex queries, it can be used to identify the relevant rows in the table, which are then retrieved through lookups using the clustered index.

Creating and dropping secondary indexes has traditionally involved significant overhead from copying all the data in the InnoDB table. The fast index creation feature makes both CREATE INDEX and DROP INDEX statements much faster for InnoDB secondary indexes.

See Also clustered index, Fast Index Creation, index.

segment
A division within an InnoDB tablespace. If a tablespace is analogous to a directory, the segments are analogous to files within that directory. A segment can grow. New segments can be created.

For example, within a file-per-table tablespace, table data is in one segment and each associated index is in its own segment. The system tablespace contains many different segments, because it can hold many tables and their associated indexes. Prior to MySQL 8.0, the system tablespace also includes one or more rollback segments used for undo logs.

Segments grow and shrink as data is inserted and deleted. When a segment needs more room, it is extended by one extent (1 megabyte) at a time. Similarly, a segment releases one extent's worth of space when all the data in that extent is no longer needed.

See Also extent, file-per-table, rollback segment, system tablespace, tablespace, undo log.

selectivity
A property of data distribution, the number of distinct values in a column (its cardinality) divided by the number of records in the table. High selectivity means that the column values are relatively unique, and can retrieved efficiently through an index. If you (or the query optimizer) can predict that a test in a WHERE clause only matches a small number (or proportion) of rows in a table, the overall query tends to be efficient if it evaluates that test first, using an index.

See Also cardinality, query.

semi-consistent read
A type of read operation used for UPDATE statements, that is a combination of READ COMMITTED and consistent read. When an UPDATE statement examines a row that is already locked, InnoDB returns the latest committed version to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE. If the row matches (must be updated), MySQL reads the row again, and this time InnoDB either locks it or waits for a lock on it. This type of read operation can only happen when the transaction has the READ COMMITTED isolation level, or when the innodb_locks_unsafe_for_binlog option is enabled. innodb_locks_unsafe_for_binlog was removed in MySQL 8.0.

See Also consistent read, isolation level, READ COMMITTED.

SERIALIZABLE
The isolation level that uses the most conservative locking strategy, to prevent any other transactions from inserting or changing data that was read by this transaction, until it is finished. This way, the same query can be run over and over within a transaction, and be certain to retrieve the same set of results each time. Any attempt to change data that was committed by another transaction since the start of the current transaction, cause the current transaction to wait.

This is the default isolation level specified by the SQL standard. In practice, this degree of strictness is rarely needed, so the default isolation level for InnoDB is the next most strict, REPEATABLE READ.
See Also ACID, consistent read, isolation level, locking, REPEATABLE READ, transaction.

server
A type of program that runs continuously, waiting to receive and act upon requests from another program (the client). Because often an entire computer is dedicated to running one or more server programs (such as a database server, a web server, an application server, or some combination of these), the term server can also refer to the computer that runs the server software.
See Also client, mysqld.

shared lock
A kind of lock that allows other transactions to read the locked object, and to also acquire other shared locks on it, but not to write to it. The opposite of exclusive lock.
See Also exclusive lock, lock, transaction.

shared tablespace
Another way of referring to the system tablespace or a general tablespace. General tablespaces were introduced in MySQL 5.7. More than one table can reside in a shared tablespace. Only a single table can reside in a file-per-table tablespace.
See Also general tablespace, system tablespace.

sharp checkpoint
The process of flushing to disk all dirty buffer pool pages whose redo entries are contained in certain portion of the redo log. Occurs before InnoDB reuses a portion of a log file; the log files are used in a circular fashion. Typically occurs with write-intensive workloads.
See Also dirty page, flush, redo log, workload.

shutdown
The process of stopping the MySQL server. By default, this process cleans up operations for InnoDB tables, so InnoDB can be slow to shut down, but fast to start up later. If you skip the cleanup operations, it is fast to shut down but the cleanup must be performed during the next restart.

The shutdown mode for InnoDB is controlled by the innodb_fast_shutdown option.
See Also fast shutdown, InnoDB, slow shutdown, startup.

slave server
Frequently shortened to “slave”. A database server machine in a replication scenario that receives changes from another server (the master) and applies those same changes. Thus it maintains the same contents as the master, although it might lag somewhat behind.

In MySQL, slave servers are commonly used in disaster recovery, to take the place of a master server that fails. They are also commonly used for testing software upgrades and new settings, to ensure that database configuration changes do not cause problems with performance or reliability.

Slave servers typically have high workloads, because they process all the DML (write) operations relayed from the master, as well as user queries. To ensure that slave servers can apply changes from the master fast enough, they frequently have fast I/O devices and sufficient CPU and memory to run multiple database instances on the same slave server. For example, the master server might use hard drive storage while the slave servers use SSDs.
See Also DML, master server, replication, server, SSD.

slow query log
A type of log used for performance tuning of SQL statements processed by the MySQL server. The log information is stored in a file. You must enable this feature to use it. You control which categories of “slow” SQL statements are logged. For more information, see Section 5.4.5, “The Slow Query Log”.
See Also general query log, log.
slow shutdown

A type of shutdown that does additional InnoDB flushing operations before completing. Also known as a clean shutdown. Specified by the configuration parameter innodb_fast_shutdown=0 or the command SET GLOBAL innodb_fast_shutdown=0; Although the shutdown itself can take longer, that time will be saved on the subsequent startup.

See Also clean shutdown, fast shutdown, shutdown.

snapshot

A representation of data at a particular time, which remains the same even as changes are committed by other transactions. Used by certain isolation levels to allow consistent reads.

See Also commit, consistent read, isolation level, transaction.

sort buffer

The buffer used for sorting data during creation of an InnoDB index. Sort buffer size is configured using the innodb_sort_buffer_size configuration option.

space ID

An identifier used to uniquely identify an InnoDB tablespace within a MySQL instance. The space ID for the system tablespace is always zero; this same ID applies to all tables within the system tablespace or within a general tablespace. Each file-per-table tablespace and general tablespace has its own space ID.

Prior to MySQL 5.6, this hardcoded value presented difficulties in moving InnoDB tablespace files between MySQL instances. Starting in MySQL 5.6, you can copy tablespace files between instances by using the transportable tablespace feature involving the statements FLUSH TABLES ... FOR EXPORT, ALTER TABLE ... DISCARD TABLESPACE, and ALTER TABLE ... IMPORT TABLESPACE. The information needed to adjust the space ID is conveyed in the .cfg file which you copy along with the tablespace. See Importing InnoDB Tables for details.

See Also .cfg file, file-per-table, general tablespace, .ibd file, system tablespace, tablespace, transportable tablespace.

sparse file

A type of file that uses file system space more efficiently by writing metadata representing empty blocks to disk instead of writing the actual empty space. The InnoDB transparent page compression feature relies on sparse file support. For more information, see InnoDB Page Compression.

See Also hole punching, transparent page compression.

spin

A type of wait operation that continuously tests whether a resource becomes available. This technique is used for resources that are typically held only for brief periods, where it is more efficient to wait in a “busy loop” than to put the thread to sleep and perform a context switch. If the resource does not become available within a short time, the spin loop ceases and another wait technique is used.

See Also latch, lock, mutex, wait.

SQL

The Structured Query Language that is standard for performing database operations. Often divided into the categories DDL, DML, and queries. MySQL includes some additional statement categories such as replication. See Chapter 9, Language Structure for the building blocks of SQL syntax, Chapter 11, Data Types for the data types to use for MySQL table columns, Chapter 13, SQL Statements for details about SQL statements and their associated categories, and Chapter 12, Functions and Operators for standard and MySQL-specific functions to use in queries.

See Also DDL, DML, query, replication.

SSD

Acronym for “solid-state drive”. A type of storage device with different performance characteristics than a traditional hard disk drive (HDD): smaller storage capacity, faster for random reads, no moving parts, and with
a number of considerations affecting write performance. Its performance characteristics can influence the throughput of a **disk-bound** workload.

See Also **disk-bound**, HDD.

**startup**

The process of starting the MySQL server. Typically done by one of the programs listed in [Section 4.3, “Server and Server-Startup Programs”](#). The opposite of **shutdown**.

See Also **shutdown**.

**statement-based replication**

A form of replication where SQL statements are sent from the **master server** and replayed on the **slave server**. It requires some care with the setting for the `innodb_autoinc_lock_mode` option, to avoid potential timing problems with **auto-increment locking**.

See Also **auto-increment locking**, `innodb_autoinc_lock_mode`, master server, replication, row-based replication, slave server.

**statistics**

Estimated values relating to each **InnoDB table** and index, used to construct an efficient **query execution plan**. The main values are the **cardinality** (number of distinct values) and the total number of table rows or index entries. The statistics for the table represent the data in its **primary key** index. The statistics for a **secondary index** represent the rows covered by that index.

The values are estimated rather than counted precisely because at any moment, different transactions can be inserting and deleting rows from the same table. To keep the values from being recalculated frequently, you can enable **persistent statistics**, where the values are stored in **InnoDB** system tables, and refreshed only when you issue an `ANALYZE TABLE` statement.

You can control how **NULL** values are treated when calculating statistics through the `innodb_stats_method` configuration option.

Other types of statistics are available for database objects and database activity through the **INFORMATION_SCHEMA** and **PERFORMANCE_SCHEMA** tables.

See Also **cardinality**, index, **INFORMATION_SCHEMA**, **NULL**, Performance Schema, primary key, query execution plan, secondary index, table, transaction.

**stemming**

The ability to search for different variations of a word based on a common root word, such as singular and plural, or past, present, and future verb tense. This feature is currently supported in **MyISAM** full-text search feature but not in **FULLTEXT indexes** for **InnoDB** tables.

See Also **full-text search**, **FULLTEXT index**.

**stopword**

In a **FULLTEXT index**, a word that is considered common or trivial enough that it is omitted from the **search index** and ignored in search queries. Different configuration settings control stopword processing for **InnoDB** and **MyISAM** tables. See [Section 12.9.4, “Full-Text Stopwords”](#) for details.

See Also **FULLTEXT index**, search index.

**storage engine**

A component of the MySQL database that performs the low-level work of storing, updating, and querying data. In MySQL 5.5 and higher, **InnoDB** is the default storage engine for new tables, superceding **MyISAM**. Different storage engines are designed with different tradeoffs between factors such as memory usage versus disk usage, read speed versus write speed, and speed versus robustness. Each storage engine manages specific tables, so we refer to **InnoDB tables**, **MyISAM tables**, and so on.

The **MySQL Enterprise Backup** product is optimized for backing up **InnoDB** tables. It can also back up tables handled by **MyISAM** and other storage engines.

See Also **InnoDB**, **MySQL Enterprise Backup**, table type.
stored object
   A stored program or view.

stored program
   A stored routine (procedure or function), trigger, or Event Scheduler event.

stored routine
   A stored procedure or function.

strict mode
   The general name for the setting controlled by the `innodb_strict_mode` option. Turning on this setting causes certain conditions that are normally treated as warnings, to be considered errors. For example, certain invalid combinations of options related to file format and row format, that normally produce a warning and continue with default values, now cause the `CREATE TABLE` operation to fail. `innodb_strict_mode` is enabled by default in MySQL 5.7.

MySQL also has something called strict mode. See Section 5.1.10, “Server SQL Modes”. See Also file format, innodb_strict_mode, row format.

sublist
   Within the list structure that represents the buffer pool, pages that are relatively old and relatively new are represented by different portions of the list. A set of parameters control the size of these portions and the dividing point between the new and old pages. See Also buffer pool, eviction, list, LRU.

supremum record
   A pseudo-record in an index, representing the gap above the largest value in that index. If a transaction has a statement such as `SELECT ... FROM ... WHERE col > 10 FOR UPDATE;`, and the largest value in the column is 20, it is a lock on the supremum record that prevents other transactions from inserting even larger values such as 50, 100, and so on. See Also gap, infimum record, pseudo-record.

surrogate key
   Synonym name for synthetic key. See Also synthetic key.

synthetic key
   An indexed column, typically a primary key, where the values are assigned arbitrarily. Often done using an auto-increment column. By treating the value as completely arbitrary, you can avoid overly restrictive rules and faulty application assumptions. For example, a numeric sequence representing employee numbers might have a gap if an employee was approved for hiring but never actually joined. Or employee number 100 might have a later hiring date than employee number 500, if they left the company and later rejoined. Numeric values also produce shorter values of predictable length. For example, storing numeric codes meaning “Road”, “Boulevard”, “Expressway”, and so on is more space-efficient than repeating those strings over and over.

   Also known as a surrogate key. Contrast with natural key. See Also auto-increment, natural key, primary key, surrogate key.

system tablespace
   One or more data files (ibdata files) containing metadata for InnoDB-related objects (the InnoDB data dictionary), and the storage areas for one or more undo logs, the change buffer, and the doublewrite buffer. Depending on the `innodb_file_per_table` setting, it might also contain table and index data for InnoDB tables. The data and metadata in the system tablespace apply to all databases in a MySQL instance. See Also Barracuda, change buffer, compression, data dictionary, database, doublewrite buffer, dynamic row format, file-per-table, general tablespace, .ibd file, ibdata file, innodb_file_per_table, instance, MySQL Enterprise Backup, off-page column, tablespace, undo log.
T

.TRG file
A file containing trigger parameters. Files with this extension are always included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.
See Also MySQL Enterprise Backup, mysqlbackup command, .TRN file.

.TRN file
A file containing trigger namespace information. Files with this extension are always included in backups produced by the mysqlbackup command of the MySQL Enterprise Backup product.
See Also MySQL Enterprise Backup, mysqlbackup command, .TRG file.

table
Each MySQL table is associated with a particular storage engine. InnoDB tables have particular physical and logical characteristics that affect performance, scalability, backup, administration, and application development.

In terms of file storage, an InnoDB table belongs to one of the following tablespace types:

- The shared InnoDB system tablespace, which is comprised of one or more .ibdata files.
- A file-per-table tablespace, comprised of an individual .ibd file.
- A shared general tablespace, comprised of an individual .ibd file. General tablespaces were introduced in MySQL 5.7.6.

.ibd data files contain both table and index data.

InnoDB tables created in file-per-table tablespaces can use the Barracuda file format, and Barracuda tables can use DYNAMIC or COMPRESSED row format. These row formats enable InnoDB features such as compression, efficient storage of off-page columns, and large index key prefixes (see innodb_large_prefix). General tablespaces support all row formats regardless of the innodb_file_format setting.

Up to MySQL 5.7.5, InnoDB tables inside the system tablespace had to use the Antelope file format for backward compatibility with MySQL 5.1 and earlier. The Antelope file format supports COMPACT and REDUNDANT row format. The system tablespace supports tables that use DYNAMIC row format as of MySQL 5.7.6.

The rows of an InnoDB table are organized into an index structure known as the clustered index, with entries sorted based on the primary key columns of the table. Data access is optimized for queries that filter and sort on the primary key columns, and each index contains a copy of the associated primary key columns for each entry. Modifying values for any of the primary key columns is an expensive operation. Thus an important aspect of InnoDB table design is choosing a primary key with columns that are used in the most important queries, and keeping the primary key short, with rarely changing values.
See Also Antelope, backup, Barracuda, clustered index, compact row format, compressed row format, compression, dynamic row format, Fast Index Creation, file-per-table, .ibd file, index, off-page column, primary key, redundant row format, row, system tablespace, tablespace.

table lock
A lock that prevents any other transaction from accessing a table. InnoDB makes considerable effort to make such locks unnecessary, by using techniques such as online DDL, row locks and consistent reads for processing DML statements and queries. You can create such a lock through SQL using the LOCK TABLE statement; one of the steps in migrating from other database systems or MySQL storage engines is to remove such statements wherever practical.
See Also consistent read, DML, lock, locking, online DDL, query, row lock, table, transaction.
table scan
See full table scan.

table statistics
See statistics.

table type
Obsolete synonym for storage engine. We refer to InnoDB tables, MyISAM tables, and so on.
See Also InnoDB, storage engine.

tablespace
A data file that can hold data for one or more InnoDB tables and associated indexes.
The system tablespace contains the InnoDB data dictionary, and prior to MySQL 5.6 holds all other InnoDB tables by default.

The innodb_file_per_table option, enabled by default in MySQL 5.6 and higher, allows tables to be created in their own tablespaces. File-per-table tablespaces support features such as efficient storage of off-page columns, table compression, and transportable tablespaces. See Section 14.9.3.2, “File-Per-Table Tablespaces” for details.

InnoDB introduced general tablespaces in MySQL 5.7.6. General tablespaces are shared tablespaces created using CREATE TABLESPACE syntax. They can be created outside of the MySQL data directory, are capable of holding multiple tables, and support tables of all row formats.

MySQL NDB Cluster also groups its tables into tablespaces. See Section 18.5.12.1, “NDB Cluster Disk Data Objects” for details.
See Also compressed row format, data dictionary, data files, file-per-table, general tablespace, index, innodb_file_per_table, system tablespace, table.

temporary table
A table whose data does not need to be truly permanent. For example, temporary tables might be used as storage areas for intermediate results in complicated calculations or transformations; this intermediate data would not need to be recovered after a crash. Database products can take various shortcuts to improve the performance of operations on temporary tables, by being less scrupulous about writing data to disk and other measures to protect the data across restarts.

Sometimes, the data itself is removed automatically at a set time, such as when the transaction ends or when the session ends. With some database products, the table itself is removed automatically too.
See Also table.

temporary tablespace
The tablespace for non-compressed InnoDB temporary tables and related objects, introduced in MySQL 5.7. The innodb_temp_data_file_path configuration file option defines the relative path, name, size, and attributes for temporary tablespace data files. If innodb_temp_data_file_path is not specified, the default behavior is to create a single auto-extending 12MB data file named ibtmp1 in the data directory. The temporary tablespace is recreated on each server start and receives a dynamically generated space ID. The temporary tablespace cannot reside on a raw device. Startup is refused if the temporary tablespace cannot be created.

The temporary tablespace is removed on normal shutdown or on an aborted initialization. The temporary tablespace is not removed when a crash occurs. In this case, the database administrator may remove the temporary tablespace manually or restart the server with the same configuration, which removes and recreates the temporary tablespace.
See Also temporary table.

text collection
The set of columns included in a FULLTEXT index.
thread
A unit of processing that is typically more lightweight than a process, allowing for greater concurrency.
See Also concurrency, master thread, process, Pthreads.

torn page
An error condition that can occur due to a combination of I/O device configuration and hardware failure. If data is written out in chunks smaller than the InnoDB page size (by default, 16KB), a hardware failure while writing could result in only part of a page being stored to disk. The InnoDB doublewrite buffer guards against this possibility. See Also doublewrite buffer.

TPS
Acronym for “transactions per second”, a unit of measurement sometimes used in benchmarks. Its value depends on the workload represented by a particular benchmark test, combined with factors that you control such as the hardware capacity and database configuration.
See Also transaction, workload.

transaction
Transactions are atomic units of work that can be committed or rolled back. When a transaction makes multiple changes to the database, either all the changes succeed when the transaction is committed, or all the changes are undone when the transaction is rolled back.

Database transactions, as implemented by InnoDB, have properties that are collectively known by the acronym ACID, for atomicity, consistency, isolation, and durability.
See Also ACID, commit, isolation level, lock, rollback.

transaction ID
An internal field associated with each row. This field is physically changed by INSERT, UPDATE, and DELETE operations to record which transaction has locked the row.
See Also implicit row lock, row, transaction.

transparent page compression
A feature added in MySQL 5.7.8 that permits page-level compression for InnoDB tables that reside in file-per-table tablespaces. Page compression is enabled by specifying the COMPRESSION attribute with CREATE TABLE or ALTER TABLE. For more information, see InnoDB Page Compression.
See Also file-per-table, hole punching, sparse file.

transportable tablespace
A feature that allows a tablespace to be moved from one instance to another. Traditionally, this has not been possible for InnoDB tablespaces because all table data was part of the system tablespace. In MySQL 5.6 and higher, the FLUSH TABLES ... FOR EXPORT syntax prepares an InnoDB table for copying to another server; running ALTER TABLE ... DISCARD TABLESPACE and ALTER TABLE ... IMPORT TABLESPACE on the other server brings the copied data file into the other instance. A separate .cfg file, copied along with the .ibd file, is used to update the table metadata (for example the space ID) as the tablespace is imported. See Importing InnoDB Tables for usage information.
See Also .cfg file, .ibd file, space ID, system tablespace, tablespace.

troubleshooting
The process of determining the source of a problem. Some of the resources for troubleshooting MySQL problems include:

• Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”

• Section 6.2.13, “Troubleshooting Problems Connecting to MySQL”

• Section B.4.3.2, “How to Reset the Root Password”

See Also FULLTEXT index.
• Section B.4.2, “Common Errors When Using MySQL Programs”

• Section 14.23, “InnoDB Troubleshooting”.

truncate
A DDL operation that removes the entire contents of a table, while leaving the table and related indexes intact. Contrast with drop. Although conceptually it has the same result as a DELETE statement with no WHERE clause, it operates differently behind the scenes: InnoDB creates a new empty table, drops the old table, then renames the new table to take the place of the old one. Because this is a DDL operation, it cannot be rolled back.

If the table being truncated contains foreign keys that reference another table, the truncation operation uses a slower method of operation, deleting one row at a time so that corresponding rows in the referenced table can be deleted as needed by any ON DELETE CASCADE clause. (MySQL 5.5 and higher do not allow this slower form of truncate, and return an error instead if foreign keys are involved. In this case, use a DELETE statement instead. See Also DDL, drop, foreign key, rollback.

tuple
A technical term designating an ordered set of elements. It is an abstract notion, used in formal discussions of database theory. In the database field, tuples are usually represented by the columns of a table row. They could also be represented by the result sets of queries, for example, queries that retrieved only some columns of a table, or columns from joined tables.
See Also cursor.

two-phase commit
An operation that is part of a distributed transaction, under the XA specification. (Sometimes abbreviated as 2PC.) When multiple databases participate in the transaction, either all databases commit the changes, or all databases rollback the changes.
See Also commit, rollback, transaction, XA.

U
.undo
Data that is maintained throughout the life of a transaction, recording all changes so that they can be undone in case of a rollback operation. It is stored in undo logs either within the system tablespace (in MySQL 5.7 or earlier) or in separate undo tablespaces. As of MySQL 8.0, undo logs reside in undo tablespaces by default.
See Also rollback, rollback segment, system tablespace, transaction, undo log, undo tablespace.

undo buffer
See undo log.

undo log
A storage area that holds copies of data modified by active transactions. If another transaction needs to see the original data (as part of a consistent read operation), the unmodified data is retrieved from this storage area.

In MySQL 5.6 and MySQL 5.7, you can use the innodb_undo_tablespaces variable have undo logs reside in undo tablespaces, which can be placed on another storage device such as an SSD. In MySQL 8.0, undo logs reside in two default undo tablespaces that are created when MySQL is initialized, and additional undo tablespaces can be created using CREATE UNDO TABLESPACE syntax.

The undo log is split into separate portions, the insert undo buffer and the update undo buffer.
See Also consistent read, rollback segment, SSD, system tablespace, transaction, undo tablespace.

undo log segment
A collection of undo logs. Undo log segments exists within rollback segments. An undo log segment might contain undo logs from multiple transactions. An undo log segment can only be used by one transaction at a time.
but can be reused after it is released at transaction commit or rollback. May also be referred to as an “undo segment”.
See Also commit, rollback, rollback segment, undo log.

undo tablespace
An undo tablespace contains undo logs. Undo logs exist within undo log segments, which are contained within rollback segments. Rollback segments have traditionally resided in the system tablespace. As of MySQL 5.6, rollback segments can reside in undo tablespaces. In MySQL 5.6 and MySQL 5.7, the number of undo tablespaces is controlled by the innodb_undo_tablespaces configuration option. In MySQL 8.0, two default undo tablespaces are created when the MySQL instance is initialized, and additional undo tablespaces can be created using CREATE UNDO TABLESPACE syntax.

For more information, see Undo Tablespaces.
See Also rollback segment, system tablespace, undo log, undo log segment.

unique constraint
A kind of constraint that asserts that a column cannot contain any duplicate values. In terms of relational algebra, it is used to specify 1-to-1 relationships. For efficiency in checking whether a value can be inserted (that is, the value does not already exist in the column), a unique constraint is supported by an underlying unique index.
See Also constraint, relational, unique index.

unique index
An index on a column or set of columns that have a unique constraint. Because the index is known not to contain any duplicate values, certain kinds of lookups and count operations are more efficient than in the normal kind of index. Most of the lookups against this type of index are simply to determine if a certain value exists or not. The number of values in the index is the same as the number of rows in the table, or at least the number of rows with non-null values for the associated columns.

Change buffering optimization does not apply to unique indexes. As a workaround, you can temporarily set unique_checks=0 while doing a bulk data load into an InnoDB table.
See Also cardinality, change buffering, unique constraint, unique key.

unique key
The set of columns (one or more) comprising a unique index. When you can define a WHERE condition that matches exactly one row, and the query can use an associated unique index, the lookup and error handling can be performed very efficiently.
See Also cardinality, unique constraint, unique index.

V

variable-length type
A data type of variable length. VARCHAR, VARBINARY, and BLOB and TEXT types are variable-length types.

InnoDB treats fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.
See Also off-page column, overflow page.

victim
The transaction that is automatically chosen to be rolled back when a deadlock is detected. InnoDB rolls back the transaction that has updated the fewest rows.

Deadlock detection can be disabled using the innodb_deadlock_detect configuration option.
A stored query that when invoked produces a result set. A view acts as a virtual table.

When an operation, such as acquiring a lock, mutex, or latch, cannot be completed immediately, InnoDB pauses and tries again. The mechanism for pausing is elaborate enough that this operation has its own name, the wait. Individual threads are paused using a combination of internal InnoDB scheduling, operating system wait() calls, and short-duration spin loops.

On systems with heavy load and many transactions, you might use the output from the SHOW_INNODB_STATUS command or Performance Schema to determine whether threads are spending too much time waiting, and if so, how you can improve concurrency.

A backup taken while the database is running, but that restricts some database operations during the backup process. For example, tables might become read-only. For busy applications and websites, you might prefer a hot backup.

To run a system under a typical workload for some time after startup, so that the buffer pool and other memory regions are filled as they would be under normal conditions. This process happens naturally over time when a MySQL server is restarted or subjected to a new workload.

Typically, you run a workload for some time to warm up the buffer pool before running performance tests, to ensure consistent results across multiple runs; otherwise, performance might be artificially low during the first run.

In MySQL 5.6, you can speed up the warmup process by enabling the innodb_buffer_pool_dump_at_shutdown and innodb_buffer_pool_load_at_startup configuration options, to bring the contents of the buffer pool back into memory after a restart. These options are enabled by default in MySQL 5.7. See Saving and Restoring the Buffer Pool State.

The combination and volume of SQL and other database operations, performed by a database application during typical or peak usage. You can subject the database to a particular workload during performance testing to identify bottlenecks, or during capacity planning.

An optimization technique that reduces write operations when dirty pages are flushed from the InnoDB buffer pool. If a row in a page is updated multiple times, or multiple rows on the same page are updated, all of those changes are stored to the data files in a single write operation rather than one write for each change.

A standard interface for coordinating distributed transactions, allowing multiple databases to participate in a transaction while maintaining ACID compliance. For full details, see Section 13.3.7, “XA Transactions”.

See Also deadlock, deadlock detection, innodb_lock_wait_timeout, transaction, view, wait, warm backup, warm up, workload, write combining, XA.
XA Distributed Transaction support is enabled by default. If you are not using this feature, you can disable the `innodb_support_xa` configuration option, avoiding the performance overhead of an extra fsync for each transaction.

As of MySQL 5.7.10, disabling `innodb_support_xa` is not permitted as it makes replication unsafe and prevents performance gains associated with `binary log` group commit. The `innodb_support_xa` configuration option is removed in MySQL 8.0.
See Also ACID, binary log, commit, transaction, two-phase commit.

young

A characteristic of a page in the InnoDB buffer pool meaning it has been accessed recently, and so is moved within the buffer pool data structure, so that it will not be flushed soon by the LRU algorithm. This term is used in some INFORMATION_SCHEMA column names of tables related to the buffer pool.
See Also buffer pool, flush, INFORMATION_SCHEMA, LRU, page.